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THE COSTS TO DEVELOPING COUNTRIES OF ENTERING THE MONTREAL PROTOCOL

(Study on assumptions and methodologies for calculations of the total cost of assistance to developing countries.)

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THE COSTS TO DEVELOPING COUNTRIES OF ENTERING THE MONTREAL PROTOCOL

by

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This report has been prepared for the executive director of UNEP, as a background support document for the General Council meetings in Nairobi in January 1990. It is preliminary and confidential and its contents should not be quoted or cited.

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I. Introduction and Background

1.1 This report has been prepared at the request of the Executive Director of UNEP as a background document for the meeting of the working party on CFCs to be held in Nairobi in January 1990 under the auspices of UNEP. The purpose of this report is to:

(a) identify the items of cost that arise for developing countries in meeting the terms of the Montreal Protocol on Substances that Deplete the Ozone Layer and to distinguish, in particular, between those costs that can properly be covered by an international fund to assist such countries in compliance with the protocol and those that cannot;

(b) attempt to get a measure of the order of magnitude of the sums involved in such a fund;

(c) establish some guidelines on how the transfers might be made.

1.2 Considerable work has already been undertaken on the impacts of the this Protocol. Four panels were set up under the Protocol (Article 6) to look respectively at the economic, technical, scientific, health and other effects of the control of the ozone depleting substances as defined under the Protocol. Of particular relevance to this report are the findings of the technical and economic panels. Final versions of these were made available to the author in August 1989 and an attempt has been made to make the maximum use of their findings. However, there is very little in these documents regarding the permissible costs that might be covered by an assistance fund set up for the developing countries and, equally importantly, what kind of sums might be involved.

1.3 The need for information along these lines was made clear at the meeting of independent experts in Geneva in July 3-7 1989 and at a

subsequent meeting of the General Council in Nairobi in August 1989. At these meetings attention was focussed on how one might assist those countries that could be regarded as 'developing', in dealing with adjustments that their economies would face once they had signed the Protocol. Issues were raised about the kinds of institutions that would be required, how big a fund they would need to manage, where the funds would come from and how they would be disbursed.

1.4 This report is organized in the following sections. Following the introduction (Section I), Section II deals on a conceptual level with the kinds of costs that need to be examined and the issues that arise in measuring them. In Section III these costs are estimated as best they can be, given the limited information and time available. In Section IV some guidelines are presented on how the transfers implied by the costs might be made. This necessarily involves setting rules and collecting information, the costs of which are also assessed. Section V concludes the report.

1.5 It must be stressed that this report has been put together in a short period of time and with limited access to information from the individual countries that would require assistance. A list of all the documents made available and the individuals contacted is attached as Annex 1. As will be clear to the reader, the estimates are often quite crude and may be no more than orders of magnitude. Nevertheless they are useful in directing the debate on the financial mechanisms for transferring resources to developing countries to meet the terms of the Protocol. What must be recognized, however is that more accurate information at the country level is desperately needed before one can go any further with this kind of analysis. It is understood that some developing countries are in the process of collecting the information relevant to them if they should join the Protocol. The systematic documentation of that information and its use in arriving at more accurate estimates of the costs to developing countries is therefore an essential

next step in the process of setting up the appropriate financial mechanisms.

II. Identifying Costs Associated with Compliance with the Protocol

2.1 The Protocol involves a reduction in the consumption and production, and a restriction in the trade, of the five most important CFCs and a freeze on the production and consumption of the three major halons with effect from January 1989[1/]. The rules differ for developed and developing countries. For the former the agreement is to reduce consumption so that by July 1989 it is not above the level it was in July 1986. Thereafter reductions are progressive so that by July 1998 consumption will be only 15% of its 1986 level[2/]. For developing countries, (which are defined as those whose per-capita consumption of CFCs is less than 0.3 kg.) the Protocol requires that the above reduction targets must be satisfied with a grace period of 10 years[3/]. As far as production is concerned, parallel reductions are required with the following exceptions:

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[1] Consumption is defined as production plus imports minus exports. All production and consumption is measured in terms of the ozone depleting potential (ODP) of the substances concerned.

[2] The original agreement entailed a reduction to only 50% of the 1986 level by 1998 but subsequent discussions, particularly those conducted in Helsinki in February of this year, have led to a greater agreed reduction. This has to be formally ratified but in the estimation of costs it is the 85% figure that is taken. Halons are restricted such that by January 1992 consumption will be permanently reduced to or below 1986 levels.

[3] In addition, the consumption and production targets are slightly more lax. For example, if developed countries have to reduce their consumption by 50% by a given year, the developing countries have to reduce theirs by around 42% and with a grace period of 10 years.

(a) developed countries may increase production from the 1986 level but only if it has been contracted for before September 1987. Further restrictions are that such plants should be completed by December 1990 and the additional production must not raise the party's annual consumption above 0.5 kg per capita.

(b) in addition, for developing countries permitted production is allowed to increase by 10% over its 1986 level.

2.2 As far as trade is concerned, the Protocol requires that, from January 1990, all parties ban the trade of controlled substances with non-parties. For developing countries (as defined above), this date has been fixed as January 1993. In addition, if a country is a small producer (i.e. producing less than 25,000 tons) it may transfer to, or receive from, any other party production in excess of the party's ceiling as set out by the Protocol.

2.3 From the terms of the Protocol, it follows that there will be a substantial reduction in the consumption of CFCs over the next decade. Thirty six countries have signed and ratified the Protocol and they account for about 80% of the global consumption of the regulated CFCs and halons. Virtually all developed countries are now party to the Protocol but many developing countries remain reluctant to join. There are several implications arising from the Protocol which developing countries face. First, they too will need to reduce their consumption of these products in due course and replace them by higher price substitutes. Where they have invested in production capacity, this may entail a faster amortization of the fixed capital. The process of shifting to these new products will entail some adjustment costs in the industries that use them as inputs: refrigeration, air-conditioning, foams etc. Even where the countries do not have a manufacturing capability, they may face higher import prices for these items. All these factors mean that these countries will face <u>costs of adjustment</u> and the purpose of the fund is to assist them financially in meeting these costs.

2.4 In the UNEP Economic Panel Report [1989], a methodology for identifying these costs has been developed (Appendix 3). This states that there are three 'control possibilities' or substitution activities that need to be considered. First is the possibility that CFC consuming products can be replaced by non-CFC consuming ones. An example is the use of paper based packaging materials to replace CFC-blown foam packaging. Second is the possibility that chemical substitutes can replace CFCs in the manufacture, installation or use of products. Third is the substitution of processes. These would involve the use of add-on recovery and recycling equipment to reduce CFC use or emissions. The optimal combination of these that should be undertaken will vary from use to use and calculating it would require information on the economic and technological parameters facing the industries in the developing countries[1/]. Such information is not available at the present time. Hence it has been necessary to adopt some broader and cruder approaches, which separate put the costs according to major identifiable categories. These are:

(a) Costs of using or manufacturing CFC substitutes.
Under this heading estimates are made of the costs of chemical substitutes, their likely earliest date of use, the length of time over which maximum penetration of use of achieved and the evolution of the cost differential over time. One would expect that, as resources are devoted to research and production of substitutes, their prices will fall.

(b) Costs of adjustment in the industries using CFCs and halons as inputs.
Industries such as aerosols, domestic refrigeration, industrial refrigeration, air conditioners etc. are likely to face additional costs as they switch over to new technologies. Costs arising here

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1 The Economic Panel Report (op. cit.) identifies 75 applications and 550 control possibilities. From these the costs of reduced use can be worked out for each application and à cost curve estimated. Given reductions would then require the lowest cost substitutions to be undertaken first.

would be: the introduction of new processing equipment, changed safety requirements, training of manpower etc.

(c) Differential costs of operating equipment

As new chemicals are used, the operating costs of equipment such as refrigerators, air conditioners and so on will change. Also, there will be a greater incentive to maintain existing CFC-using machinery so that less CFCs are emitted. This in turn will entail higher maintenance costs.

(d) Costs of amortizing existing production capacity faster.

It is possible that the capacity to produce CFCs that exists in developing countries will not be able to be used over the full lifetime that it was planned for. Hence there will be a loss of value resulting from earlier amortization of plant.

(e) Higher costs of importation.

In many developing countries there is very little manufacture or use of CFCs in production. Instead, equipment incorporating CFCs is imported. As substitutes are introduced in the manufacture of this equipment its price may rise. Although this cost has already been identified in the producer country under items (a)-(b) above, and in an overall estimate of social cost it would be double counting to include it again, for the purposes of identifying financial flows to developing countries it is a relevant cost and may be of importance.

(f) Costs of collecting further information.

A precursor to any financial arrangements for CFC substitution, and of importance to each country in establishing an appropriate industrial strategy in this area, is an adequate database of the use and applications of CFCs in the country. Collecting information on the scale required will entail significant costs and these also need to be allowed for.

Each of these costs is considered in turn below. It should be stated at the outset, however, that the information made available refers only to CFCs. No information on costs relating to halons was available. Hence this is one area where this analysis needs to be extended.

III. Estimating the Costs of Compliance

Costs of using higher price substitutes

2.5 In estimating the higher costs of substitutes, two methods have been applied. The first takes an aggregated approach to the question, and looks at the looks at the likely costs of substituting non-CFCs for CFCs in developing countries when the latter are treated as a single product. The key parameters are the rate at which substitution takes place, and the rate at which the price differential between the CFCs and their substitutes closes as production of the latter expands worldwide. The method is an aggregated one, because no attempt is made to identify the development of substitutes for specific uses. Rather a single price for substitutes is assumed to apply and to evolve over time in accordance with empirical experience from other chemical products, including CFC11 and CFC12. The second approach attempts to estimate the development of technical substitution possibilities in more detail, and then assesses the likely price at which these will be made available for commercial use. Developing countries are assumed to adopt the new products as they come onto the market, but allowing reasonable time for market penetration to build up and taking account of the fact that adoption can be delayed where the terms of the Protocol do not require it immediately. The reason for taking two approaches is that for each approach, but particularly the second one, a large number of assumption about prices and substitution possibilities have to be made. These are not easily verified and it is valuable, therefore, to be able to compare the results from two independent methodologies.

The aggregated method

2.6 With the aggregated method, use is made of the fact that there is some estimate of the current price differential between CFCs and their substitutes, and that the chemical industry has some method of estimating how the prices are likely to evolve over time. At present the international price of CFC11 and CFC12 is around $1430 per ton and it is stated that the main substitutes such as CFC134a will be around 3-5 times more expensive[1/]. However, the prices of substitutes must be expected to fall as production expands and technical advances are made. Previous work in this area indicates that the rate of fall is a function of the cumulative production, and that each doubling of production results in a constant percentage fall in the price of the product, at least over a considerable range of production. This relationship is shown in Figure 1 for CFC12. The fitted line to the scatter of points indicates a 30% fall in the price of CFC12 for each doubling of production. A similar relation has been found for CFC12 and for a number of chemical products. In general the elasticity of price with respect to cumulative production is around -0.2 to -0.3[2/].

2.7 In Table 1, estimates of the costs of substitution based on these observations have been made. The total demand for CFCs and their substitutes in all developed countries has been taken from the UNEP Economic Panel Report [1989]. The demand for substitutes has been calculated on the assumption that the conditions of the Protocol are

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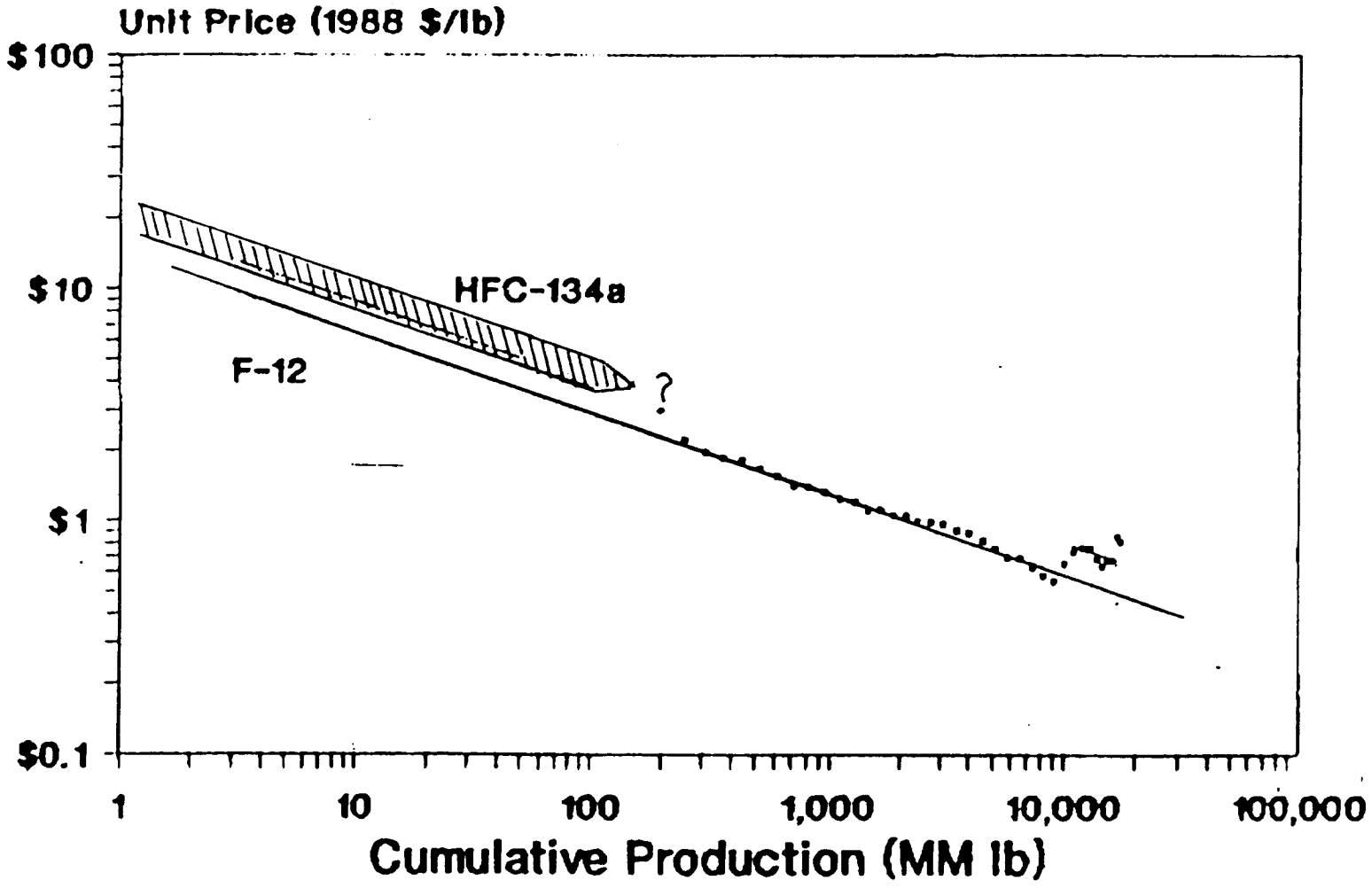
[1] Economic Panel Report and personal communications from Dupont & Company.

[2] Figures for CFC11 and CFC12 are from Dupont & Co. Further information on the process of price decline through learning see 'Perspectives on Experience', Boston Consulting Group, 1972. The slope of the fitted line in Figure 1 is referred to as the 'elasticity' of price with respect to cumulative production.

Fluorocarbon Experience Curve
F-12 and HFC-134a



Source: Dupont & Co.

TABLE 1

ESTIMATING THE COSTS OF CFC SUBSTITUTION IN DEVELOPING COUNTRIES USING THE AGGREGATED METHOD

		1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
TOTAL DEMAND FOR CFCS AND SUBSTITUTES IN M.P. COUNTRIES1/	(000) (TONNES)	1126	1185	1247	1312	1351	1392	1434	1477	1522	1567	1615	1663
REPLACEMENT BY SUBSTITUTES 2/	(000) (TONNES)	0	118	249	459	869	1007	1111	1215	1319	1423	1453	1580
CUMULATIVE WORLD PRODUCTION OF SUB. CFCS IN M.P. COUNTRIES	(000) (TONNES)	0	118	368	827	1696	2703	3814	5029	6347	7770	9223	10803
ESTIMATED COST PER TONNE OF SUBSTITUTES 3/	($1989)	N.A.	7165	5657	4597	3632	3200	2937	2750	2606	2489	2396	2314
COST PER TONNE OF CFCS 4/	($1989)	1433	1433	1433	1433	1433	1433	1433	1433	1433	1433	1433	1433
DEMAND IN DEVELOPING COUNTRIES FOR CFCS AND SUBS. 5/	(TONNES)	209	228	249	273	291	311	333	357	383	412	444	479
INDIA & CHINA		86	100	116	134	149	165	183	203	225	249	276	305
GROUP I		42	45	49	53	56	59	62	65	69	72	76	80
GROUP II		82	83	84	86	86	87	88	89	90	91	92	93
RESIDUAL USE OF CFCS 6/	(TONNES)		217	225	233	225	212	188	159	143	125	104	98
INDIA & CHINA			95	105	115	115	113	103	90	84	75	64	63
GROUP I			43	44	45	43	40	35	29	26	22	18	16
GROUP II			79	76	73	67	60	50	40	34	28	21	19
CONSUMPTION COSTS OF SUBSTITUTION IF IN M.P. 7/	($1989) (MN.)		61	102	125	146	175	218	261	282	304	328	335
INDIA & CHINA			27	47	62	75	93	120	148	165	183	204	214
GROUP I			12	20	24	28	33	41	48	50	53	56	56
GROUP II			22	34	39	43	49	58	65	66	67	68	65

NOTES 1/ GROWTH FIGURES FOR DEMAND FOR CFCS TAKEN FROM ECONOMIC PANEL REPORT: 5.4% TO 1992 AND 3.0% FROM 1992-2000

2/ ASSUMING COMPLIANCE WITH M.P. LEVELS OF PRODUCTION IN INTERVENING YEARS INTERPOLATED

3/ ASSUMING DECLINE IN COST AS PRODUCTION INCREASES WITH ELASTICITY OF -0.2 WITH RESPECT TO CUMULATIVE PRODUCTION

4/ BASED ON CURRENT AVERAGE COST OF 65 US CENTS PER POUND

5/ OF 1989 CONSUMPTION 15.7% IS ASSUMED TO BE FROM LDCS. GROWTH THEREAFTER BASED ON TABLE 2.13 OF ECONOMIC PANEL REPORT

6/ RESIDUAL CONSUMPTION OF CFC IS ASSUMED TO BE THE SAME AS THAT CALCUILATED IN TABLE 4.

7/ CALCULATED AS AMOUNT SUBSTITUTED MULTIPLIED BY DIFFERENCE IN THE AVERAGE PRICES OF CFCS AND THEIR SUBSTITUTES

ESTIMATES OF DOMESTIC PRODUCTION ARE TAKEN FROM VARIOUS SOURCES AND ARE VERY APPROXIMATE, PARTICULARLY FOR GROUP II COUNTRIES

NET PRESENT VALUE OF CONSUMPTION COST IS:

INDIA & CHINA	1056 MILLION DOLLARS
GROUP I	331 MILLION DOLLARS
GROUP II	453 MILLION DOLLARS
TOTAL	1840 MILION DOLLARS

TABLE 1 (CONTD.)

ESTIMATING THE COSTS OF CFC SUBSTITUTION IN DEVELOPING COUNTRIES USING THE AGGREGATED METHOD

		2001	2002	2003	2004	2005	2006	2007	2008
TOTAL DEMAND FOR CFCS AND SUBSTITUTES IN M.P. COUNTRIES1/	(000) (TONNES)	1713	1765	1818	1873	1929	1987	2047	2109
REPLACEMENT BY SUBSTITUTES 2/	(000) (TONNES)	1628	1677	1727	1779	1833	1888	1945	2003
CUMULATIVE WORLD PRODUCTION OF SUB. CFCS IN M.P. COUNTRIES	(000) (TONNES)	12431	14108	15835	17614	19447	21334	23279	25282
ESTIMATED COST PER TONNE OF SUBSTITUTES 3/	($1989)	2244	2184	2130	2082	2039	1999	1963	1929
COST PER TONNE OF CFCS 4/	($1989)	1433	1433	1433	1433	1433	1433	1433	1433
DEMAND IN DEVELOPING COUNTRIES FOR CFCS AND SUBS. 5/	(TONNES)	517	560	606	657	713	775	843	918
INDIA & CHINA		338	375	416	460	510	565	626	694
GROUP I		85	89	94	99	105	110	116	123
GROUP II		94	95	96	97	98	99	100	102
RESIDUAL USE OF CFCS 6/	(TONNES)	92	87	81	74	64	33	32	18
INDIA & CHINA		60	58	56	52	46	24	23	13
GROUP I		15	14	13	11	9	5	4	2
GROUP II		17	15	13	11	9	4	4	2
CONSUMPTION COSTS OF SUBSTITUTION IF IN M.P. 7/	($1989) (MN.)	345	355	366	379	393	420	430	447
INDIA & CHINA		226	238	251	265	281	307	319	338
GROUP I		57	57	57	57	58	60	59	60
GROUP II		63	60	58	56	54	54	51	49

NOTES 1/ GROWTH FIGURES FOR DEMAND FOR CFCS TAKEN FROM ECONOMIC PANEL REPORT:
2/ ASSUMING COMPLIANCE WITH M.P. LEVELS OF PRODUCTION IN INTERVENING YEARS INTERPOLATED
3/ ASSUMING DECLINE IN COST AS PRODUCTION INCREASES WITH ELASTICITY OF -0.2 WITH RESPECT TO CUMULATIVE PRODUCTION
4/ BASED ON CURRENT AVERAGE COST OF 65 US CENTS PER POUND
5/ OF 1989 CONSUMPTION 15.7% IS ASSUMED TO BE FROM LDCS. GROWTH THEREAFTER BASED ON TABLE 2.13 OF ECONOMIC PANEL REPORT
6/ RESIDUAL CONSUMPTION OF CFC IS ASSUMED TO BE THE SAME AS THAT CALCUILATED IN TABLE 4.
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ESTIMATES OF DOMESTIC PRODUCTION ARE TAKEN FROM VARIOUS SOURCES AND ARE VERY APPROXIMATE, PARTICULARLY FOR GROUP II COUNTRIES

SOURCES: See Text and Notes.

satisfied[1/]. Taking an elasticity of 0.2 and taking the initial price of substitutes to be around 5 times that of CFCs yields the price series for substitutes in Table 1 (row 4)[2/]. In order to calculate the cost of using these substitutes in developing countries, estimates of the existing demand and the rate of substitution are needed. The existing demand has been calculated using the data supplied in the Economic Panel Report and the rate of substitution has been calculated to meet the objective of an 85% substitution in developing countries by the year 2008. Further details of the latter are given in the discussion of the disaggregated method, where the same rate of substitution is assumed. From all these data, the costs of substitution have been calculated. They come out at around 1.8 billion dollars in present value terms (using a 5% real discount rate) for all developing countries, with those of India and China being about half of the total. According to this method, this item of cost will be most significant in the next five to six years and will gradually die out as the price differential between the two disappears.

2.8 These estimates of cost are of course dependent on the precise assumptions made. Hence it is necessary to check for their sensitivity to the assumptions described above. This was done and it was found that:

(a) with a higher elasticity the price drop is so fast that the cost differential drops very rapidly. For example if the elasticity is -0.3, the total cost of substitution is only $320 million;

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[1] The Protocol only defines 'demand' for substitutes in certain years, viz. 1989 and 1998. In the intervening years demand is interpolated on a linear basis.

[2] The relationship between cumulative production and price holds best after a certain level of production has been achieved. Hence it would not necessarily apply for the first 2-3 years of the 1990s. To allow for this, the elasticity is assumed to build up from -0.1 to -0.2 by 1993. A similar adjustment applies to the other 'scenarios' referred to later in the text.

(b) with the initial price being only 3 times the existing price of CFCs, the Cost estimate is also much less - only $300 million instead of the reported $1.8 billion.

Hence it can be seen that the reported figures are at the upper end of the range of cost estimates using this method. However, as will be seen below, this upper end is quite close to the estimate obtained by the disaggregated method.

The disaggregated method

2.9 As stated above, CFCs have many uses and the extent to which substitutes can be found vary from one use to another. For some products, the production of substitutes to CFCs is quite rapid, with some items such aerosols already having cheaper and more effective chemicals available. In others, particularly refrigeration, work still needs to done. Table 2 below summarizes the current state of the art as far as the costs of adjustment and the availability of substitutes for the major uses is concerned.

2.10 The extent to which developing countries will bear the costs of these substitutes will depend on how fast they shift from conventional CFCs to the new products. If the use of substitutes can be delayed long enough there may be no cost, as these products will be available at prices equal to or lower than those of the current CFCs. The rate of transfer to the new products will be dictated by the rate of growth of their own demand as well as the change in the supply of existing CFCs. In the next section some assumptions about the demand for these CFCs and substitutes are made, as well as about the available supply of conventional CFCs and the expected rate of decline in the price of the substitutes. From these an estimate of the costs of the shift to the new products can be made for broad groups of developing countries.

2.11 Along with Table 2, which is based on the UNEP Economic Panel Report, that Panel also estimated likely dates for the availability of

TABLE 2

Technological Substitution Possibilities with CFCs

SECTOR	SAVINGS POSSIBLE WITH EXISTING EQUIPMENT	PROSPECTS OF SUBSTITUTES TO CFCS	CHANGES USE OF CFC SUBSTITUTES WILL ENTAIL
Domestic Refrigeration	Recycling of CFC'S possible; costs under investigation.	Several alternative refrigerants should be available by 1995. But they will be costly.	New equipment required, will probably reduce energy efficiency.
Commercial Refrigeration	Minor technical adjustments to reduce CFC'S use or emission. Recycling of CFC'S upon disposal of unit. Substitution of CFC'S with alternative refrigerants possible but costly.	Two costly refrigerants should be available by 1995.	New equipment required for optimal use of CFC substitutes. Cost increase for new equipment estimated at 10-20%. Drop in operating costs expected.
Refrigerated Transport	Minor technical adjustments, recycling.	Good. Several alternative refrigerants now in testing. Available late 1990s.	New equipment required. No certain cost estimates available. Effective replacement costs high due to extended lifetime of existing equipment.
Cold Storage	Minor technical adjustments, recycling, use of CFC substitutes.	Good. Several alternative refrigerants now in testing. Available late 1990s.	New equipment will be more energy efficient but costly. Effective replacement costs high, again due to extended lifetime of existing equipment (avg. 15 yrs.)

SECTOR	SAVINGS POSSIBLE WITH EXISTING EQUIPMENT	PROSPECTS OF SUBSTITUTES TO CFCS	CHANGES USE OF CFC SUBSTITUTES WILL ENTAIL
Comfort Air Conditioning	Recycling. leakage reduction, and use of CFC substitutes possible but costly.	Good. Several alternative coolants now in testing. Available early 1990s.	New equipment required for optimal use of CFC substitutes. No certain cost estimates available.
Industrial Refrigeration	Improved maintenance, recycling, and use of CFC substitutes.	Alternative refrigerants now in testing. Available mid-1990s.	No further information available.
Heat Pumps Used For Heating	Improved maintenance.	Good CFC substitutes should be available by 1993.	New equipment required. No cost estimates available.
Mobile Air Conditioning	Technical adjustments (some major), use of CFC substitutes (some options very costly).	Good. CFC substitutes should be available by 1995.	New equipment required for optimal use of CFC substitutes. Added cost $30-100 per vehicle.
Rigid and Flexible Foams	Use of CFC substitutes (including water).	Good. CFC substitutes should be available by early 1990s.	New equipment required for total elimination of CFC'S.
Electronic Degreasing and Dry Cleaning Solvents	Recovery of solvent losses, use of CFC substitutes (including water).	Good. Many alternative cleaning solutions already in use.	New equipment required for some industrial uses (i.e. dry cleaning). Costs significant but not specified.

SECTOR	SAVINGS POSSIBLE WITH EXISTING EQUIPMENT	PROSPECTS OF SUBSTITUTES TO CFCS	CHANGES USE OF CFC SUBSTITUTES WILL ENTAIL
Aerosols	Use of CFC substitutes	Excellent. Many non-CFC gas propellants or pumps now available with few technical impediments.	New equipment required in many instances, but not significantly costly. Cost of final aerosol product generally less than corresponding CFC-using product.
Sterilants	Use of CFC substitutes, technical adjustments.	Excellent. Many CFC substitutes now available, others in development.	Few changes required, total CFC replacement feasible using already existing technology.

substitutes for specific uses. In addition, there has been a separate analysis of the evolution of substitutes and their uses as well as an estimate of the prices at which they will be available and whether those prices are likely to fall with development. This was carried out by McKinsey and Company [1989]. As far as the dates of earliest availability are concerned, both documents have similar estimates; and these are reported in Table 3, as well as in the Notes to Table 4. However, the estimates of prices of substitutes at the time of availability are only available from McKinsey. These are also reported in Table 3, and have been used in the calculation of costs which is reported in Tables 4 and 5. To carry out this analysis, one needs to estimate the use of CFCs and their substitutes in developing countries, by end use. The demand for CFCs by end use has been estimated from growth rates given in the UNEP Economic Panel Report. The calculated rates are given in Table 3, along with the details of how they were obtained from the information in the Economic Panel Report. The substitution of demand by non-CFCs was worked out assuming:

(a) the earliest availability dates given in Table 3;

(b) that full penetration of use would take at least seven years, from the date of initial application, and longer where the technical information indicated it; and

(c) towards the end of the period of calculation (2008), faster penetration is required for comfort and mobile air-conditioning if the conditions of the Montreal Protocol are to be met. To achieve these it is assumed that the developing countries choose to expand the cheapest option first.

2.12 Given the demand for substitutes for each end use, and of their prices, the calculation of the total substitution cost is straightforward. This is reported in Table 5. The figures indicate that the total cost for all developing countries to 2008, in present value terms at a discount

Table 3

Growth Rates for End Uses in Developing Countries

	1986-1992	1993-2000	2000-2008
Aerosols	8.5%	6.8%	6.6%
Ind. Refrigerants	8.8%	6.9%	6.6%
Solvents	12.2%	9.5%	6.6%
Non-Rigid Foam Blowing Agents	7.5%	6.3%	6.6%
Rigid Foam Blowing Agents	8.1%	6.6%	6.4%
Comfort Airconditioning	8.2%	4.0%	17.3%
Domestic Refigeration	8.4%	3.8%	17.4%
Mobile Airconditioning	8.6%	3.8%	17.4%
Average all Uses	9.3%	7.3%	8.3%

Sources: UNEP Economic Panel Report, Tables 2.12 and 2.13 and author's calculations.

Notes: The average of all uses is taken from Table 2.13. This required averaging 3 sectoral growth rates, using sectoral consumptions as weights. Details of sectoral consumption are given in Table 2 of this document. The individual end use growth rates are based on the same relative growth rates as in Table 2.12 (op. cit.). These have been scaled to achieve the desired overall growth rate.

Incremental Costs of Substitutes for CFCs and Dates of Availability

	Additional Cost ($/Kg.)	Available Dates
Aerosols	Nil	Available Now
Ind. Refrigerants	0.95	1995
Solvents	1.15	1993
Non-Rigid Foam Blowing Agents	1.75->0.8	1990->1998
Rigid Foam Blowing Agents	1.75->0.8	1990->1998
Comfort Airconditioning	1.45->0.95	1990->1998
Domestic Refigeration	14.60->11.90	1995->1998
Mobile Airconditioning	13.25->10.95	1994->1998

Sources: Mckinsey & Co. [1989]

Notes: Where more than one figure is given, the cost is expected to fall from the higher to the lower figure. The dates at which the two figures apply are given in the second column.

Table 4

Demand for CFCs, their Substitutes and the Costs of Substitution in Developing Countries
Developing Countries: Disaggregated Method

		1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Total Consumption (000) tonnes 1/		209	228	249	273	292	312	334	358	384	413	445	480
Individual Uses 2/	Share (%)												
Aerosols	17	35.5	38.6	41.8	45.4	48.4	51.7	55.2	58.9	62.9	67.2	71.7	76.5
Ind. Refrigerants	27	56.4	61.4	66.8	72.7	77.8	83.1	88.9	95.0	101.6	108.6	116.1	124.2
Solvents	23	48.1	53.9	60.5	67.9	74.3	81.4	89.1	97.6	106.9	117.1	128.2	140.4
Non-Rigid Foam Blowing Agents	13	27.2	29.2	31.4	33.8	35.9	38.2	40.6	43.1	45.8	48.7	51.8	55.0
Rigid Foam Blowing Agents	4	8.4	9.0	9.8	10.6	11.2	12.0	12.8	13.6	14.5	15.4	16.5	17.5
Comfort Airconditioning	5	10.5	11.3	12.2	13.2	13.8	14.3	14.9	15.5	16.1	16.7	17.4	18.1
Domestic Refrigeration	4	8.4	9.1	9.8	10.7	11.1	11.5	11.9	12.3	12.8	13.3	13.8	14.3
Mobile Airconditioning	7	14.6	15.9	17.3	18.7	19.5	20.2	21.0	21.8	22.6	23.5	24.4	25.3

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Use of CFC substitutes 3/												
Total Subsituted CFCs (000) tonnes		11.0	24.3	39.8	67.3	99.9	146.1	198.7	240.6	288.0	341.5	381.8
Individual Uses												
Aerosols		5.5	12.0	19.4	27.7	36.9	47.3	58.9	62.9	67.2	71.7	76.5
Ind. Refrigerants							7.4	15.8	25.4	36.2	48.4	62.1
Solvents					10.6	23.3	38.2	55.8	76.4	100.4	128.2	140.4
Non-Rigid Foam Blowing Agents		4.2	9.0	14.5	20.5	27.3	34.8	43.1	45.8	48.7	51.8	55.0
Rigid Foam Blowing Agents		1.3	2.8	4.5	6.4	8.6	10.9	13.6	14.5	15.4	16.5	17.5
Comfort Airconditioning			0.6	1.3	2.1	2.9	3.7	4.6	5.6	6.7	7.8	9.0
Domestic Refrigeration							1.7	3.5	5.5	7.6	9.9	12.3
Mobile Airconditioning						1.0	2.1	3.3	4.5	5.9	7.3	8.8
Residual Use of CFCs 4/		217.0	224.7	233.2	224.7	212.1	187.9	159.3	143.4	125.0	103.5	98.2
Permitted use of CFCs if within the Protocol 5/											166.5	149.9
Residual Use as % of Permitted Use											62.1%	65.5%

Sources: UNEP Economic Panel Report [1989], McKinsey & Co. [1989] and authors calculations. For notes to the Table, see text and Table 4 (contd.).

Table 4 (contd.)

Demand for CFCs, their Substitutes and the Costs of Substitution in Developing Countries: Disaggregated Method

		2001	2002	2003	2004	2005	2006	2007	2008
Total Consumption (000) tonnes 1/		518	560	607	658	714	756	822	895
Individual Uses 2/	Share (%)								
Aerosols	17	81.6	86.9	92.7	98.7	105.2	112.2	119.6	127.4
Ind. Refrigerants	27	132.3	141.0	150.2	160.1	170.6	181.7	193.7	206.3
Solvents	23	149.7	159.5	170.0	181.1	193.0	205.7	219.2	233.6
Non-Rigid Foam Blowing Agents	13	58.7	62.5	66.7	71.1	75.8	80.7	86.1	91.8
Rigid Foam Blowing Agents	4	18.7	19.9	21.1	22.5	23.9	25.5	27.1	28.8
Comfort Airconditioning	5	21.2	24.8	29.1	34.2	40.1	47.0	55.1	64.6
Domestic Refrigeration	4	16.8	19.7	23.2	27.2	31.9	37.5	44.0	51.6
Mobile Airconditioning	7	29.7	34.8	40.9	48.0	56.3	66.1	77.6	91.0

Use of CFC substitutes 3/	2001	2002	2003	2004	2005	2006	2007	2008
Total Subsituted CFCs (000) tonnes	426.1	473.1	525.6	584.3	650.0	723.8	790.7	877.7
Individual Uses								
Aerosols	81.6	86.9	92.7	98.7	105.2	112.2	119.6	127.4
Ind. Refrigerants	77.2	94.0	112.7	133.4	156.3	181.7	193.7	206.3
Solvents	149.7	159.5	170.0	181.1	193.0	205.7	219.2	233.6
Non-Rigid Foam Blowing Agents	58.7	62.5	66.7	71.1	75.8	80.7	86.1	91.8
Rigid Foam Blowing Agents	18.7	19.9	21.1	22.5	23.9	25.5	27.1	28.8
Comfort Airconditioning	11.6	14.9	18.9	23.9	30.1	37.6	46.9	64.6
Domestic Refrigeration	16.8	19.7	23.2	27.2	31.9	37.5	44.0	51.6
Mobile Airconditioning	11.9	15.7	20.4	26.4	33.8	43.0	54.3	73.6
Residual Use of CFCs 4/	91.9	86.9	81.4	73.7	64.0	32.5	31.5	17.5
Permitted use of CFCs if within the Protocol 5/	133.4	116.8	100.3	83.7	67.2	50.6	34.0	17.5
Residual Use as % of Permitted Use	68.9%	74.4%	81.2%	88.1%	95.3%	64.3%	92.7%	100.3%

Sources: UNEP Economic Panel Report [1989], McKinsey & Co. [1989] and authors calculations. For notes to the Table, also see text.

Notes to Table 4

1/ Calculated using 1986 total for LDCs and then applying growth rates for 1986 -1989 as given in Table 2.13 of the UNEP Economic Panel Report [1989]

2/ Shares of total use are taken from McKinsey [1989], Exhibit 2.3. Growth rates for individual categories are as reported in Table 3.

3/ The use of CFCs has been calculated on the following basis:
i) full replacement of any use must take at least 7 years
ii) aerosols can start to be replaced immediately, with 7 years for full phase-out
iii) industrial refrigerants start being replaced in 1995, with 12 years for full phase-out
iv) solvents start in 1993 and take 7 years
v) blowing agents start immediately and take 7 years for full phase-out
vi) comfort airconditioning begins in 1991 but takes 20 years for full phase-out
vii) domestic refrigeration starts in 1995 and takes 7 years
viii) mobile air conditioning starts in 1994 and takes 20 years for full phase out.
The move to full phase out is assumed to be at a constant percentage rate except at the end of the period when it is accelerated to achieve the Protocol requirements. These assumptions are based on the Economic Panel Report with some adjustment by the author.

4/ The residual use of CFCs is the difference between total demand and use of substitutes

5/ The permitted use limits are for 1999 consumption to be no more than the 1986 level and for the 2008 consumption to be 15% of the 1986 level.

Table 5

Demand for CFCs, their Substitutes and the Costs of Substitution in Developing Countries: Disaggregated Method

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Incremental Costs of Substitutes ($1989 /Kg.)												
Aerosols	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ind. Refrigerants	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.95	0.95	0.95	0.95	0.95	0.95
Solvents	n.a.	n.a.	n.a.	n.a.	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Non-Rigid Foam Blowing Agents	n.a.	1.75	1.59	1.44	1.30	1.18	1.07	0.97	0.88	0.80	0.80	0.80
Rigid Foam Blowing Agents	n.a.	1.75	1.59	1.44	1.30	1.18	1.07	0.97	0.88	0.80	0.80	0.80
Comfort Airconditioning	n.a.	n.a.	1.45	1.37	1.28	1.21	1.14	1.07	1.01	0.95	0.95	0.95
Domestic Refrigeration	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	14.60	13.64	12.74	11.90	11.90	11.90
Mobile Airconditioning	n.a.	n.a.	n.a.	n.a.	n.a.	13.25	12.63	12.05	11.48	10.95	10.95	10.95
Total Costs of Using Substitutes ($1989 Mn.)												
Aerosols		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ind. Refrigerants		n.a.	n.a.	n.a.	n.a.	n.a.	7.0	15.0	24.1	34.4	46.0	59.0
Solvents		n.a.	n.a.	n.a.	12.2	26.7	43.9	64.2	87.8	115.4	147.5	161.5
Non-Rigid Foam Blowing Agents		7.3	14.2	20.8	26.8	32.2	37.3	41.9	40.4	39.0	41.4	44.0
Rigid Foam Blowing Agents		2.3	4.4	6.5	8.4	10.1	11.7	13.2	12.8	12.4	13.2	14.0
Comfort Airconditioning		n.a.	0.9	1.8	2.7	3.5	4.2	5.0	5.7	6.3	7.4	8.6
Domestic Refrigeration		n.a.	n.a.	n.a.	n.a.	n.a.	24.8	48.1	70.0	90.4	117.3	146.0
Mobile Airconditioning		n.a.	n.a.	n.a.	n.a.	13.4	26.5	39.3	51.9	64.2	80.0	96.9
Total Costs		9.6	19.6	29.1	50.0	86.0	155.5	226.8	292.7	362.1	452.7	530.0

Present Value of Costs at 5% discount rate are:$1147 Mn. (1990-2000) and $1818 Mn. (1990-2008)

Sources: UNEP Economic Panel Report [1989] and McKinsey & Co. [1989]

Table 5 (contd.)

Demand for CFCs, their Substitutes and the Costs of Substitution in Developing Countries: Disaggregated Method

	2001	2002	2003	2004	2005	2006	2007	2008
Incremental Costs of Substitutes ($1989 /Kg.)								
Aerosols	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ind. Refrigerants	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Solvents	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Non-Rigid Foam Blowing Agents	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Rigid Foam Blowing Agents	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Comfort Airconditioning	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Domestic Refrigeration	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90
Mobile Airconditioning	10.95	10.95	10.95	10.95	10.95	10.95	10.95	10.95
Total Costs of Using Substitutes ($1989 Mn.)								
Aerosols	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ind. Refrigerants	73.3	89.3	107.0	126.7	148.5	172.7	184.0	196.0
Solvents	172.1	183.4	195.5	208.3	222.0	236.5	252.1	268.6
Non-Rigid Foam Blowing Agents	46.9	50.0	53.3	56.9	60.6	64.6	68.9	73.4
Rigid Foam Blowing Agents	14.9	15.9	16.9	18.0	19.1	20.4	21.7	23.1
Comfort Airconditioning	11.1	14.2	18.0	22.7	28.5	35.7	44.5	61.4
Domestic Refrigeration	200.0	234.8	275.6	323.6	379.8	445.9	523.5	614.5
Mobile Airconditioning	129.9	171.6	223.8	288.9	369.9	470.3	594.4	805.6
Total Costs	648.3	759.1	890.1	1045.0	1228.5	1446.1	1689.0	2042.5

Present Value of Costs ate 5% discount

Sources: UNEP Economic Panel Report [1989] and McKinsey & Co. [1989]

Notes to Table 4

The incremental costs of substitution are taken from McKinsey [1989], Appendix D. Where prices are projected to fall, the percentage rate of fall is assumed to be constant.

n.a. = substitute not available.

The total costs are the unit incremental costs multiplied by the amount substituted, as given in Table 4.

rate of 5%, is about $1.8 billion. This is almost the same cost as that obtained from the disaggregated method. Equally importantly, it shows a rising cost of substitution over the period 1990-2008. The latter result arises because there is no built in assumption that substitute prices will go on falling as they have done for CFCs in the past. Some fall in prices is assumed for foam blowing agents, air conditioners and refrigerants. But the falls are fairly small, compared to what results from applying the rule applied by the Chemical industry, which was used in the application of the aggregated method. Hence the fall in prices is lower with this method.

2.13 However, it should be borne in mind that this figure of around $2 billion is at the upper end of the figures obtained by the first method, and that, if the learning curve results in faster price falls, the actual figure could be much lower, perhaps as little as $300 million. It is impossible to be more precise at this stage, but it is more likely that the second method is closer to the 'correct' answer and that the best guesstimate of what is likely to be required to compensate developing countries for this item of the cost of joining the Protocol is somewhere around $2 billion. In any event the principle that compensation should be paid equal to the difference between the price of the CFC and its substitute, multiplied by the amount used in each of the uses is clear enough and should be applied. The financial and distributive implications of this are discussed further in Section IV.

Costs of adjustment in the user industries (capital and operating)

2.14 As Table 2 shows, there are several industries in which the shift to the new products would impose costs on those industries. Many of these costs are to do with changes in maintenance practices but mostly will result from changed production processes, many of which require new manufacturing equipment: refrigerators, air conditioners foams etc. In addition there will be changes in the operating costs of the new equipment (mainly changes in the costs of energy used). At present it is difficult

to say how big these costs will be[1/]. The use of the new technology is very much in its infancy, with some exceptions such as aerosols. From all the work of the UNEP Technical Panel on CFCs, and from other sources consulted, only a partial picture of the capital and operating costs could be made. This picture, and its implications of the costs for developing countries is summarized in Table 6.

2.15 A number of points of importance emerge from this Table. These are listed below.

(i) While there is no precise estimate of the capital or operating costs of shifting to non-CFCs in the user industries, it can be seen that they range from being quite small in some industries, such as aerosols, to very large in others, such as refrigerated transport, or drycleaning. For some industries no estimate of the cost can be provided at present. If assistance is to be provided to developing countries to cover such costs, a distinction will have to be made between capital and operating expenditures, and between support for recycling and new technologies.

(ii) Where industries have a higher operating costs with substitutes, care has to be taken not to double-count the costs. The additional costs of the chemicals have already been accounted for, in the calculations presented in Tables 1 and 5. Hence it is only the other operating costs that are relevant. In some cases, however, these will be negative, as for example is the case with cleaning processes and aerosols. In order to allow for these benefits it is suggested that in calculating the subsidy to each industry any savings in operating costs are netted out.

(iii) The issue of recycling is a difficult one to assess. There is no requirement within the Protocol to undertake recycling as such. However, if the price of CFCs rises, as governments

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[1] Some may indeed be negative. For example operating costs of refrigerators could be lower with the substitute products.

restrict its use, then it will be economical to undertake recycling. The question then arises, how much should developed countries support this process financially? The ideal economic solution is that as the 'price' CFCs rises to reflect its scarcity value, so firms should undertake the optimal combination of recycling and replacement. If 'outside' help is available for the latter but not the former, then the pattern of substitution will be biased in favour of replacement. In order to avoid this, developing countries should be assisted in developing recycling and conservation programs as well. However, at the end of the day, it will be a matter for the developing countries as to which method they wish to pursue in reducing their total consumption of CFCs. Hence both forms of technology transfer should be made available: to assist in improving maintenance and to acquire and develop the appropriate technology for manufacturing equipment that uses substitutes to CFCs.

(iv) In almost all cases, developing countries will face, in addition to the capital and operating costs, costs of technology transfer. These may involve the actual purchase of new processes, as well as the training of personnel in the use of the equipment and chemicals. At present the Environmental Protection Agency of the USA, and other agencies in developed countries, are providing assistance to producers in countries such as China to adapt production technology to the new products. From discussions with officials of these agencies, it appears that, the main effort required is to provide technical support to the manufacturers and to bring technicians and engineers over to developed countries for training.

(v) One point which emerges in some of the discussions of adjustment in industry is that of small producers. The changes required may not be large in absolute terms, but they are likely to be significant for small enterprises. The

extent to which governments in developing countries want to protect such firms is a mater for them, but the process of transfer should not be such as to favour larger manufacturers, at the expense of competition in the relevant sector.

2.16 What can one conclude from all this about the size of the transfer to developing countries that be required to cover the costs of adjustment in the user industries? The first point is to note that further information is needed before even a rough estimate of the capital and operating costs can be obtained. As an order of magnitude, it is likely to be in the hundreds of millions of dollars, and is likely to be concentrated in a few sectors, with a large number of the other sectors receiving only small amounts. If a fund had to be set up now, the best suggestion would probably be for it to have an initial capital of $200 million for the first three years to be disbursed world-wide. The terms for such disbursement are discussed further in Section IV of this document.

2.17 As far as the technical assistance fund is concerned, one is also in uncertain waters. However, on the basis of these discussions with some of the agencies involved in CFC work, it is suggested that an initial annual budget for such assistance be around $10 million. After this technical assistance program has been operational for 1-2 years, the size of the fund can be reviewed in the light of its actual and potential achievements. Again the details of the terms of the operation of such a fund are given in Section IV.

Table 6

Capital and Operating Costs to User Industries of Substituting CFCs

Aerosols

Substitution of CFCs with hydrocarbons is technically and economically feasible. Costs of conversion, including retrofitting of equipment, have been estimated. A large part of these arise from additional safety requirements. Although in general these costs are not significant, for small manufacturers they are likely to prove to be too high. Per 100 million aerosols produced, the total cost in the UK of converting to alternatives was estimated at around $3.3 million in 1989 prices[1/]. An additional annual maintenance/operating cost of around £190,000 was also identified. On the other hand the substitutes are themselves cheaper and a saving of $2-6 million per 100 million cans is expected.

Developing countries

Taking the EC ratio of CFC input per can there are approximately 420 million cans of aerosols being produced in LDCs. On this basis, and ignoring the difference in operating costs, the conversion costs in developing countries would be around $14 million at current prices. In addition, developing countries will need technical assistance with the transfer to the new technology, and small manufacturers may need some government support.

Refrigeration

Costs of recovery of CFCs at the disposal of existing refrigerators are put at around $15 per refrigerator for the Federal Republic of Germany. The same applies to commercial and retail refrigeration. No cost estimates of the changes in capital equipment to manufacture the new refrigerators are available. In terms of operating costs the current state of knowledge is also uncertain. It is stated that for certain mixtures there is scope for energy improvement but for others an energy increase is likely.

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1 'Possible Effects of Additional Control Measures on CFCs in the UK Aerosol Industry', IAL Consultants Ltd., UNEP Socioeconomic Workshop, Rome, 1986.

Table 6 (Contd.)

Developing countries

Assistance with adopting recycling and conservation technologies, and with developing appropriate alternative using technology is likely to be a large item here, but no cost estimate can be made. Once developed, the new technology may involve higher operating costs but that is not obvious at the present time.

Refrigerated transport. To reduce the use of CFCs in this sector by 245 tonnes by the year 2000, would require an investment of around $2,000 million in developed countries. The conversion of the world fleet of ships would cost $700 million to convert to non-CFC use. For cold storage there is expected to be no noticeable cost of conversion.

Developing countries

It is difficult to see precisely what these figures mean for developing countries but it is clear that costs in this area are likely to be significant. On a simple pro rata basis, for example, with developing country use of CFCs being 16% of world use, would give a figure of 46 tonnes of total use in refrigerated transport in LDCs. From the above figures, this would cost $370 million to convert over the period 1990-2008. For shipping the conversion cost would depend on the percentage of the world fleet that belongs to LDCs. Again, such countries would need access to the new technology.

Comfort Airconditioning

Recovery and recycling is expensive and would only be justified if the price of CFC refrigerants rose significantly. The possibility of retrofitting existing systems could be very high and it may be cheaper to buy a new system. Costs of switching manufacturing systems is reported at around $2 million for a typical single manufacturer. In addition, a large amount would have to spent on manpower training.

Developing countries

Developing countries will need assistance with both recycling and new technologies but no estimate can be made at this time of the total cost.

Table 6 (Contd.)

Industrial Refrigeration

Similar remarks hold her as for domestic refrigeration. No cost estimates are available for new equipment manufacturing. Cost figures for achieving emission reductions have been estimated and are at around $9 million per annum for all developed countries.

Developing countries

No cost estimates for new systems are available> If improved maintenance is adopted, then on a pro rata basis the cost in developing countries amounts to about $1 million per annum.

Mobile Airconditioning

Retrofitting the existing cars would cost around 1.5-2 thousand dollars per vehicle. Lower figures are available for partial refitting now ($80 per vehicle). The additional cost of using substitutes for new vehicles is around $30-100 by the mid 1990s).

Developing countries

It is unlikely that developing countries would have to undertake retrofitting of existing cars. The costs for new vehicles are important and could be used as the basis of calculating the additional costs in this sector. However, as they include both the costs of substitute chemicals and the costs of conversion, the extent to which they have already been incorporated in the figures given in Table 5 are unclear. Hence further data are need before this calculation can be done.

Foams

A number of technical options are relevant here and these are discussed below. For each of them account also needs to be taken of the difference in energy efficiency between foams blown with CFCs and with their substitutes. Alternative insulating products do not provide the same thermal conductivity as CFC products, and in general the efficiency is less. Thus the choice is between using a greater volume of insulating material or incurring an energy penalty.

Table 6 (Contd.)

Flexible PU foam slabstock: If CFC recovery through carbon absorption is undertaken, the capital cost is likely to be high. The use of AB technology, which would reduce the use of CFCs; or the use of methylene chloride, which would substitute for them, could cost between $100,000 and $250,000 for an average sized plant. The use of soft polyols could also reduce CFC requirements for foam blowing, but would raise chemical costs by about 15%.

Flexible Foam moulded: Here the use of alternative chemical could add 5-15% to annual operating costs.

Rigid PU foam insulation: If HCFCs are used plants would have to be better protected against explosion, which would incur a considerable capital cost. In operating cost terms, it is estimated that operating costs could be 10-20% higher for water blowing systems then for CFC blowing.

Rigid PS foam sheet: Considerable safety concerns arise here with respect to the use of hydrocarbon substitutes. The costs of meeting safety standards are estimated at not less than $1 million per plant. If air pollution requirements have also to be met an additional cost of around $1 million per plant would be required. If HCFC22 is used to replace CFC12 capital costs of around $50,000 per plant are likely. Operating costs should be about the same.

Rigid PS boardstock: No capital cost or operating cost estimates are available. The same applies to other sub-applications such as as phenolic and polyolefin foams.

Developing countries

Changes in foam production in developing countries is likely to incur significant costs, given the figures presented above. This applies to both capital and operating costs. In addition these countries will need technical assistance in adopting the new technologies.

Table 6 (Contd.)

Electronics

No appreciable increase in capital or operating costs are reported if conservation and recovery of CFC113 are introduced, and if aqueous cleaning is employed.

Developing countries

The only additional cost arising here would be that associated with the acquisition of the new technology.

Precision cleaning

The use of aqueous cleaning and alcohols is estimated to be less expensive than the current CFC113. No costs of conversion are available.

Developing countries

Information on capital costs and technology acquisition costs is unavailable.

Metal cleaning

A combination of conservation and recovery, and use of aqueous cleaning is expected to be employed here. It is estimated that aqueous systems will have lower capital costs and lower operating costs once instituted.

Developing countries

No firm estimates of the additional costs are available but they are not expected to be large.

Drycleaning

HCFC substitutes are being developed. However, the capital costs of their use could be substantial because new drycleaning machines would have to be employed. No estimate of the cost is available.

Developing countries

This is expected to be a major item of cost, once industry starts to adopt the new non-CFC using plants in these countries.

Costs of amortizing existing capacity faster

2.18 A number of developing countries have recently set up manufacturing facilities for CFC11 and CFC12 and it may be the case that they will not be able to use them for the full life of the plants as a result of the Protocol. In India, for example, total capacity at the end of 1989 will be 18,000 tons of CFC11, CFC12 and CFC22 with 10,000 tons having been added this year[1/]. Unfortunately, similar figures are not available for all other countries. Eight countries known to produce CFCs are: Argentina, Brazil, China, India, Indonesia, Korea and Mexico and Venezuela. Such information as is available is presented in Table 7. This indicates that the total capacity of these plants in these countries is estimated at around 65,000 tons. However, these figures need to be confirmed.

2.19 Information on the ages of the plants or their capital costs is not available but is required to estimate the loss of value. For example, if all the plants were built since 1986, they would all have to close down by 1999, when production must revert to 110% of the 1986 level. In that event the economic value of the plants less any salvage value would be a cost to the countries concerned of joining the Protocol.

2.20 In order to obtain an upper bound to the magnitude of the costs involved in faster amortization, it is assumed in the figures calculated in that Table that all plants had a remaining life of 25 years in 1989 and that, as a result of the Protocol, they would have to be closed down in 1999 instead. Also, the capital cost figure is based on $20 million for a 5,000 ton plant. On this basis, the loss in capital value for all

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[1] Figures provided to UNEP by Gujarat Fluorochemicals Limited of India.

TABLE 7

Major Manufacturing Facilities in Developing Countries for CFCs

Country	Plant	Information Available
Argentina	Ducilio S.A.	Capacity around 7000 tons
Brazil	Dupont do Brasil S.A.	Total capacity of both is around 17,000 tons.
	Hoechst do Brasil Quimica e Farmaceutica	
China		No plant information except that overall capacity was around 22,000 tons in 1986.
India	Gujarat Fluorochemicals ltd.	5000 tons built in 1989.
	Navin Fluorine Industries	5000 tons built in 1988 (?)
	Other Plants	8000 tons capacity. Date of construction not known.
Indonesia		No details available. Capacity around 5,000 tons (?)
Mexico	Quimobasicos S.A.	No plant details available
	Halocarburis S.A.	Capacity estimated at around 10,000 tons (?)
South Korea		No details available. Capacity around 5,000 tons (?)
Venezuela	Atochem of France	No details available. Capacity around 5,000 tons.

On the assumptions that: (a) total capacity is 65,000 tons, (b) a plant of 5,000 tons has a capital cost of $20 million (c) the plants have a remaining average life of 25 years in 1986 and (d) all plants would have to scrapped in 1999, the salvage value of the total stock would be $156 million.

Sources: UNEP; Gujarat Fluorochemicals, India; Embassy of Mexico; Dupont & Co.

plants through faster amortization is around $155 million[1/]. Although this cost would not have to be incurred until the plants were actually closed down, part of the fund set aside for this purpose could be used to assist manufacturers in establishing new production facilities ahead of 1999. Further details of the mechanism of financing this transfer are given in Section IV.

Higher costs of importation

2.21 As CFC production is reduced, the goods made with these chemicals will be replaced by others using the new products. Some of these will be cheaper but most will be more expensive, at least in the short run. How should the developing countries be compensated for these price rises? If the country is not a party to the Protocol, it would be unable to import products using controlled substances from a country that was a party to the Protocol. On the other hand, if it were a member there would be no such restriction. Hence, in one way a country may find it advantageous to be a member of the Protocol if it wishes to purchase products containing controlled substances. On the other hand, as a party, it cannot trade controlled substances with non-parties. So, for example, if China were not to be a Party and were to produce refrigerators using the old substances, it could sell them to other non-party countries, and both countries engaging in the trade would gain relative to their position if they were signatories. The overall balance of the effect of importing controlled substances is unclear and will depend, inter alia, on which manufacturing countries are likely to remain outside the Protocol.

2.22 The importation of goods using replacements will therefore also depend on what other goods are on the market at the time. If all manufacturing countries were to be parties, there would be no savings to non-parties, as they would have to import from the party countries anyway.

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[1] The amortization has been calculated on a straight line basis. Estimates of plant costs were provided by Dupont & Co. as a rough order of magnitude.

2.23 Some idea of the additional cost involved in importing goods which have been produced with substitutes can be obtained by looking at the extent to which prices of such goods are likely to rise as a result of the substitution of CFCs. This has been done in Table 8. As a percentage of the market price of most of the final products, CFCs are a very small percentage - ranging from being negligible for products such as electronics, to being 2-3% of the price for some foam products. However, for intermediate products, such as PU rigid foam, the cost of the CFC inputs could be as high as 20-30% of the final price. Replacing these CFCs with substitutes has been estimated to increase that component of cost by a factor ranging from 100 to 1000%. The latter figures are taken from Tables 1 and 5 of this report. Hence the increase in final price works out at 1-4% for the final products, and between 24 and 37% for the intermediate products.

2.24 Imports of CFC based products will also vary enormously from one developing country to another. To give an idea of the sorts of sums involved, a country such as Thailand imported around $15 million of airconditioning and refrigeration equipment in 1988. At 1% of the value the increase in cost would be $150,000, which is a small sum in this context. Nigeria imported around $5 million of such equipment in 1987, and again allowing for a 1% rise in price this would amount $50,000 as an addition to the import bill. Finally Pakistan imported $22.8 million of refrigeration and airconditioning equipment, which would imply an increase of $228,000 in this item of the import bill. As percentages of the total import bill these figures will also vary, with smaller and less developed countries facing, in general, larger increases in percentage terms. Finally countries importing mainly intermediate products could be much more seriously affected than those importing largely final products.

2.25 Estimating the size of the fund required to compensate for these price increases is possible, but would require further research. However, the figure could only be an approximate guide to the additional import costs, as the price differences are still very uncertain and the patterns

of imports are likely to change over time. Furthermore, the conceptual case for such compensation is not clear. The appropriate amount to compensate would be the difference between the cost of importation when within the Protocol and cost of importation outside the Protocol. As has been argued above, it is not clear that this would even be positive. However, where there are users of intermediate products in developing countries, who would be adversely affected by the large increases in costs of materials such as foams, there may be a case, on development assistance grounds, for providing some compensation to such producers. In such cases it is suggested that provision be made for financial compensation on an ad hoc basis. This is discussed further in Section IV.

Table 8
Additional Costs of Products Using CFC Substitutes

Product	CFC Cost as % of Price of Product	Cost of Substitute as % of CFC Cost	Increase in Final Price (%)
Flexible Foams	1.0-3.0	220	1.2-3.7
Rigid Foams	0.5-3.0	220	0.6-3.7
PU Rigid Foams (Intermediate)	20-30	220	24-37
Domestic Refrigerants	0.1	1120	1.0
Electronics	1.0	180	0.8

Sources: authors calculations, and UNEP Economic Panel Report, Table 2.8

Notes: Column 2 is taken from the UNEP Panel Report.
Column 3 is based on the additional costs of substitutes given in Table 5, and on the current average price of CFCs.
Column 4 is calculated from columns 2 and 3 as:

$$X4 = (X3-100)*(X2)/100$$

where X2, X3 and X4 are the values in columns 2,3 and 4 respectively.

Costs of collecting information

2.26 The discussion so far has indicated strongly that there is a great need for further information on the precise circumstances in each country as far as CFC production and consumption is concerned. This includes the industries in which the materials and their substitutes are used, or are likely to be used. Hence part of the budget of any putative organization would have to be spent on such items.

2.27 It is essential for the success of this fund that a set of "CFC Audits" be carried out for each of the parties that are developing countries. The type of information collected under such an audit is listed in Table 9. The cost of collecting it would naturally vary from country to country but, as a rough estimate, allowance should be made for $500,000 - $1 million in large countries, to $25,000 - $200,000 in small to medium countries. An estimated total budget is $10 million, on the assumption that most developing countries become parties. These audits should be carried out as soon as possible, and certainly within the next two years.

TABLE 9

Information Required Under a CFC Audit

1. Consumption: Present consumption by type of chemical. Estimates of future consumption. Consumption figures for substitutes and estimates of future consumption.

2. Production: Profile of existing plants, capacities, age of plant, expected future production. Estimates of current value.

3. User Industries: List of all user industries. Current technology. Scope for shifting to new chemicals. Estimates of costs of shifting. Estimates of new industries to be established that would use CFCs.

4. Trade: Identify all imports and exports of CFC and related chemicals by source. Enumerate imports and exports of all products using CFCs as inputs, also by source.

IV. Guidelines for Transfers Under the Fund

4.1 At the first meeting of the "Open Ended Working Group of the Parties of the Montreal Protocol" it was agreed that a Trust Fund or some specific mechanism should be created to meet the incremental costs to developing countries of meeting the terms of the Montreal Protocol. In this report, types of transfers and their magnitudes have been identified. In this Section, the mechanisms for making those transfers are reviewed. Specifically, each of the items of cost identified above are now considered from this point of view.

4.2 As far as the first item of cost is concerned, this involves a direct compensation for the higher cost of using CFC substitutes. A figure of $1.8 billion over 18 years has been estimated, running at around $200-400 million a year. For each country the additional quantity of substitutes used, whether imported or manufactured, can be calculated, and a transfer equal to the amount used times the difference between the international prices of the substitutes and their CFC equivalents made. Such a transfer is probably most readily carried at out at the government level, which then leaves the responsibility of allocating those funds to local manufacturers to the government. Detailed rules for determining the calculation of the amounts involved, and for presenting an annual budget to a committee of donors and recipients would be the responsibility of a secretariat dealing specifically with this issue. That secretariat could also be responsible for effecting the transfers. If the terms of the Protocol extend to 2008 for developing countries, then that is how long this secretariat would have to be in existence.

4.3 The question may be raised as to whether there is a difference in cost between a developing country that chooses to produce the substitute product and one that chooses to import it. From an economic point of view there is no distinction between the two. The domestically manufactured product has to be valued at its international traded price and so the two are equivalent. The domestic cost may be higher, because the country has

chosen to protect that particular commodity, and the domestic price may also be higher for that reason or because of domestic taxes. However, it would be difficult to justify providing a subsidy from international funds to support the difference between the international price and the price that prevails domestically for reasons of protection or inefficiency. Thus, a country that wished to set up a production facility for a substitute would be able to claim, from the fund, a sum equal to the difference between the international price of substitute and the price of the old product, multiplied by the level of production consumed at home or exported. Equally, however, a country wishing to import the product would be able to make a similar claim.

4.4 Under the support for industrial restructuring, two major components would have to be provided. One is a technical assistance facility, including training, and the other is an industrial investment facility.

4.5 The technical assistance would have to be sensitive to the technological needs of the developing countries, rather than just 'transferring' production technologies evolved in the developed countries; technologies which are often inappropriate in terms of operational and maintenance facilities in the developing countries. Again, a secretariat needs to be set up to:

(a) coordinate technical assistance among the many donors involved with technology transfer in this area;

(b) maintain a policy dialogue between industry and government in the recipient countries, as well as between the donors and the recipients. Often the adoption of particular technology is impeded by the central government's economic policies, and often the role of the private sector in this process is not given enough importance;

(c) provide some direct assistance itself, through the use of consultants.

4.6 Such tasks would be coordinated through the same secretariat as that involved in the financial transfers, but in a separate division. As indicated earlier its budget should probably be around $10 million per annum, reviewable after 2 years.

4.7 As far as assistance with actual investment is concerned, this is probably better handled through existing institutions such as the World Bank and the regional banks. The task of the secretariat here would be to screen applications and identify and seek out areas in which productive investments in new technology could be made. It would then assist the lending institution in appraising the projects. Of the budget of $65 million a year suggested earlier for adjustment lending in this area, about $2 million could be allocated to the secretariat for this purpose. The remainder would be lent through the existing channels on whatever terms were applicable to the country in question. However, the investment in new plant and equipment would have to be on undertaken on some loan basis, probably through the development banks. The task of the secretariat would be to identify suitable projects and to support the lending banks in appraising and implementing them.

4.8 Payments for the faster amortization of existing CFC plants would be made in much the same way as the financial transfers for the higher costs of CFC substitutes. For individual industries an audit of their plants and evidence that they had been permanently closed down would have to be provided. The payment would be made to the central government, which would then be responsible for any subsequent compensation to the manufacturers.

4.9 As was indicated earlier, assistance for the higher costs of imports is unlikely to be much, and calculating and transferring the sums involved would cost almost as much as the transfers themselves. However, an application procedure should be left open for those countries that have an industry or industries that make heavy use of intermediate products such as PU rigid foam. If their costs of importing the substitute

products is so high as to cause major dislocation, then payment on a case by case basis should be considered. The task of vetting these applications would be undertaken by the secretariat. It is impossible to estimate the size of the required fund for this purpose but it not likely to be large compared to the other sums involved.

4.10 Finally the CFC audits would be entirely the responsibility of the secretariat. Most of the work would be tendered out to consulting firms, preferably in the countries concerned. But the coordination would be undertaken by the secretariat. Given the kind of tasks identified, the consultant allocation would be large at the beginning but declining over time, and with very few tasks after 10 years.

4.11 In Table 10 the mechanisms for financial transfer are summarized.

4.12 It has been forcefully stated by some members of the Protocol that such transfers should be made within the framework of existing institutions, rather than through new ones set up specially for this purpose. This objective can be met by making an institution such as UNEP responsible for the overall compensation program. However, its tasks in doing so will be complex, requiring technological, economic and legal expertise. In addition, there will be a major role of coordinating the efforts of other agencies, both multilateral and bilateral, who will necessarily be involved in this program and related technology transfer activities. Hence the organisation will need a secretariat of the sort described above, as well as a consultancy budget to carry out its tasks. The main items of that budget are identified in the above discussion.

TABLE 10

Guidelines for Transfers Under the Fund

PURPOSE OF SUPPORT	SIZE OF FUND INVOLVED	TERMS FOR THE TRANSFERS
Higher Cost of CFC Substitutes in Manufacturing	Approx. $1.8 billion, world-wide, over 18 years.	Based on the difference between the international substitute price and the price of CFCs. Claims filed to show actual consumption of substitutes. Payments as grants made to Central Government.
Faster Amort-ization of CFC Producing Plants in Developing Countries	Maximum $155 million world-wide, mostly to be disbursed around 1998	Payments made to central government as grants. Companies to show close down of plant. Audits required.
Costs of Adjust-ment in the User Industries	$10 million for technical assist-ance for the first 2 years. Also a further $200 mill-ion to be lent by development banks for investment in new industry using CFC substitutes over 3 years.	Technical assistance provided by secretariat of fund. Lending by development banks but project identification to be done by secretariat. Lending on normal terms applicable to the country. Secretariat to also coordinate technical assistance.
Higher Costs of Importation	No specific transfer to be made. Support for specific hard hit industries on a case by case basis.	Applications for grants to be made by central government to fund secretariat. Evidence required in support as indicated in text.
Costs of Infor-mation Collection	$10 million to be spent over the next 2 years.	Entire activity to be undertaken by secretariat.

V. Conclusions

5.1 This report has examined the implications of the Montreal Protocol for developing countries and has attempted to estimate the costs to those countries of joining the Protocol. A number of items of cost have been identified. Probably the most significant is the use of more expensive substitutes in manufacturing products in these countries. An upper estimate of this cost in present value terms is $1800 million in 1990, falling to zero over the next 8 years. However, it is possible that the cost will be much less than this.

5.2 There is also a cost associated with the faster amortization of the CFC producing equipment in developing countries. This is estimated at around $155 million, with the figure again being on the high side, if anything. This cost should not be incurred for another 10 years. However, it is suggested that developing countries be able to borrow from the fund against this depreciation allowance now, so as to begin restructuring their CFC producing industries. Eventually, of course this payment is also viewed as a grant.

5.3 To assist industries using CFCs in manufacturing, it is proposed that a technical assistance fund be set up, wit an initial allocation of $10 million for the first two years. Subsequently, this fund could be expanded, depending on the demand for its services. In addition, the secretariat managing the fund would be responsible for identifying investment projects to increase manufacturing capability using new technologies with CFC substitutes. The lending for these projects, however, should probably be undertaken by the existing institutions. An initial allocation of $200 million for 3 years is suggested for such loans.

5.4 Although some increase in the costs of CFC substitute using imports may result from the Protocol, the additional cost in most cases is not likely to be large. Calculating it and making the appropriate transfers

is likely to cost as much as the transfers themselves. Hence it is recommended that this item not be funded. However, if there are industries using CFC based products as intermediate inputs, then a compensation fund to assist them on case by case basis should be set up. No budget can be estimated for this but the sum involved should be small compared to the other sums.

5.5 Finally there is a great need for systematic information to be collected on the production, consumption and use of CFCs and their substitutes by country. This is an urgent task that should be undertaken immediately and an allocation of $10 million is proposed for this purpose.

5.6 It remains to reiterate that the numbers given here are very preliminary and that they should be checked before proceeding further. Also it should be noted that the costs of substituting for halons have not been included.

ANNEX 1

DEVELOPING COUNTRIES: MAJOR USERS OF CFCS

Year	COUNTRY	PER CAPITA CONSUMPTION OF CFCS (KG.)	MEMBER OF PROTOCOL?
1985	Brazil	0.07	NO
1985	Egypt	0.06	YES
1984	Honduras	0.04	NO
1985	Hong Kong	0.31	NO
1985	India	0.05	NO
1984	Indonesia	0.03	YES(*)
1985	Korea	0.07	NO
n.a.	Malaysia	0.09	NO
1983	Mexico	0.07	YES
1985	Thailand	0.02	YES(*)
n.a.	P.R. China	0.02	NO

(*) Treaty signed but not ratified. The treaty referred to here is the 1985 Montreal Protocol on substances that deplete the ozone layer.

Per capita consumption estimates refer to

Source: UNEP, various documents.

ANNEX 2

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ANNEX 2

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