UNITED
NATIONS

EP

United Nations
Environment
Programme

Distr.
LIMITED

UNEP/OzL.Pro/ExCom/36/34
7 February 2002

ORIGINAL: ENGLISH

EXECUTIVE COMMITTEE OF
THE MULTILATERAL FUND FOR THE
IMPLEMENTATION OF THE MONTREAL PROTOCOL
Thirty-sixth Meeting
Montreal, 20-22 March 2002

REPORT ON THE STUDY ON ALTERNATIVES TO CFCS IN RIGID FOAM APPLICATIONS

A STUDY ON ALTERNATIVES TO CFCS IN RIGID FOAM APPLICATIONS

FINAL REPORT

Prepared for:

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January 2002

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APPENDICES

KEY FACTORS CONSIDERED IN THE STUDY OF ALTERNATIVES TO CHLOROFLUOROCARBONS IN RIGID FOAM APPLICATIONS

1 INTRODUCTION

For the Multilateral Fund for the Implementation of the Montreal Protocol (the Multilateral Fund), Wakim Consulting (Wakim) has performed a study on alternatives to chlorofluorocarbons (CFCs) in rigid foam applications. Appendix F presents the Terms of Reference for the study. The study:

- Sets forth major factors leading to the choice of alternative technologies by countries eligible for assistance from the Multilateral Fund (Article 5 countries)
- Enumerates the economic consequences for enterprises converting to alternatives to CFCs
- Indicates the level of understanding by enterprises in Article 5 countries of the economic effects of conversion to various alternatives
- Provides a clearer picture for the Executive Committee of the degree of influence, if any, of Multilateral Fund policies on the choice of CFC alternatives.

The findings and conclusions of the study are based on data obtained from:

- Review of project files and completion reports at the Secretariat
- Field visits to Argentina, Egypt, and Malaysia and input from 47 enterprises in the 3 countries
- Responses to questionnaires from 63 enterprises in 7 Article 5 countries
- Discussions with suppliers of polyurethane systems, blowing agents, and equipment
- Discussions with government representatives during the field visits
- Discussions with UNDP representatives
- Wakim's information system and extensive contacts with industry sources.

We went to great length in this study to ensure that the data gathered represented conditions at the producing enterprise level. Doing so was necessary to provide transparency and comprehensive information for the use of government agencies and enterprises in Article 5 countries to access the economic impact of their conversion to CFC alternatives.

2 EXECUTIVE SUMMARY

To meet the study objectives, Wakim conducted a comprehensive analysis of information concerning the factors leading to the choice of alternative technologies in Article 5 countries at the producing enterprise level. This Executive Summary presents a summary of Wakim's findings and conclusions, starting with the results of the theoretical calculations of differences in cost between CFC-based and alternative technologies. Specifically, for one case the theoretical calculations address the differences in total costs—capital, plus operating costs—for a conversion by an enterprise, with funding for the conversion from the Multilateral Fund, to cyclopentane or to hydrochlorofluorocarbon-141b (HCFC-141b).

2.1 Comparison of the Total Costs of Conversion to Cyclopentane vs. HCFC-141b

The total conversion costs consist of the required capital costs associated with purchase or modification of equipment, as well as the costs of technology transfer and training, and incremental operating costs (IOC). The capital costs, which are relatively large, are incurred at the start of the conversion process. The net present value (NPV) of the capital costs is thus equal to the actual costs incurred because no discounting is needed to account for the time value of money. Given the high capital costs, an enterprise needs some assurance that it can recover those costs over the life of the project and that it will receive an acceptable return on the capital investment. For these reasons, enterprises that provide their own capital scrutinize these expenses extensively before proceeding with a capital investment.

Capital costs are quantifiable with certainty at the beginning of the project and are recovered by depreciating the capital in fixed annual increments over the life of the project. The annual increments are then divided among the units produced annually and are included as a part of the forecast unit cost of production.

The return on capital investment itself is not certain, however. Its estimation requires analysis of revenues, fixed costs, variable costs, plant taxes and insurance, other plant and head office expenses, and corporate income taxes. Therefore, whereas enterprises may estimate return on investment during the project evaluation stage, the real return is always calculated annually after plant commissioning and actual revenues are generated.

At the project evaluation stage, operating costs are uncertain. Typically, enterprises forecast future prices of raw materials, energy, labor, and other operating costs on a project-by-project basis. However, the level of confidence in these forecasts is lower than that for capital costs. Therefore, an enterprise weighs a quantifiable capital outlay in the present against an uncertain operating cost and thus revenue in the future.

For the rigid foam projects of interest in this study, the relevant capital costs are limited to those paid directly by the enterprises; the enterprises Wakim interviewed did not conduct economic evaluations to determine the economic viability of the capital costs paid by the Multilateral Fund in terms of capital recovery or return on investment.

Indeed, the large majority of the enterprises interviewed did not conduct any evaluation to determine the short- or long-term economic effects of the conversion to CFC alternatives on their enterprises. We also found that very few enterprises paid any part of the capital costs; those that did, paid only a small percentage of those costs.

Because very few enterprises contributed capital cost, it is possible to select a variety of options for use in conducting the theoretical calculations. For illustrative purposes, we use the example in Section 3.5, "Comparison of Operating Cost for Alternative Technologies" below (pages 26-28). We further assume that the only options available to the enterprise consist of choices among HCFC-141b, HFC, and cyclopentane. An abbreviated analysis of the economic evaluation that an enterprise could have performed follows.

Table ES 1 presents the NPV of the cash flow streams. The NPV of the capital outlay is the difference between the capital costs for conversion from CFC-11 to HCFC-141b and the capital costs that would have been incurred for conversion to cyclopentane. Because the capital is invested at the outset of the conversion, the NPV is the same as the actual money spent.

Table ES 1 also presents the NPV of the operating costs that the enterprise will incur from using cyclopentane or HCFC-141b. The NPVs for both alternatives are presented for plant lives of 4 and 10 years and for discount rates of 8% and 12%. Note that the NPV for the return on the investment expected by the enterprise is not presented in Table ES 1; it is not included because annual expected returns assumed by enterprises, as a percent of capital costs, can vary with fluctuations in the prime rate, plus a premium of 3% to 50%.

Table ES 1
NPV of Cash Flows of Total Conversion Costs
(Thousands of U.S. Dollars)

	Discount Rate					
	8%	**8%**	**Difference**	**12%**	**12%**	**Difference**
	HCFC-141b	**Cyclopentane**		**HCFC-141b**	**Cyclopentane**	
NPV of total capital cost	78	507	– 429	78	507	– 429
Operating cost NPV						
For 4 years	79	21	58	75	19	56
For 10 years	159	41	118	135	35	100
Percent of capital recovered						
In 4 years			13.5			13.1
In 10 years			27.5			23.3

Regardless of assumed plant life and discount rate, an enterprise will realize reduced operating costs by using cyclopentane compared with HCFC-141b. Using a discount rate of 8%, the NPV of the benefits to the enterprise will be US$58,000 for a project life of 4 years and US$118,000 for a project life of 10 years. Using a discount rate of 12%, the NPV of the benefits to the enterprise will be US$56,000 for a project life of 4 years and US$100,000 for a project life of 10 years.

When the enterprise takes the total costs of the conversion into consideration, the capital costs, the operating costs, and the expected return on investment must be considered. Because of the large number of permutations possible in estimating the return on investment and to simplify the analysis, the data presented in this analysis include only the capital costs and the operating costs. We have also assumed that the enterprise paid that portion of the total capital investment not covered by the Multilateral Fund. (Alternative cases in which the enterprise pays only a part of the capital can also be assessed using the data presented in Table ES 1.) The following analysis presents the potential benefits that could have been realized, using only the two components of the total costs, if the enterprise converted to cyclopentane:

- Using an 8% discount rate, the enterprise would have recovered 13.5% of the capital costs in 4 years, and 27.5% of the capital costs in 10 years.
- Using a 12% discount rate, the enterprise would have recovered 13.1% of the capital costs in 4 years, and 23.3% of the capital costs in 10 years

The inclusion of any return on investment in the calculations would have reduced the percentage of the capital that the enterprise could have recovered under the two previous cases shown in Table ES 1.

The analysis clearly shows that any enterprise, similar to the one cited above, when facing a choice between cyclopentane and HCFC-141b, would choose the latter based on the economic evaluation if the enterprise were paying the full cost.

Table ES 2 presents a comparison of the NPVs of cash flows arising from a two-stage conversion and a one-stage conversion for a project in Malaysia. The data for the conversion from CFC-11 to HCFC-141b reflect the actual incremental capital costs (ICC) and operating cost paid by the Multilateral Fund to the enterprise. (The Multilateral Fund will not contribute to a second stage conversion from HCFC-141b to HFC-245fa or any other blowing agent.) The data for the single-stage conversion from CFC-11 to cyclopentane is based on the information prepared by the Implementing Agency in collaboration with the enterprise and reviewed and approved by the Secretariat and the Executive Committee.

Because the timing of the second conversion in the two-stage process is indefinite, we introduced the following parameters to frame the case:

- The conversion from HCFC-141b to HFC-245fa occurs 5 years after the first conversion.
- The enterprise pays the actual capital cost, less the Multilateral Fund grant for the first-stage conversion.
- The enterprise pays the total cost of conversion from HCFC-141b to HFC-245fa.
- The enterprise pays the NPV of the IOC in the first 5 years, less the portion paid by the Multilateral Fund; that portion typically covers 2 years.

- The enterprise pays the total NPV of IOC from year 6 to 10.
- The NPVs are calculated using a 12% discount rate.
- Starting from the first year, the cost of the HFC-245fa system is 15% higher than an HCFC-141b system.

Table ES 2
NPV of Cash Flows for Single-Stage and Two-Stage Conversion Costs
(Thousands of U.S. Dollars)

	Two-Stage Conversion			One-Stage Conversion	
Item	**To HCFC-141b**	**To HFC-245fa**	**HCFC-141b + HFC-245fa**	**Cyclopentane**	**Cost of Two-Stage Conversion vs. One-Stage Conversion**
Capital cost to the enterprise	0	5	5	411	– 406
Capital cost to the Multilateral Fund	78	0	78	96	- 18
Total Capital Cost	78	5	83	507	– 424
NPV of operating cost					
To the enterprise, year 0-10	70	112	182	35	147
Year 0 to 5	70	0	70	17	53
Year 6 to 10	0	112	112	18	94
To the Multilateral Fund	18	0	18	0	18
Total operating cost	88	112	200	35	165
Total cost to enterprise	70	117	187	446	– 259
Total Cost to the Multilateral Fund	96	0	96	96	0

The data indicate that the total ICC for the two-stage conversion from CFC-11 to HCFC-141b, followed by conversion to HFC-245fa, is about 16% of the cost of the single-stage conversion from CFC-11 to cyclopentane. The Multilateral Fund would have paid about 19% of the total capital costs. However, choosing the single-stage conversion to cyclopentane would have cost the enterprise US$406,000 more than the two-stage conversion.

The Multilateral Fund would have paid none of the IOC incurred by the enterprise in the one-stage conversion. Therefore, the NPV of the incremental operating cost paid by the enterprise for the first 5 years was US$70,000. Furthermore, by converting to the more expensive HFC-245fa at the end of year 5, the enterprise had to pay an additional US$112,000 from year 6 to 10; bringing the total operating cost contribution of the enterprise to US$182,000.

The Multilateral Fund's contribution for the total costs to the enterprise would have been the same regardless of whether the enterprise proceeded with a one-stage or two-stage conversion from CFC-11. However, the enterprise would have paid an additional US$259,000 for the single-stage conversion to cyclopentane than for the two-stage conversion to HCFC-141b followed by conversion to HFC-245fa.

2.2 Factors Leading to Selection of Alternative Technologies

In fulfillment of our mandate, we collected comprehensive information on the factors that led enterprises, in Article 5 countries, to choose among alternatives to CFC-11. The information was gathered from interviews during the field visits and from the responses to the questionnaires. A partial listing of these factors follows.

- **Proven technology**: Enterprises were inclined to select technologies that had been applied successfully elsewhere. They were unwilling to spend the time and effort required to develop a new technology, and in many instances did not have the expertise needed to do so.
- **Local availability of alternatives at reasonable prices**: Enterprises preferred to purchase alternatives from stocks available in their domestic markets. Market forces made it difficult for many enterprises to anticipate demand beyond a limited time, and thus in many instances they would be unable to wait the 3–4 months needed for the alternatives to be imported. Furthermore, local prices, which are influenced by availability and by supply and demand, always play an important role before a purchase order for a CFC alternative is sent to suppliers.
- **Local support from the system supplier:** Enterprises rely heavily on technical support supplied by system suppliers. To conduct their businesses, many of the enterprises need this support to complement their technical capabilities, which are frequently limited. Moreover, many of the enterprises involved in this study listed the technical support received from UNDP and UNIDO as a significant contribution that the Multilateral Fund supplied to these enterprises. Furthermore, most of the enterprises surveyed purchase preblended systems; therefore, they rely on the system suppliers for availability and technical support for those systems.
- **Maintenance of foam properties:** Enterprises preferred to select CFC alternatives that maintained or improved the properties of the rigid foam. Doing so was difficult, however, because commercially available alternatives either reduce the thermal insulation properties of the foam or alter its fire-retardant properties.
- **Compliance with regulations set by local or national authorities:** A significant number of enterprises indicated that local regulations—particularly fire regulations—prevented them from using pentanes and other hydrocarbons as alternatives to CFC. Indeed, at least two enterprises had to change locations, buy new land, buy new equipment, and build a new factory—at significant expense—to be able to use pentanes.

- **Cost-effectiveness of conversion to CFC alternatives:** The large majority of the enterprises surveyed indicated that they did not analyze the costs and benefits of converting to CFC alternatives. Many of the enterprises indicated that they did not have the expertise to perform such an analysis. Others indicated that such an analysis would have amounted to an academic exercise that would not have helped them in making their selection. They did not have the expertise to forecast demand or pricing of raw materials and finished products. Therefore, they could not estimate future cash flows, financial benefits or losses, or the NPV of such financial benefits or losses.

These local market realities had a major influence on each enterprise's choice of a CFC alternative, especially for small and medium size enterprises. For example, if an alternative and the compatible isocyanate and polyol systems were not available in the local market at the time conversion was being considered, the enterprise did not choose that alternative. Furthermore, the majority of small and medium size enterprises used preblended systems. Therefore, an enterprise selected a CFC alternative only if the local suppliers kept stocks of the systems and offered the necessary technical support. Our analysis indicates that, in the early to late 1990s, several systems compatible with CFC alternatives were available in Europe, Japan, and North America, but were not promoted by suppliers in Article 5 countries such as Argentina, Egypt, and Malaysia.

2.3 Discussions with Enterprises

Wakim visited the factories or the head offices of enterprises and discussed the questionnaire with their representatives in Argentina, Egypt, and Malaysia. There were significant similarities among the answers submitted by the various enterprises. A summary of the main themes discovered during the field surveys follows:

- All the enterprises that commented on the subject indicated that the Implementing Agencies provided the only source of information about how the Multilateral Fund policies were likely to affect them.
- Most of the enterprises started considering converting from CFCs to alternatives after receiving encouragement from the National Ozone Units (NOUs), Implementing Agencies, or chemical suppliers.
- Most of the enterprises did not have the expertise to perform the necessary analysis to determine the economic impact of conversion to CFC alternatives on their companies. Furthermore, neither the NOUs nor the Implementing Agencies explained the long-term economic ramifications of the conversion to the enterprises.
- All enterprises considered commercially available alternatives before making the selection. However, the selection was invariably based on the technical advice received from the Implementing Agencies.
- Polyurethane systems using cyclopentane as a blowing agent were not introduced until the late 1990s in the domestic markets.

- Most of the enterprises purchase preblended systems; preblended cyclopentane systems were not available.
- All enterprises consuming less than 50 tonnes per year (t/yr) of CFC-11 indicated that their operations were too small to justify the high capital investment needed for use of hydrocarbon blowing agents, including cyclopentane. Therefore, they decided to use HCFCs until reasonably priced hydrofluorocarbons (HFCs) become available commercially.
- A major obstacle for large enterprises wishing to convert to hydrocarbons was obtaining permits from fire marshals and local authorities.

2.4 Discussions with Technology Suppliers

The debate over whether high- or low-pressure foaming machines are appropriate for the conversion from CFC-11 to alternative technologies was settled, at least for projects funded by the Multilateral Fund, when the Executive Committee approved the use of high-pressure machines for most rigid foam applications. In many instances, the replacement of low-pressure machines with high-pressure machines represented upgrades for the foam producing facility. This is particularly true in those cases where HCFC-141b was used as a substitute for CFC-11. In many of these instances, a mere retrofit of the low-pressure machine would have enabled the enterprise to convert to the alternative technology.

The remaining issue is whether or not these machines are capable of handling the next generation of alternatives when enterprises convert from HCFC-141b to the next-generation alternatives. Would some of these enterprises have to incur expensive retrofitting when HCFC-141b is phased out? The Montreal Protocol measures indicate that Article 5 countries need to freeze the use of HCFCs by 2016 and phase them out completely by 2040. (Some believe that commercial decisions based on market access could lead to earlier conversion dates.) Therefore, the affected enterprises have a long time before they have to make the decision. However, when that time comes, the retrofitting could be as simple as replacing any one of the following: a pump, hoses, mix head, instruments, temperature control, or a tank, or as costly as purchasing a new foaming machine. The complexity and the cost of the conversion will depend on the condition of the foaming machines at the time of conversion and the alternative blowing agent selected. A short description of what needs to be done for converting to various blowing agents is presented below.

The major CFC-11 alternative technologies include HCFCs, pentanes—cyclopentane, n-pentane, and iso-pentane—water/carbon dioxide (CO_2) and HFCs. Other emerging alternatives include HFC-245fa, HFC-365mfc, blends of HFCs, 2-chloropropane, and others. In addition, physical foaming processes that do not require a chemical blowing agent, employing vacuum, etc., could be used; however, their applications are thus far limited. Table ES 3 provides a partial listing of the characteristics of selected blowing agents.

Table ES 3
Physical Properties of Typical Blowing Agents

Blowing Agent	Ozone-Depleting Potential	K-factor Gas	Boiling Point, °C
CFC-11	1.00	0.06	+ 24
HCFC-141b	0.11	0.066	+ 32
HCFC-22	0.05	0.073	– 41
HCF-142b	0.065	0.080	– 9
HFC-134a	0	0.095	– 27
HFC-245fa	0	0.085	+ 15
HFC-365mfc	0	0.074	+ 40
n-Pentane	0	0.104	+ 36
iso-Pentane	0	0.097	+ 28
Cyclopentane	0	0.083	+ 49
CO_2	0	0.113	– 78

The analysis also indicated that, whereas the enterprises are genuinely interested in using zero ozone-depleting potential (zero ODP) CFC alternatives, they are also pragmatic in realizing that an interim phase is needed before zero ODP alternatives become commercially viable. Table ES 4 lists some interim CFC alternatives and potential final alternatives that are likely to be used in the various rigid foam subsectors. The HFCs mentioned most frequently at this stage are HFC-245fa and HFC-365mfc; also mentioned are blends of these HFCs with pentanes and other blowing agents.

Table ES 4
Rigid Foam Segments and Alternative Technologies

Segment	Interim Alternative	Final Alternative
Thermoware	HCFC-141b	HFCs/water/CO_2
Pipe insulation	HCFC-141b	HFCs/pentanes
Discontinuous boards and blocks	HCFC-141b	HFCs/water/CO_2
Continuous boards	HCFCs/pentanes	HFCs/pentanes
Domestic refrigerators and freezers	HCFCs/pentanes	HFCs/pentanes
Commercial refrigerators and freezers	HCFCs/pentanes	HFCs/pentanes
Continuous panels	HCFCs/pentanes	HFCs/pentanes
Discontinuous panels	HCFCs/pentanes	HFCs/pentanes
Spray foams	HCFCs	HFCs

2.5 Discussions with Government Officials

Wakim visited the offices of the NOUs in Argentina, Egypt, and Malaysia. A summary of the main points of the discussions with the NOU representatives about their governments' perspective on the conversion to CFC alternatives in the rigid foam sector follows:

- Most rigid foam projects in these countries have been completed and closed.
- All rigid foam projects in these countries were handled by UNDP and UNIDO; the World Bank was not a significant participant.
- The NOUs would have liked the Implementing Agencies to provide more training for the employees in the various enterprises during the conversion process from CFCs to alternative technologies.
- Customs officials have started tracking and reporting CFC imports to the NOUs.
- The NOUs in Egypt and Malaysia are concerned about shipments of CFCs from India, China, Italy, and France at depressed prices (around US$1.20/kg). The low prices encourage illegal uses of CFCs.
- The NOUs are asking importers about CFC end uses before issuing import permits.
- The NOUs believe that their national consumption of CFCs will remain below the ceiling required by the Montreal Protocol measures.

2.6 Analysis of Questionnaire Results

With the assistance of the Secretariat and the relevant Implementing Agencies, 135 questionnaires were sent to enterprises in 22 countries in addition to the ones sent to Argentina, Egypt, and Malaysia. Wakim received 63 completed questionnaires from enterprises in 7 Article 5 countries; however, 50 of these came from large, small, and medium enterprises included in umbrella projects in Mexico. A summary of the common responses follows.

- Most of the enterprises indicated that the Implementing Agencies provided the only source of information about how the Multilateral Fund policies were likely to affect them.
- The majority of the respondents indicated that the Multilateral Fund policies helped them proceed with the conversion to CFC alternatives by supplying capital grants and technical support. However, the respondents did not indicate that the policies influenced their decision to select any particular CFC alternative.
- Most of the enterprises were encouraged to convert from CFCs to alternatives by their NOU and the Implementing Agencies.

3 STUDY FINDINGS

3.1 RIGID FOAM APPLICATIONS

Global consumption of rigid polyurethane and polyisocyanurate foams in the applications that follow slightly exceeded 2 million tonnes in 2000:

- 90%: Low-density (25-40 kg/m³) foams used primarily for insulation purposes
- 5%: High-density (300-600 kg/m³) foams used for decorative moldings, wood imitation, furniture moldings, and electronic equipment cabinets
- 5%: Ultra low-density (12-16 kg/m³) foams used for packaging.

The last two application areas, amounting to about 10% of total consumption, generally use water or other zero ODP blowing agents.

The global rigid foam insulation sector, amounting to about 1.8 million tonnes, is important because it used approximately 200,000 tonnes of blowing agents. HCFCs accounted for the large majority of the blowing agents used in 2000; a similar trend is expected in 2001. The United States, Canada, and Western Europe will begin the conversion to alternatives during 2002 so that the use of HCFCs (mainly HCFC-141b) will be phased out starting 1 January 2003. The consumption of HCFCs in the rest of the world will continue according to the directives issued by applicable national governments.

A brief description of the rigid foam application subsectors follows. Insulation panels, which are the largest subsector by far, are mostly used in buildings and construction. The products fall into two main categories—continuous and discontinuous panels. Common characteristics of foams used in these subsectors include insulation value and flammability resistance.

3.1.1 Continuous Panels

Continuous panels, typically 25 to 100 millimeters (mm) thick and about 1.25 meters (m) wide, are produced on large conveyor presses, which are commonly known as double band laminators. The facing materials, generally bitumen paper, aluminum foil, or combinations thereof, are usually reinforced with fiberglass or similar materials. Some factories also produce panels with metal facers.

Line speeds of the double band laminators vary with the thickness of the foam and the age of the equipment. Modern machines, producing 25 mm panels with flexible facers, operate at speeds of 100 to 150 meters per minute (m/min). Machines producing metal-faced panels operate at speeds of 5-15 m/min.

3.1.2 Discontinuous Panels

Discontinuous panels are normally metal faced and are 50 to 150 mm thick. They are used for commercial cold storage units or for insulation of walls and roofs of cold storage warehouses. They are made in large presses, 1 to 1.5 m wide and up to 20 m in length.

The normal cycle time to produce one of these panels is 6-8 minutes and they have a density of about 35 kg/m³; that density is slightly higher than that of continuous panels because of the over-packing of the foam.

3.1.3 Pipe Insulation Foam

Rigid foam is used for insulation of pipes in industrial applications such as refineries, chemical plants, and pipelines. This application is generally referred to as “pipe-in-pipe insulation.” In all cases, the foam serves to maintain the temperature of the medium in the pipeline, whether hot or cold. Therefore the insulating factor (known as the “K factor”) of the foam is extremely important.

In some instances, the foam is sprayed in place on pipes that are part of existing machinery. Under those conditions, it is imperative to use systems that do not create fire hazards in the workplace. In other instances, the polyurethane is foamed over pipes under controlled conditions in the coating factory, with the foaming usually taking place between a sleeve and the pipe inside.

3.1.4 Refrigeration Foam

As noted, refrigeration foams are not covered in this study; they are described here only for illustration. Refrigeration foams cover both domestic and commercial refrigeration units. They are made using various jigs, clamps, or specially configured presses fashioned to enclose both the inside and outside of the refrigerator shell during foaming and to contain the pressure of the expanding foam. Foam densities are about 30 to 32 kg/m³ and the cycle time is about 2 to 4 minutes depending on the configuration of the refrigerator. The K factor of the foam is important here because a minimum thickness is desired to maximize the amount of room for goods inside the unit. Foam flammability is less important in this application because the foam is enclosed within fire-retardant facings.

3.1.5 Spray Foam

Spray foam is used for roof insulation when the roof configuration is not convenient for flat panels, or for re-roofing when insulation and leak sealing are needed. Spray insulation is also used for tanks and pipes in refineries, chemical plants, and food factories. The spray foam is suitable for both cold and hot service in these plants. Depending on the application, flammability requirements can be stringent. Normally, spray foam insulation is covered with a silicone or some other coating to protect it from degradation by ultraviolet light. Spray foam is applied through special equipment at rates from 3-15 kg/min and foams almost instantaneously so that subsequent coats can be rapidly applied.

3.1.6 Board and Block (Bun) Foam

This type of foam can be made both discontinuously and continuously, depending on the subsector. In the former case, large boxes generally about 2 m long, 1.2 m wide, and 1 m high, are used to contain the foam. The foam components are often mixed in a batch process and simply poured in the box and allowed to foam. A typical cycle takes 5 to 8 minutes.

In the continuous process, the foam mix is continuously poured onto a moving conveyor with side constraints. The width and height of the foam are about 1.2 m and 1 m, respectively; the operator uses a flying cutoff saw to create segments of varying lengths. The reactivity of continuous foam is about the same as that of the discontinuous foam. The line speed is about 3 m/min.

3.1.7 Miscellaneous Pour-in-Place Foams

In many applications (e.g., water heaters, thermoware, picnic and water coolers, boat hulls, doors), simple pour-in-place techniques are used to fill a desired cavity. In all of these applications, the foam is expected to provide insulation and structural integrity. The density of these foams is 30 to 40 kg/m^3

3.2 ALTERNATIVE TECHNOLOGIES

Wakim reviewed the alternative technologies used for producing rigid foam in lieu of CFCs. The major alternative technologies used globally include HCFCs, pentanes—cyclopentane, n-pentane, and iso-pentane—and water/CO_2. Emerging alternatives include HFC-245fa, HFC-365mfc, blends of HFCs, and 2-chloropropane, as well as others. In addition, physical foaming processes that do not require a chemical blowing agent, employing vacuum, etc., could be used; however, their applications are thus far limited. We also compared the acceptability of liquid technologies vs. gaseous technologies. Table 1 provides a partial listing of the characteristics of selected blowing agents.

Table 1
Physical Properties of Typical Blowing Agents

Blowing Agent	ODP	K-factor Gas	Boiling Point, °C
CFC-11	1.00	0.06	+ 24
HCFC-141b	0.11	0.066	+ 32
HCFC-22	0.05	0.073	– 41
HCF-142b	0.065	0.080	– 9
HFC-134a	0	0.095	– 27
HFC-245fa	0	0.085	+ 15
HFC-365mfc	0	0.074	+ 40
n-Pentane	0	0.104	+ 36
iso-Pentane	0	0.097	+ 28
Cyclopentane	0	0.083	+ 49
CO_2	0	0.113	– 78

Our review indicated that, in rigid foam applications, HCFC-141b is the main alternative for CFC-11, followed by pentanes. The use of water/CO_2 as a blowing agent, which is attractive because it has zero ODP potential, has not progressed significantly because of application problems in the field. The emerging low-ODP blowing agents include blends of HCFCs such as HCFC-22 and HCFC-142b and others. The HFCs include HFC-245fa and its blends, HFC-134a and its blends, and HFC-365mfc and its blends.

Whereas the conversion from CFC-11 to HCFC-141b was basically a drop-in process, the upcoming conversion from HCFC-141b to other alternatives will be quite challenging. It is expected that the easiest solution, from a technical standpoint, will be the use of the emerging liquid HFCs. Two potential new blowing agents—HFC-245fa and HFC-365mfc—have been developed, patented, and are currently offered in trial test quantities to the marketplace. We understand that Bayer has granted exclusive patents for these blowing agents to Solvay (for Europe) and to Honeywell (for the United States and

Canada). The introduction of these blowing agents in Article 5 countries is still under consideration. In any case, both products are fairly easy to handle, quite compatible with polyols, and HFC-245fa is nonflammable; they can also be used to make good integral skin foams. However:

- They are very expensive (at US$4–10/kg).
- Availability will be limited, even when the new blowing agent plants come on stream in 2002 and 2003.
- The insulating values of the foam produced with these alternatives are about 10% poorer than the foam made using HCFC-141b.

Depending on the application, it may be possible to tailor different blowing agent alternatives to an application and, most likely, combinations of the various blowing agent technologies can be employed. A general description of the full range of available alternative technologies follows.

3.2.1 HFC-134a

HFC-134a has a zero ODP level. It makes excellent, dimensionally stable foams. However, it is a gas at room temperature, and machines must be retrofitted with special equipment to handle it. Like HFC-245fa and HFC-365mfc, it is also very expensive (US$4—5/kg.), and its availability in preblended systems for rigid foam applications is limited.

3.2.2 CO_2

The two routes to blow foams with CO_2 are:

3.2.2.1 Water

Water-based systems are desirable because they represent an alternative with a zero ODP solution and entail minimal health and safety risks. However, water-blown foam systems result in manufacturing and use problems such as poor adhesion to substrates, poor flow patterns, increased foam friability, and questionable insulation values. Furthermore, these systems suffer from poor polyol storage stability because of hydrolysis. Consequently, the suppliers of these systems continue to conduct research to resolve these shortcomings so that the systems can become viable alternatives to CFCs and HCFCs as the latter are phased out in the near future.

Water-based systems also suffer from an overall problem of relatively poor insulating properties of the foam. Depending on the K factor, foams blown with water, compared with those blown with hydrocarbon blowing agents, require a 40–50% increase in foam thickness to achieve the same insulating value. Furthermore, the CO_2 is generated from the reaction of water with isocyanate. Therefore, the relative price of foam produced with water compared with one produced with other blowing agents depends on the relative price of the isocyanate compared with that of the other blowing agent.

An additional problem also arises when using water. Without the low-viscosity blowing agent in the formulation, the viscosities of some polyol premixes are sufficiently high that they preclude high-pressure machines from achieving good mixing; under these conditions, the geometry of the mixing head and the small size of the orifice make it difficult to produce the fine mist of high-viscosity fluids that is required.

3.2.2.2 Liquid CO_2

Machine manufacturers are conducting research on the liquid CO_2 injection process for rigid foams to reproduce the findings obtained from research on flexible slab and molded foams. Although data are currently insufficient to speculate about the success of the research, this approach could result in finer foam cell size, which would improve the insulating values of CO_2 foams blown in this manner.

3.2.3 Hydrocarbons

Foam producers and system suppliers have experimented with several hydrocarbons containing 3 to 6 carbon atoms per molecule. These products were used separately and as blends. Pentanes—n-, iso-, and cyclopentane—have emerged as the most favored blowing agents among the hydrocarbons. Experience to date has shown that using pentane mixtures instead of single isomers appears to improve blowing. Pentanes are especially attractive because of their relatively low prices. In North America and Western Europe, pentanes can currently be obtained at about US$0.7/kg; however, pentane prices are significantly higher in Article 5 countries. Pentanes are also attractive because the level of their use needed to achieve the same foam density is substantially lower than that for other blowing agents such as HCFC-141b.

The use of pentanes is proven commercially, and they are employed in several developed and Article 5 countries. However, pentanes and other hydrocarbons are flammable; thus, major factory retrofits are required to ensure safe handling and to prevent fires that could result from hydrocarbon emissions during manufacturing. The high capital investments required for such factory retrofits make this option unattractive for small and medium size enterprises especially those using preblended polyol systems. Furthermore, the use of pentanes requires flame retardants to make the rigid foam comply with Underwriters Laboratories fire specifications; hydrocarbon blowing agents made it impossible for some manufacturers to pass the burn tests required to allow the foam use in roofing and siding applications. The high cost of the flame retardants negates part of the financial advantage that pentanes offer over other blowing agents. To mitigate the high cost of the flame retardants, researchers are developing new fire-retardant formulations that meet the Underwriters Laboratories specifications without making the products uncompetitive.

The most serious problem delaying the acceptance of hydrocarbon blowing agents is their flammability. All manufacturing sites using hydrocarbons in Europe and North America have had to be made explosion-proof to comply with local, regional, and federal ordinances; doing so has been costly. European manufacturers, particularly refrigerator manufacturers, have already converted to this technology, and insulation board manufacturers are in the process of converting. Some North American foam producers are following the European example.

Another problem facing hydrocarbon blowing agents is that they are not readily soluble in most polyols, and preblended polyol systems containing hydrocarbons are not available commercially. Some large foam producers solve this problem either by preblending pentanes just before use or by metering them directly to the mix head of the machine where they can be easily handled in a closed system. However, the compatibility problem continues to plague the systems suppliers that are the majority suppliers of blowing agents to enterprises in Article 5 countries.

3.2.4 Other, Miscellaneous Blowing Agents

Other materials such as acetone, methylene chloride, n-propyl bromide, and chlorobromomethane are being considered as alternative low-cost blowing agents in North America, Western Europe, and other countries. However, the health and safety ramifications of most of these materials in the workplace are still under investigation. Therefore, these materials cannot be considered as viable candidates at this time.

3.3. POLICIES AND FUNDING RULES

Wakim reviewed the Multilateral Fund's policies and rules governing funding for converting to CFC alternatives in rigid foam applications to determine how the choice of alternatives by enterprises in Article 5 countries may have been influenced by those policies and rules. The review indicated that the policies and funding rules evolved as the Secretariat and the Implementing Agencies gained experience over time. Therefore, the funding rules that were applicable to projects approved in the early 1990s, for example, were different from those used for projects approved in later years. A partial listing of the policies follows.

- Decision V/8 of the Meeting of the Parties on HCFCs and review of a series of decisions of the Executive Committee on HCFCs
- Cost-effectiveness thresholds (ExCom 16/20, Para 32c, 32d)
- Decisions 23/18, 25/47, and 33/2 on safety issues and related costs in hydrocarbon technology
- Decision 20/45 on cost-effectiveness for rigid polyurethane foam projects and discounting for safety costs
- Decision 18/8 on duration of operating costs in the rigid foam sector; two years
- Decision 18/25 on technology upgrade
- Decision 20/6 on admissibility of using operating costs to fund eligible capital cost overruns
- Decision 17/10 allowing partial funding of projects exceeding the cost-effectiveness threshold
- Decision 23/41 on counter-part funding
- Decision 31/44 on foam density.

Appendix B presents transcripts of the policies and the funding rules.

An analysis of the project documents and completion reports demonstrating the number of projects approved for the use of HCFC-, HFC-, water/CO_2-, and hydrocarbon-based technologies follows.

Wakim reviewed the files of 394 projects in 31 Article 5 countries. The 394 projects accounted for 17,762 ODP tonnes of CFCs to be phased out. Wakim also reviewed evaluations conducted by the Secretariat to determine the technical and financial cost-benefit effectiveness of the conversion to CFC alternatives by enterprises in Article 5 countries.

Appendix A sets forth the projects approved by the Executive Committee of the Multilateral Fund. One approach for assessing the approved projects is to compare their numbers by year of approval. Table A 1 in Appendix A lists the number of projects approved by year and by blowing agent. Of the 394 projects approved from 1991 through

2000, 108 were approved from 1991 through 1996. The number of projects approved annually then increased, reaching 109 in 1999, but declined to 41 in 2000.

Another approach for assessing the approved projects is to relate each approved project to the commercially available technologies in the domestic market of the enterprise at the time when the alternative technology was chosen. Appendix E presents a detailed analysis of this approach.

Still another approach for assessing the approved projects is to relate the size of the projects to the alternative technologies chosen by the enterprises (see Appendix E). Table 2 presents a breakdown of the projects by type of technology.

Table 2
Approved Projects by Technology

Approved Technology	Projects
HCFC-141b	319
HCFC-22	13
HCFC-22/142b	2
50% reduced CFC	13
Water/CO_2	18
Cyclopentane	11
Pentanes	15
HFC-134a	2
Liquid CO_2	1
Total	394

A total of 47 projects have converted to zero ODP technologies using water/CO_2, pentanes, cyclopentane, HFC-134a, or liquid CO_2. The remaining enterprises selected HCFCs or reduced CFCs as intermediate solutions in anticipation of conversion to zero ODP as suitable alternatives become available commercially in their domestic markets.

The projects in which cyclopentane and pentane were selected as the alternative technologies account for 6.6% of the total number of projects approved by the Multilateral Fund. However, the significance of the role played by hydrocarbon technologies chosen in these projects was greater than indicated by that percentage: The 15 projects approved for using pentane accounted for 2,537 ODP tonnes; and the 11 projects approved for cyclopentane accounted for 956 ODP tonnes. Thus, the total ODP tonnes replaced by hydrocarbons accounted for 20% of the total ODPs phased out in the approved projects.

Two remaining issues require clarification: (1) the effects of the Multilateral Fund policies and funding rules on the choice of alternatives in the approved projects, as well as possible effects on future projects; and (2) the factors leading to the choice of alternative technologies by enterprises in Article 5 countries. The analysis of both issues is based on feedback obtained in our field visits to enterprises in Argentina, Egypt, and Malaysia, and from the questionnaires returned by enterprises in other Article 5 countries.

The analysis of the impact of the Multilateral Fund policies and funding rules on the choice of alternatives in the approved projects indicates that the enterprises depended exclusively on the Implementing Agencies as the source of information about the Multilateral Fund policies. It also indicates that the enterprises did not have a clear picture of how the Multilateral Fund policies affected them. Appendix E presents a more detailed analysis of the impact of the Multilateral Fund policies on the conversion process.

The possible impact of the Multilateral Fund policies and funding rules on future projects will depend, to a large extent, on the dissemination of the policies to the relevant enterprises. However, our analysis indicates that the 394 rigid foam projects already approved by the Multilateral Fund represent essentially the majority of the large and medium size projects in most Article 5 countries. The remaining projects are small and will be assembled in groups by the appropriate NOUs and Implementing Agencies and presented to the Multilateral Fund for approval.

Analysis of the factors leading to the choice of alternatives by enterprises in Article 5 countries indicates that common factors, among the enterprises that were interviewed and those that responded to the questionnaire, influenced the selection. A partial listing of these factors follows.

- **Proven technology:** Enterprises were inclined to select technologies that had been applied successfully elsewhere. They were unwilling to spend the time and effort required to develop a new technology, and in many instances did not have the expertise needed to do so.
- **Local availability of alternatives at reasonable prices:** Enterprises preferred to purchase alternative chemical systems from stocks available in their domestic markets. Market forces made it difficult for many enterprises to anticipate demand beyond a limited time, and thus in many instances they would be unable to wait the 3–4 months needed for alternatives not readily available in the local market to be imported. Furthermore, local prices, which are influenced by availability and by supply and demand, always play an important role before a purchase order for a CFC alternative is sent to suppliers.
- **Local support from the system supplier:** Enterprises rely heavily on technical support supplied by system suppliers. To conduct their businesses, many of the enterprises need this support to complement their technical capabilities, which are frequently limited.
- **Preference for preblended systems**: Most of the enterprises surveyed purchase preblended systems; therefore, they rely on the system suppliers for availability and technical support for those systems.
- **Maintenance of foam properties:** Enterprises preferred to select CFC alternatives that maintained or improved the properties of the rigid foam. Doing

so was difficult, however, because commercially available alternatives either reduce the thermal insulation properties of the foam or alter its fire-retardant properties.

- **Compliance with regulations set by local or national authorities:** A significant number of enterprises indicated that local regulations—particularly fire regulations—prevented them from using pentanes and other hydrocarbons as CFC alternatives. Indeed, at least two enterprises had to change locations, buy new land, buy new equipment, and build a new factory, at significant expense, to be able to use pentanes.

- **Cost-effectiveness of conversion to CFC alternatives:** The large majority of the enterprises surveyed indicated that they did not analyze the cost-effectiveness of converting to CFC alternatives. Many of the enterprises indicated that they did not have the expertise to perform such an analysis. Others indicated that such an analysis would have amounted to an academic exercise that would not have helped them in making their selection. They did not have the expertise to forecast demand or pricing of raw materials and finished products. Therefore, they could not estimate future cash flows, financial benefits or losses, or the NPV of such financial benefits or losses.

The analysis also identified the direction in which the rigid foam industry appears to be moving. Whereas the industry is genuinely interested in using zero ODP CFC alternatives, it is also pragmatic in realizing that an interim phase is needed before zero ODP alternatives become commercially viable. Table 3 lists some interim CFC alternatives and final alternatives that are likely to be used in rigid foam applications. The HFCs mentioned most frequently at this stage are HCF-245fa and HFC-365mfc; also mentioned are blends of these HFCs with pentanes and other blowing agents. Physical foaming processes (e.g., vacuum) were also mentioned; however, these technologies are still under development and their potential scope of application is not yet clear.

Table 3
Rigid Foam Segments and Alternative Technologies

Segment	Interim Alternative	Final Alternative
Thermoware	HCFC-141b	HFCs/water/CO_2
Pipe insulation	HCFC-141b	HFCs/pentanes
Discontinuous boards and blocks	HCFC-141b	HFCs/water/CO_2
Continuous boards	HCFCs/pentanes	HFCs/pentanes
Domestic refrigerators and freezers	HCFCs/pentanes	HFCs/pentanes
Commercial refrigerators and freezers	HCFCs/pentanes	HFCs/pentanes
Continuous panels	HCFCs/pentanes	HFCs/pentanes
Discontinuous panels	HCFCs/pentanes	HFCs/pentanes
Spray foams	HCFCs	HFCs

3.4 DESCRIPTION OF FOAMING EQUIPMENT

Considerable debate has centered on which foaming machines should be used when converting from CFC-11 to alternative technologies. Most of the debate focuses on whether high- or low-pressure foaming machines would be appropriate for the conversion. In conversions from CFC-11 to HCFC-141b, the Multilateral Fund has paid for many high-pressure machines and technology transfer to replace low-pressure units. In many instances, the replacement of low-pressure machines with high-pressure machines, rather than being a prerequisite for the conversion to an alternative technology, amounted to upgrades to the foam producing facility. This is particularly true when HCFC-141b was used as a direct substitute for CFC-11. In many of these instances, a retrofit of the low-pressure machine would have enabled the enterprise to convert to the alternative technology.

In any case, the Multilateral Fund made the investment, and most of the approved projects in Article 5 countries have been equipped with high-pressure dispensing machines. The new machines constitute a positive development from environmental and foam quality perspectives. The remaining issue is whether or not these machines can handle the next generation of alternatives when enterprises convert from HCFC-141b to those alternatives. Will some of these enterprises have to incur expensive retrofitting when HCFC-141b is phased out?

The Montreal Protocol measures specify that Article 5 countries need to freeze HCFC use by 2016 and phase out HCFCs completely by 2040. Therefore, enterprises in Article 5 countries have a long time before they have to decide when they need to convert from HCFCs and choose the alternative technology to use. However, when that time comes, the retrofitting could be as simple as replacing a pump, hoses, mix head, instruments, temperature control, or tank, or as costly as purchasing a new foaming machine. The complexity and the cost of the conversion will depend on the condition of the foaming machines at the time and the selected alternative blowing agent. A short description of what needs to be done for converting to various blowing agents follows.

3.4.1 Hydrocarbon Blowing Agents

An enterprise desiring to convert from HCFC-141b to a hydrocarbon blowing agent will require expensive retrofitting of its foaming equipment that is likely to include new pumps, a separate hydrocarbon handling system, explosion-proof controls and workplace, switches, presses, air circulation systems, hydrocarbon detection systems, fire fighting equipment, etc. The high-pressure foaming machine will probably require some modifications. In some cases, the enterprise may need to purchase a new high-pressure foaming machine and renovate the entire workplace.

3.4.1.1 HFC Blowing Agents

An enterprise desiring to convert from HCFC-141b to HFCs, such as HFC-134a, HFC-245fa, or blends of HFCs, is likely to need to perform minor retrofitting of its existing equipment. We also understand that little or no retrofitting will be required for HFC-365mfc and its blends.

3.4.1.2 Liquid CO_2

An enterprise desiring to convert from HCFC-141b to liquid CO_2 will require expensive retrofitting of its foaming equipment. Furthermore, the enterprise traditionally had to pay a licensing fee for the right to use liquid CO_2 technology.

3.4.1.3 Summary

In summary, present equipment, with today's polyurethane technology, probably cannot safely and effectively handle the conversion from HCFC-141b to hydrocarbons, mixtures containing hydrocarbons, and injection of CO_2 without extensive retrofitting and cost. The present equipment can, however, handle conversions from HCFC-141b to HFC-365mf, HFC-245fa, and HFC-134a, with minor retrofitting and cost.

Detailed analyses of the foaming and auxiliary equipment needed for conversion from CFC-11 to the various alternative blowing agents are presented in the case studies in Appendix E. The analyses contain, on a case-by-case basis, listings of all the equipment needed for each conversion, the capital costs of the various pieces of machinery and related equipment; with estimates for the incremental capital cost needed for conversion in each case.

The machine builders have shown that they can solve most processing problems encountered in producing polyurethane foams. The analysis indicates that they will be able to supply the needed modifications for conversion from HCFC-141b to alternative zero ODP blowing agents. The chemical suppliers also are making every effort to adapt future systems to zero ODP status and making those systems work on existing customer machinery. The needed research and development effort is already in progress.

3.4.2 Useful Life of Foaming Equipment

Most process equipment, including foaming machines and other equipment used for producing rigid polyurethane foam, is written off in 5–10 years by the accounting departments of North American and Western European companies. However the useful life of the machines and equipment depends on many factors, including changes in hardware technology, maintenance practices, and the chemistry of the systems used. An assessment of the impact of technological change, changes in the chemistry of blowing agents, and maintenance practices follows.

3.4.3 Technological Changes

High-pressure technology has been used in rigid urethanes since the early 1960s when Bayer used Bosch diesel pumps to fashion the first high-pressure mixing machine for use in refrigerator insulation. Gusmer soon followed with the first piston pump high-pressure metering machine for rigid spray foam.

During the 1980s, modifications were needed for some equipment for polyisocyanurate rigid foams, which run at a feed ratio of 2:1. Modifications to pumps and mixing heads made it possible to produce these new foams on existing equipment with minor retrofitting.

Both high- and low-pressure machines have been improved since then, with the addition of electronic and computerized control systems and temperature conditioning capability for the chemical component streams. However, a single blowing agent—CFC-11—was used for the vast majority of rigid foams throughout this period, and the machines were designed with that blowing agent's chemistry in mind.

When the Montreal Protocol mandated the phase-out of CFC-11, there was almost a duplicate product on the shelf, HCFC-141b, with a much lower ODP. Almost no changes were technically required in existing machinery and good foam could be made. However the Montreal Protocol also recognized the transitional nature of HCFC-141b and scheduled its phase-out, albeit delayed well into the 21st century for Article 5 countries. Governments in North America and Europe independently decided to phase out HCFC-141b by 1 January 2003 and in some European countries, even earlier.

These developments led to a major change in rigid foam blowing technology by the mid-1990s. The introduction of economical but flammable hydrocarbons as new blowing agents, made the conventional, non-explosion-proof, machines obsolete (or more expensive to retrofit than to replace). Similarly, the promotion of water/CO_2 blown foams, which use high-viscosity polyol components, required the redesign of the metering pumps, pressures, and mix heads. These changes have already taken place, or will soon be completed, in North America and Western Europe.

Enterprises in Article 5 countries, having just converted from CFC-11 to HCFC-141b, can be expected, under normal conditions to continue to use HCFC-141b without worrying about the useful life of their machines for the next 8–10 years.

3.4.4 Maintenance

The high-wear components of high-pressure equipment consist basically of the pumps, mixing-head piston(s), and chamber. The manufacturers normally rebuild these components after a specified number of hours in service.

The electronic controls, sensors, gauges, switches, filters, hydraulic systems, heating and cooling units, day tank agitators, seals, high-pressure hoses, etc., are normally checked and maintained or replaced on a regular basis. The machine manufacturers recommend maintenance schedules for all of these items.

In a well-managed enterprise, if maintenance instructions are followed, and if leaks are repaired and spills cleaned up when they happen, machines may operate as long as 20 years. However, in real life, maintenance schedules are not always followed, particularly when inexperienced personnel operate or perform maintenance on the machines. This is particularly true with the sophisticated computer-controlled systems and electronic components; especially when operators bypass alarms and safety devices and fail to observe machine design limits. Such events happen under the pressure of production needs; for example, to restore production when a machine goes out of service, it is fixed in a hurry, but no one tries to solve the original problem.

The analysis indicates that some machine manufacturers technicians' visit their customers regularly after a new installation to check the machines and give further maintenance instructions to the factory operators and technicians. These visits are extremely helpful, but they are expensive and cannot be made regularly to all customers. Usually, the large customers receive more attention than the smaller ones. Wakim also understands that some of the machine manufacturers have established offices in the major Article 5 countries and staffed them with trained technicians.

3.4.5 Equipment Useful Life

The analysis indicates that the useful life of foaming machines and other equipment used for producing rigid polyurethane foam can be estimated, for practical purposes, at 8 to 10 years. In a well-managed enterprise, if ideal maintenance practices are followed, and leaks are repaired and spills cleaned up, the machines may last 20 years. However, as noted, in reality maintenance schedules are not always followed. Furthermore, technological change and changes in the chemistry of blowing agents tend to make machines technically obsolete before they reach the end of their useful lives as a result of the wear and tear of normal use.

3.5 COMPARISON OF OPERATING COSTS FOR ALTERNATIVE TECHNOLOGIES

The comparison of the operating costs for the alternative technologies is based on the prevailing market conditions in the specific Article 5 countries at the times the decisions to convert to CFC alternatives were made by the enterprises. Stated differently, a comparison based on technologies and prices available in Europe or North America at that time but unattainable by the relevant enterprises in Article 5 countries, would not explain how Multilateral Fund policies and funding rules affected the selection of alternative technologies by these enterprises. Furthermore, a comparison based on prices prevalent in Europe or North America in 2001 or, in more extreme cases, on projected prices for products that will not be available commercially until 2003 or after, would not assist Article 5 country enterprises gain a greater understanding of the economic impact of conversion to alternative technologies. Nor would such a comparison present a clearer picture to the Executive Committee of how the policies of the Multilateral Fund influence the choice of alternatives. Certainly, such a comparison could not explain the effects of the policies on choices made by enterprises in Article 5 countries in the past.

For projects under consideration at the present, or in the future, a comparison of the operating costs of alternative technologies, available in the domestic market of the relevant enterprises, is of value in making the selection. The operating costs are affected mostly by the prices of the raw materials, usually systems, purchased by the enterprises. Furthermore, comparing operating costs over 4, 10, and 15 years requires forecasting future prices. The accuracy of the comparison thus depends on the accuracy of the forecast prices. Our analyses, over the last 30 years, of future prices indicate that even experts, including producers of raw materials such as blowing agents, polyols, isocyanates, and systems, cannot predict future prices accurately. Furthermore, the forecast prices become less and less reliable as the forecast period extends further into the future. Our experience indicates that forecasts beyond 10 years become unreliable and indeed in many cases confusing. For these reasons and in consultation with the Secretariat, we considered project lives of 4 years to represent the short-term economic impact of the conversion to alternative technologies and 10 years to represent the long term impact.

To provide a comparison of economic impact that would be of maximum value to varied types of enterprises, it is necessary to compare alternatives available in the domestic markets of these enterprises. Therefore, we identified the interim and final alternatives that have been or could be considered in the future by these enterprises. The rigid foam subsector and the appropriate interim and final alternatives are listed in Table 3 above.

A detailed analysis of the alternatives that were available to the enterprises in Article 5 countries, with consideration of transitional matters, is presented in Appendix E. Of the final alternatives, pentanes were available in the latter years considered in the study. The HFCs, apart from HFC-134a, are expected to become available in the future. Our analysis indicates that the most likely candidates are HFC-245fa and its blends, and HFC-365mfc and its blends. The only producer of HFC-365mfc (Solvay Fluor) started a pilot plant with a capacity of several hundred t/yr in March 2000 and plans to start a new plant in Tevaux, France, with a capacity of 15,000 t/yr by the end of 2002. The only producer of HFC-245fa (Honeywell) is currently supplying semi-commercial quantities from its pilot plant and plans to start a new plant in Geismar, Louisiana, United States, with a capacity of probably 20,000 t/yr by July 2002. The combined capacity of both plants can satisfy only a small part of the demand for blowing agents in rigid foam in 2003 in Europe and North America. Increases in production thereafter will be targeted for Europe and North America as HCFC-141b is phased out. It is likely that these products will not be aggressively marketed in Article 5 countries until much later. Consumption of HCFCs in Article 5 countries will not be frozen until 2016; and final phase-out is expected to occur by 2040.

For projects already approved by the Multilateral Fund, a detailed analysis of the prices of various alternatives and systems, and different scenarios for comparing operating costs for enterprises in Article 5 countries is presented in Appendix E. Predictably, historical and present prices for alternatives and systems varied from country to country. In all cases, prices in Article 5 countries were significantly different from those in Europe and North America. Our analysis indicates that, for the operating costs to have any meaning for the affected enterprises, it is imperative that domestic prices be used in comparing operating costs.

An analysis of future prices of CFCs and their alternatives applicable to projects currently under consideration and potential future projects follows.

3.5.1 Scenario 1. Abundant Supply of CFC-11

As producing countries continue to flood the markets of Article 5 countries with CFC-11, the price for that chemical will remain depressed. In mid-2001, CFC-11 from China, India, and some European companies was delivered to Malaysia and Egypt at prices of about US$1.20/kg. Production in these countries is currently within the limits allowed by the Multilateral Fund; unless that production is reduced drastically, CFC-11 prices can be expected to remain at their present levels in real terms so long as CFC-11 is being produced; probably until 2010.

As long as CFC-11 prices remain depressed, prices of zero ODP and low ODP alternatives will be dragged downward in Article 5 countries.

3.5.2 Scenario 2. Continuation of Existing Regulations for HCFCs

The existing Montreal Protocol measures allow the use of HCFCs in Article 5 countries until 2040. Production of HCFCs to satisfy the markets of Article 5 countries will continue both in those and other countries. As non-Article 5 countries phase out the use of HCFCs, oversupply in the markets of Article 5 countries is likely. Prices of HCFCs, already under pressure from the residual low prices of CFC-11, will decline even further. The low prices of HCFCs will delay the transition from HCFCs to zero ODP products such as HFCs and pentanes.

3.5.3 Scenario 3. No Breakthrough in Hydrocarbon Technologies

The wide acceptance of hydrocarbon technologies in rigid foam applications has been hampered by:

- Fire and safety considerations
- Lack of availability of preblended hydrocarbon systems
- High capital costs for
  - Equipment
  - Modification of electrical circuits in the workplace
  - Hydrocarbon storage facilities
  - Fire-fighting facilities
  - Preblending equipment
- Lack of acceptance in some rigid foam subsectors such as spray foam.

No major breakthroughs are expected in the foreseeable future. However, some improvements may be introduced, particularly so in the development of preblended systems containing hydrocarbons. Such developments will reduce capital costs by eliminating the need for hydrocarbon storage facilities and preblending equipment.

3.5.4 Scenario 4. Adoption of HFC Technologies in Article 5 Countries

The limited supplies and the relatively high cost of HFCs will delay their adoption to any significant extent in Article 5 countries for the foreseeable future. HFC prices are expected to be significantly higher than those of HCFCs. Aggressive marketing of HFC blends that are price-competitive with HCFCs is possible, but is not expected to become significant anytime soon.

HFC-245fa prices are expected to be significantly higher than prices for HCFC-141b when HFC-245fa is introduced commercially in 2003. Prices of HFC-365mfc are expected to be at least as high as those of HFC-245fa.

3.5.5 Scenario 5. Potential for Conversion from HCFCs to HFCs in Article 5 Countries

The enterprises in Article 5 Countries we interviewed expressed a definite desire to convert from HCFCs to zero ODP blowing agents when those become commercially viable in their local markets. When that time comes, it is most likely that they will convert from HCFCs to HFCs.

Therefore, to assess the impact of this scenario at the enterprise level, we compare the economics of a two-stage conversion from CFC-11 to HCFC-141b to HFC-245fa with a one-stage conversion from CFC-11 to cyclopentane.

3.6 ECONOMIC COMPARISON OF CONVERSION FROM CFC-11 TO ALTERNATIVES

Appendix E presents six case studies that assess the economic impact of conversion to CFC alternatives on enterprises in Article 5 Countries. We have selected a case study of an enterprise in Malaysia to illustrate the economic impact on the enterprise of the actual alternative chosen (HCFC-141b), the theoretical impact if the enterprise had chosen cyclopentane, and the theoretical impact if the enterprise decides to proceed with a second conversion from HCFC-141b to HFC-245fa. A presentation of the three cases is given below.

3.6.1 Comparison of Conversion from CFC-11 to HCFC-141b or Cyclopentane (Case C 1. FMCP)

FMCP, a small Malaysian enterprise, consumed an average of 13.3 t/yr of CFC-11 from 1996 to 1998. A detailed comparison of incremental costs using different alternative technologies developed jointly by the enterprise, the Implementing Agency, and the NOU is presented in Appendix C and Appendix D.

3.6.1.1 Capital Costs

A detailed breakdown of the capital costs for converting from CFC-11 to HCFC-141b and cyclopentane is presented in Table C 1 in Appendix C. The breakdown includes the cost of foam dispensers, air compressors, electrical system modifications, training, production trials, technology transfer, and contingency. The capital costs for conversion to cyclopentane also include the costs for preblending equipment, a gas detection system, a ventilation system, press modifications, encapsulation of foaming areas, an antistatic floor covering, a sprinkler fire protection system, a cyclopentane storage tank, pumps, an emergency power generator, and safety inspections. The data indicate that the capital cost needed to convert from CFC-11 to HCFC-141b was about US$78,000; the capital cost needed to convert to cyclopentane was about US$507,000.

Using the cost-effectiveness threshold established by the Multilateral Fund, an enterprise must use about 65 t/yr of CFC-11 to receive a compensation that covers the conversion to cyclopentane. Therefore, an enterprise that consumes less than 65 t/yr must use its own or borrowed funds to cover the balance of the capital costs. However, some readers might say that the capital cost difference between converting to cyclopentane and HCFC-141b is not in reality as high as the numbers indicate because HCFC-141b is an interim solution; therefore, at some time in the future, the enterprise must go through another conversion to a zero ODP alternative. That observation is true. Nonetheless, the Multilateral Fund has established 2040 as the final date for phasing out HCFCs, including HCFC-141b in Article 5 countries. Consequently, enterprises that converted to HCFC-141b in Article 5 countries do not need to go through another conversion for many years—certainly more than 10 or 15 years under the present rules. Therefore, given the useful life of equipment, they do not expect to incur any additional capital costs.

Furthermore, when the time comes for a second conversion, most of the enterprises interviewed indicated that they will convert to nonflammable zero ODP blowing agents such as HFCs. The capital costs needed for the second conversion will cover minor retrofitting of existing equipment and the costs of production trials. Both of these expenses will be fairly small and are not expected to exceed US$5000 in a similar plant.

3.6.1.2 Operating Costs

Table C 4 presents a detailed breakdown of raw materials consumed (including CFC-11, HCFC-141b, and cyclopentane) per kilogram of foam is presented. Also presented in the table are the prevalent prices for all the raw materials in the domestic market at the time the enterprise made the selection. The data were then used to calculate the cost of producing a kilogram of foam using CFC-11, HCFC-141b, or cyclopentane.

The average annual foam production was estimated to be the same regardless of the blowing agent used. It is also assumed that the formulations presented in Table C 4 produce comparable foams. Therefore, the formulation changes will take into account change in foam properties such as density and K factor and the impact of these changes on operating costs. The enterprise's average annual operating cost for producing the foam was then calculated. Thus, the IOC for HCFC-141b and for cyclopentane, compared with CFC-11, can be estimated. Alternatively, the IOC for HCFC-141b can be compared with that for cyclopentane.

For a detailed analysis of price changes for CFC-11 and alternative blowing agents during the life of the project, the reader may wish to review Appendix E.

Table C 4 compares the IOC when HCFC-141b or cyclopentane is used as an alternative to CFC-11. The data indicate that FMCP's annual IOC increased by US$22,472 when using HCFC-141b and by US$5,785 with using cyclopentane. Alternatively, for a reader interested in the IOC of HCFC-141b compared with cyclopentane, the data in Table C 4 indicate that using HCFC-141b will cost the enterprise US$16,687 more annually than using cyclopentane.

The analysis indicates that the operating costs, with both HCFC-141b and cyclopentane, were higher than those with CFC-11 in Malaysia when FMCP made its decision. Therefore, FMCP could not realize any savings from using either CFC alternative to recover the depreciation of the capital investment; not to mention realizing any return on its investment.

Table C 7 presents the analysis of the short- and long-term economic impact of the change in IOC resulting from the conversion to CFC alternatives on FMCP. The cost-benefit analysis of converting from CFC-11 to HCFC-141b, assuming a plant life of 4 or 10 years and using discount rates of 8% or 12%, indicates that FMCP will incur additional expense over the use of CFC-11. The NPV of the increased IOC at an 8% discount rate is about US$79,000 for a plant life of 4 years and about US$159,000 for a plant life of 10 years. The NPV of the increased IOC at 12% is about US$75,000 for a plant life of 4 years and US$135,000 for a plant life of 10 years.

A similar analysis indicates that the NPV of the increased IOC, for converting from CFC-11 to cyclopentane, at a discount rate of 8% is about US$21,000 for a plant life of 4 years and about US$41,000 for a plant life of 10 years. The NPV of the increased IOC at 12% is about US$19,000 for a plant life of 4 years and US$35,000 for a plant life of 10 years.

Alternatively, a reader interested in comparing HCFC-141b with cyclopentane would be interested in the NPV of the IOC resulting from that comparison. The data in Table C 7 indicate that the NPV of the increased IOC using HCFC-141b at a discount rate of 8% is about US$58,000 for a plant life of 4 years and about US$118,000 for a plant life of 10 years. The NPV of the increased IOC at a discount rate of 12% is about US$56,000 for a plant life of 4 years and about US$100,000 for a plant life of 10 years.

3.7 TOTAL COSTS FOR ALTERNATIVE TECHNOLOGIES

The total costs for converting to alternative technologies to replace CFCs consist of the capital costs associated with purchase of equipment and factory modifications, and IOC.

The capital costs are usually fairly sizable; they are needed at the start of the conversion process; and there is no ambiguity about their size. In addition, the NPV of the capital costs, as compared with future costs incurred in a project, is usually high because no discounting is used to account for the time value of money. For these reasons, capital costs are scrutinized extensively by all enterprises, including those in Article 5 countries, before a decision is reached to proceed with a capital investment.

Capital costs are also significant because before an enterprise commits to a capital outlay, it searches for assurance that the capital can be recovered over the life of the project. The enterprise also expects to receive an acceptable return on the capital investment; usually above a hurdle rate approved by the management of the enterprise. Capital recovery, which is quantifiable with a fair degree of certainty at the beginning of the project, is usually realized by depreciating the capital in fixed annual increments over the life of the project. The annual increments are then divided among the units produced annually to determine the actual cost of production per unit. The return on capital investment, certainly desired by the enterprise, is not at all certain. Its estimation requires an analysis of revenues, fixed costs, variable costs, plant taxes and insurance, other plant and head office expenses, and corporate income taxes.

The operating costs, and therefore the IOC, are unpredictable. Typically, enterprises forecast future prices of raw materials, energy, labor, and other operating costs, on a project-by-project basis, at the beginning of a project. However, the level of confidence in the forecasts is not as high as that for capital costs. Therefore, the enterprise weighs a certain and quantifiable capital outlay at the present against an uncertain operating cost and, thus, revenue in the future.

For the rigid foam projects of interest in this study, the relevant capital costs are only those paid by the enterprises; the interviewed enterprises did not conduct an evaluation to determine the economic viability of the capital costs paid by the Multilateral Fund. Indeed, the large majority of the enterprises interviewed indicated that they did not conduct any evaluation to determine the short- or long-term economic impact of the conversion to CFC alternatives on their enterprises. Our analysis also indicates that very few enterprises paid any part of the capital costs; and those that did, paid only a small percentage of the total costs.

Therefore, to determine the total costs for an alternative technology, it is necessary to determine the capital cost portion contributed by the enterprise. Because very few enterprises contributed any capital cost, it is up to the interested parties to select one or more options from the many possible permutations. For illustrative purposes, we use the example discussed in Section 3.5, "Comparison of Operating Costs for Alternative Technologies" above. We further assume that the enterprise only had the option of choosing between HCFC-141b and cyclopentane. For this analysis, we assume a single-stage conversion. An abbreviated analysis of the economic factors to be considered by the enterprise follows.

The NPV of the various cash flow streams is presented in the Table 4. The NPV of the capital outlay is the difference between the capital costs for conversion to cyclopentane and those that would have been incurred for conversion to HCFC-141b. Because the capital is spent at the outset of the conversion, the NPV is the same as the actual money spent for the conversion.

Table 4 also presents the NPV of the operating costs that the enterprise will incur using cyclopentane and HCFC-141b. The NPVs for both alternatives are presented for plant lives of 4 and 10 years. The NPVs are also presented for discount rates of 8% and 12%. The NPV for the return on the investment expected by the enterprise is not presented in Table 4. Annual expected returns, as a percent of capital costs, can vary from prime rate plus a premium of 3% to 50%.

Table 4
NPV of Cash Flows of Total Conversion Costs
(Thousands of U.S. Dollars)

	Discount Rate					
	8%	**8%**	**Difference**	**12%**	**12%**	**Difference**
	HCFC-141b	**Cyclopentane**		**HCFC-141b**	**Cyclopentane**	
NPV of capital	78	507	– 429	78	507	– 429
Operating cost NPV						
For 4 years	79	21	58	75	19	56
For 10 years	159	41	118	135	35	100
Percent of capital recovered						
In 4 years			13.5			13.1
In 10 years			27.5			23.3

In all cases, the enterprise will realize reduced IOCs by using cyclopentane. Using a discount rate of 8%, the NPV of benefit to the enterprise will be US$58,000 for a project life of 4 years and US$118,000 for a project life of 10 years. Using a discount rate of 12%, the NPV of benefit to the enterprise will be US$56,000 for a project life of 4 years and US$100,000 for a project life of 10 years.

When the enterprise takes the total costs of the conversion into consideration, the capital costs, the operating costs, and the expected return on the investment must be considered. Because of the large number of possible permutations for estimating the return on investment, and to simplify the analysis, the data presented in this analysis include only the capital costs and the operating costs. The following analysis, by using only these two components of the total costs, presents the potential benefits that the enterprise converting to cyclopentane could have realized:

- Using an 8% discount rate, the enterprise would have recovered 13.5% of the capital costs in 4 years; and 27.5% of the capital costs in 10 years.
- Using a 12% discount rate, the enterprise would have recovered 13.1% of the capital costs in 4 years; and 23.3% of the capital costs in 10 years.

The inclusion of any return on investment in the calculations would have reduced the percentage of the capital that could have been recovered by the enterprise under the two previous scenarios.

3.7.1 Comparison of Two-Stage with Single-Stage Conversion

The economic impact on an enterprise converting from CFC-11 to a zero ODP blowing agent in two stages—CFC-11 to HCFC-141b to HFC-245fa—and in a single stage—CFC-11 to cyclopentane—illustrates what happens under Scenario 5, described above. However, because the timing of the second conversion is indefinite, we introduced the following parameters to frame the case:

- The conversion from HCFC-141b to HFC-245fa occurs 5 years after the first conversion.
- The enterprise pays the actual capital cost, less the Multilateral Fund grant.
- The enterprise pays the total cost of conversion from HCFC-141b to HFC-245fa.
- The enterprise pays the NPV of IOC in the first 5 years, less the portion paid by the Multilateral Fund; typically 2 years.
- The enterprise pays the total NPV of IOC from year 6 to 10.
- The NPVs are calculated using a 12% discount rate.
- The cost of the HFC-245fa system is 15% higher than the cost of HCFC-141b system starting from the first year.

Table 5 compares the NPVs of cash flows arising from the two-stage conversion and a single-stage conversion. The data for the conversion from CFC-11 to HCFC-141b reflect the actual ICC and operating cost paid by the Multilateral Fund to the enterprise. These data were reviewed and approved by the Secretariat, presented to and approved by the Executive Committee. The data for the conversion from CFC-11 to cyclopentane is based on the information prepared by the Implementing Agencies in collaboration with the enterprise.

Table 5

NPV of Cash Flows for Single-Stage and Two-Stage Conversion Costs (Thousands of U.S. Dollars)

	Two-Stage Conversion			One-Stage Conversion	
Item	**To HCFC-141b**	**To HFC-245fa**	**HCFC-141b + HFC-245fa**	**Cyclopentane**	**Cost of Two-Stage Conversion vs. One-Stage Conversion**
Capital cost to the enterprise	0	5	5	411	– 406
Capital cost to the Multilateral Fund	78	0	78	96	- 18
Total Capital Cost	78	5	83	507	– 424
NPV of operating cost					
To the enterprise, year 0-10	70	112	182	35	147
Year 0 to 5	70	0	70	17	53
Year 6 to 10	0	112	112	18	94
To the Multilateral Fund	18	0	18	0	18
Total operating cost	88	112	200	35	165
Total cost to enterprise	70	117	187	446	– 259
Total Cost to the Multilateral Fund	96	0	96	96	0

The data indicate that the total ICC for the two-stage conversion from CFC-11 to HCFC-141b followed by conversion HFC-245fa is about 16% of the cost of the single-stage conversion from CFC-11 to cyclopentane. The Multilateral Fund would have paid about 19% of the total capital costs. However, choosing the single-stage conversion to cyclopentane would have cost the enterprise US$406,000 more than the two-stage conversion.

The Multilateral Fund would have paid none of the IOCs incurred by the enterprise in the one-stage conversion. Therefore, the NPV of the incremental operating cost paid by the enterprise for the first 5 years was US$70,000. Furthermore, by converting to the more expensive HFC-245fa at the end of year 5, the enterprise had to pay an additional US$112,000 from year 6 to 10; bringing the total operating cost contribution of the enterprise to US$182,000.

The Multilateral Fund’s contribution for the total costs to the enterprise would have been the same regardless of whether the enterprise proceeded with a one-stage or two-stage conversion from CFC-11. However, the enterprise would have paid an additional US$259,000 for the one-stage conversion to cyclopentane than for the two-stage conversion to HCFC-141b followed by conversion to HFC-245fa.

3.8 SUMMARY OF CASE STUDIES

The selection of the case studies is based on information gathered from:

- Review of 394 project files and completion reports
- Field visits and inputs from 47 enterprises in Argentina, Egypt, and Malaysia
- Sending questionnaires to 135 enterprises in 22 Article 5 countries
- Review of responses to questionnaires from 63 enterprises in 7 Article 5 countries
- Discussions with suppliers of polyurethane systems, blowing agents, and equipment
- Discussion with government representatives during the field visits
- Discussions with UNDP representatives.

The selected case studies for enterprises in Argentina and Malaysia illustrate the short- and long-term economic consequences for enterprises that have converted to CFC alternatives in rigid foam. The selected enterprises represent small (consuming less than 20 t/yr of CFC-11), medium (consuming 20–49 t/yr), and large enterprises (consuming 50 t/yr or more). Therefore, the selected enterprises can be used to illustrate the effect of economies of scale on the funding for the projects.

The case studies are of projects approved from 1993 to 1999, the period in which the Multilateral Fund approved about 88% of the projects. Therefore, the selected projects represent the large majority of approved projects. Furthermore, the time span is sufficiently long to illustrate the evolution of the Multilateral Fund's policies over time.

We also attempted to select cases from projects implemented by all the Implementing Agencies. However, we were able to find sufficient details only for projects implemented by UNDP and UNIDO.

In all cases, we considered the case studies from the point of view of the end users in keeping with our understanding of the intent of the Executive Committee. Therefore, we attempted to present the findings using the different options faced by each enterprise for different project lifetimes, as well as for firms of different sizes. Table 6 presents a summary of the case studies.

A detailed analysis of the economic impact on the enterprises of the conversion to CFC alternatives is presented in Appendix C (Tables C 1 through C 9) and Appendix D (Tables D 1 through D 9) and is discussed in detail in Appendix E.

Table 6
Summary of Case Studies

Case Study	C 1	C 2	C 3	D 1	D 2	D 3
Approval year	1999	1994	1993	1999	1997	1998
Implementing Agency	UNDP	UNDP	UNDP	UNIDO	UNDP	UNDP
CFC-11 consumption, tonnes	13.3	20	45	30.2	72	18.5
Alternatives considered	Cyclopentane	HFC-134a	HFC-134a	Cyclopentane	Cyclopentane	Cyclopentane
	HCFC-141b	HCFC-141b	HCFC-141b	HCFC-141b	HCFC-141b	HCFC-141b
	Water/CO_2	HCFC-141b/ water	HCFC-141b/ water	HCFC-141b/ water	HCFC-141b/ water	HCFC-141b/ water
Alternative chosen	HCFC-141b	HCFC-141b/ water	HCFC-141b/ water	HCFC-141b/ water	Cyclopentane	HCFC-141b/ water

3.9 RESULTS FROM FIELD SURVEY AND QUESTIONNAIRE

The major objective of the filed surveys and the questionnaires was to collect the necessary data to determine:

- The major factors leading to choice of alternative technologies by Article 5 countries
- The economic consequences for enterprises converting to alternatives to CFCs
- The degree of understanding by the enterprises of Article 5 countries of the economic impacts of conversion to various alternatives
- How Multilateral Fund policies may have influenced the choice of alternatives selected by enterprises.

To examine the economic impact of conversion from CFCs in the rigid foam sector in an Article 5 country, it was necessary to consider the following factors:

- Raw material and capital costs
- Commercial availability of alternatives
- Whether the alternative selected was an interim or final choice
- Local safety and fire regulations
- Availability of Multilateral Fund assistance.

The analysis of the data collected by Wakim is described in greater detail by country below.

3.9.1 Argentina

Among the 394 projects recorded in the Secretariat files, 14 rigid foam projects were in Argentina; 3 of these were umbrella projects covering several small and medium size enterprises. The Executive Committee approved the 14 projects between 1994 and 2000.

Wakim selected seven enterprises to represent the large and small to medium size enterprises from the rigid foam sector in Argentina. Table 7 presents the names, Multilateral Fund project numbers, ODP tonnes used, and the CFC alternatives selected by each enterprise. With the assistance of the Secretariat and the National Ozone Program in Argentina (OPROZ), Wakim obtained the addresses, and scheduled and held discussions with representatives of the seven selected enterprises.

In addition, with the assistance of OPROZ, Wakim circulated an additional 18 questionnaires to enterprises representing small and medium size enterprises in Argentina.

Table 7
Rigid Foam Enterprises Interviewed in the Argentinean Field Survey

Project Number	Company Name	CFC	ODP (tonnes)	Replacement
ARG/FOA/28/INV/110	Powler S.R.L.	CFC-11	27	HCFC-141b
ARG/FOA/22/INV/57	Calofrig Asilaciones Jacobi	CFC-11	72	HCFC-141b/ n-Pentane
ARG/FOA/29/INV/97	Friolatina	CFC-11	2	HCFC-141b
ARG/FOA/29/INV/97	FADEP Ingenieria S.R.L.	CFC-11	2	HCFC-141b
ARG/FOA/26/INV/78	COMENCO Asilaciones	CFC-11	31	HCFC-141b
ARG/FOA/22/INV/55	Rheem S.A.	CFC-11	12	HCFC-141b
ARG/FOA/29/INV/95	Obras de Ingenieria	CFC-11	17	HCFC-141b
Total	7 projects		163	

During the field survey, Wakim also held discussions with representatives of the government; three major suppliers of polyurethane systems, CFCs, and CFC alternatives; one blender of polyurethane systems; and one supplier of machinery and services to the foam industry in Argentina.

3.9.1.1 Discussions with Government Representatives

A summary of the discussions held with the Government of Argentina to obtain its perspective on the conversion to CFC alternatives in the rigid foam sector follows:

The dissemination of Multilateral Fund policies to enterprises in Argentina was primarily carried out by the Implementing Agencies, although OPROZ also assisted. Therefore, as far as the enterprises are concerned, the Implementing Agencies represented the Multilateral Fund and its policies.

- The conversion program from CFCs to alternatives is proceeding on schedule.
- The consumption of CFCs in Argentina will remain below the ceiling set by the Montreal Protocol measures.
- The enterprises are appreciative of the grants received from the Multilateral Fund and the technical support provided by UNDP and UNIDO.
- The cost-effectiveness level set by the Multilateral Fund defined the options that small to medium size enterprises, in particular, could consider.
- The application and location of an enterprise’s factory influenced its selection of alternative technologies. For example, rigid spray foam producers and factories located in residential areas or heavily populated areas could not use hydrocarbons; the fire marshals would not issue permits for such applications.
- Some enterprises with approved hydrocarbon projects are having difficulty producing foam that meets fire-retardant specifications demanded by clients.

3.9.1.2 Discussions with Selected Enterprises

Wakim met with representatives of the seven enterprises in the offices of OPROZ and discussed the questions listed in the questionnaire with specific focus on the thought processes that led to the selection of CFC alternatives and how, if at all, the Multilateral Fund policies affected the selection.

There were significant similarities among the answers submitted by the various enterprises. A summary of the main findings of the discussions follows:

- All the enterprises indicated that the Implementing Agencies provided the only source of information about how the Multilateral Fund policies were likely to affect them.
- Most of the enterprises considered converting from CFCs to alternatives after receiving encouragement from OPROZ or the Implementing Agencies.
- Most of the enterprises did not have the expertise to perform the necessary analyses to determine the economic impact on their companies, either short- or long-term, of conversion to CFC alternatives.
- All enterprises considered the commercially available alternatives before making the selection. However, the selection was invariably based on the technical advice received from the Implementing Agencies.
- The use of cyclopentane as a CFC alternative in Argentina started in 1999; before 1999, none of the enterprises had the equipment to use hydrocarbons.
- Several enterprises decided not to use hydrocarbons after two companies that had converted to pentanes went bankrupt.
- Most of the enterprises purchase preblended systems; therefore, they can use only CFC alternatives that are incorporated in commercially available systems.
- All enterprises consuming less than 50 t/yr of CFC-11 indicated that their operations were not large enough to justify the large capital investment needed for the use of hydrocarbon blowing agents. Therefore, they decided to use HCFCs until reasonably priced HFCs become available commercially

3.9.2 Egypt

The rigid foam sector in Egypt consisted of 6 projects among the 394 projects recorded in the Secretariat files. One of these was an umbrella project covering seven small and medium size enterprises. The Executive Committee approved the six projects in 1993 and 1994.

Wakim selected nine enterprises to represent the large and small to medium size enterprises from the rigid foam sector in Egypt. Table 8 presents the names, Multilateral Fund project numbers, ODP tonnes used, and the CFC alternatives selected by each enterprise. With the assistance of the Secretariat and UNDP, Wakim obtained the addresses, and held discussions with representatives of the nine selected enterprises.

Table 8
Rigid Foam Enterprises Interviewed in the Egyptian Field Survey

Project Number	Company Name	CFC	ODP (tonnes)	Replacement
EGY/FOA/10/INV/17	Cairo Light Industries Company (Olympic Electric)	CFC-11	75	HCFC-141b
EGY/FOA/11/INV/18	Specialized Engineering Contracting Company	CFC-11	15	HCFC-141b
EGY/FOA/12/INV/29	Industrial Engineering Co. for Construction & Dev. (ICON)	CFC-11	51	n-Pentane
EGY/FOA/12/INV/27	SCIB Chemical Company (United Paints & Chemicals)	CFC-11	12	HCFC-141b
EGY/FOA/12/INV/28	Al Fateh Establishment	CFC-11	59	Cyclopentane
EGY/FOA/15/INV/36	GMC	CFC-11		HCFC-141b
EGY/FOA/15/INV/36	Petrojet (Petroleum Projects & Tech. Consultations Co.)	CFC-11		HCFC-141b
EGY/FOA/15/INV/36	Egyptian Solar Energy	CFC-11		HCFC-141b
EGY/FOA/15/INV/36	El Tawfikia Company	CFC-11	69	HCFC-141b
Total	9 projects		281	

3.9.2.1 Discussions with Government Representatives

With the assistance of the Secretariat, the UNDP, and the Egyptian Environmental Affairs Agency (EEAA), Wakim obtained the addresses and scheduled meetings with representatives of the nine selected enterprises. Wakim also met with the UNDP representatives in Cairo—UNDP handled all the rigid foam projects in Egypt—to obtain their feedback about the conversion to CFC alternatives in rigid foam.

A summary of the main points of Wakim's discussions with EEAA representatives about the Egyptian Government's perspective on the conversion to CFC alternatives in the rigid foam sector follows:

- All rigid foam projects, except for Al Fateh, have been completed and closed.
- Al Fateh has completed conversion and is preparing documents for project closure.
- All rigid foam projects were handled by UNDP.
- The EEAA would have liked the Implementing Agencies to provide more training for the employees in the various enterprises during the conversion process from CFCs to alternative technologies.
- Egyptian Customs started in September 2000 to track and report CFC imports to the Ozone Unit.

- The EEAA is concerned about shipments of CFCs from India, China, Italy, and France to Egypt at depressed prices (around $1.20/kg). The low prices encourage illegal uses of CFCs.
- The EEAA is asking importers about CFC end use before issuing import permits.
- The EEAA believes that Egyptian consumption of CFCs will remain below the ceiling agreed to by the Multilateral Fund and the Egyptian Government.

3.9.2.2 Discussions with Selected Enterprises

After circulating the questionnaire to the nine enterprises, Wakim visited the factories or the head offices of each enterprise and discussed the questionnaire with its representatives. There were significant similarities among the answers submitted by the various enterprises. A summary of the main themes discovered during the field surveys follows:

- All the enterprises indicated that the Implementing Agencies provided the only source of information about how the Multilateral Fund policies were likely to affect them.
- Most of the enterprises started considering converting from CFCs to alternatives after receiving encouragement from the EEAA, an Implementing Agency, or chemical suppliers.
- Most of the enterprises did not have the expertise to perform the necessary analysis to determine the economic impact of the conversion to CFC alternatives on their companies. Furthermore, neither the EEAA nor the Implementing Agencies explained the economic ramifications of the conversion to the enterprises.
- All enterprises considered commercially available alternatives before making the selection. However, the selection was invariably based on the technical advice received from the Implementing Agencies.
- Polyurethane systems using cyclopentane as a blowing agent were introduced in 1995 for the refrigeration sector.
- Cyclopentane or hydrocarbon based systems for rigid foam applications were introduced in 1999.
- Most of the enterprises purchase preblended systems.
- All enterprises consuming less than 50 t/yr of CFC-11 indicated that their operations were too small to justify the high capital investment needed for use of hydrocarbon blowing agents. Therefore, they decided to use HCFCs until reasonably priced HFCs become available commercially.
- Industrial Engineering Company converted to n-pentane. However, the company had to spend about US$400,000 in addition to the Multilateral Fund grant to complete the project.

- Al Fateh Establishment converted to cyclopentane. However, the company had to spend about US$150,000 on the machines and cyclopentane storage and delivery system in addition to the Multilateral Fund grant. Al Fateh also had to pay for installing a fire-fighting system to meet the fire marshal's safety requirements and to obtain a permit for operating the factory.
- Cairo Light Industry, which consumed about 75 t/yr of CFC-11, converted to HCFC-141b because it could not obtain the necessary permits to use flammable hydrocarbons because of the zoning of its property; the factory is adjacent to residential communities.

3.9.3 Malaysia

The rigid foam sector in Malaysia consisted of 32 projects among the 394 projects recorded in the Secretariat files. Wakim selected seven enterprises to represent the large and small to medium size enterprises from the rigid foam sector in Malaysia. Table 9 sets forth the names, Multilateral Fund project numbers, ODP tonnes used, and the CFC alternatives selected by each enterprise.

Table 9
Rigid Foam Enterprises Interviewed in the Malaysian Field Survey

Project Number	Company Name	CFC	ODP (tonnes)	Replacement
MAL/FOA/12/INV/22	Cycle World Sdn. Bhd.	CFC-11	45	HCFC-141b
MAL/FOA/22/INV/96	Rollbond SDN. Bhd.	CFC-11	22	HCFC-141b
MAL/FOA/11/INV/16	Insafoam Insulation Sdn.	CFC-11	30	HCFC-141b
MAL/FOA/15/INV/47	Ricwil Sdn. Bhd.	CFC-11	25	HCFC-141b
MAL/FOA/28/INV/127	Chong Brother Group	CFC-11	28	HCFC-141b
MAL/FOA/13/INV/38	Wong Brothers Electrical and Refrigeration	CFC-11	35	HCFC-141b
MAL/FOA/23/INV/102	Visdamax Sdn. Bhd.	CFC-11	19	HCFC-141b
Total	7 projects		204	

With the assistance of the Secretariat, the UNDP, and Malaysia's NOU, Wakim obtained the addresses and scheduled meetings with representatives of the seven selected enterprises. Wakim met with representatives of an additional six enterprises in the offices of NOU. Wakim also met with representatives of the major suppliers of CFCs, CFC alternatives, and chemicals to the rigid foam sector in Malaysia.

3.9.3.1 Discussions with Government Representatives

Wakim met with representatives of the NOU and discussed the Malaysian Government's perspective of conversion to CFC alternatives in the rigid foam sector. A summary of the main points follows:

- Conversion from CFCs to CFC alternatives is proceeding on schedule in Malaysia.
- The NOU has performed a survey of consumption of CFCs in Malaysia by end use and sector.
- The NOU has in place a program of permits to track CFC imports to Malaysia.
- The NOU has published the names of all recipients of Multilateral Fund funds and informed all suppliers of CFCs and CFC alternatives that these recipients are not allowed to use CFCs.
- The NOU is concerned about shipments of CFCs from countries such as India and China at depressed prices. The low prices could encourage illegal uses of CFCs.
- The NOU believes that Malaysian consumption of CFCs will remain below the ceiling agreed to by the Multilateral Fund and the Malaysian Government.

3.9.3.2 Discussions with Selected Enterprises

After circulating the questionnaire to the enterprises in the rigid foam sector, Wakim discussed the questionnaire with representatives of the seven enterprises listed in Table 9. There were significant similarities among the answers submitted by the various enterprises. A summary of the main issues that surfaced during the field surveys follows:

- All the enterprises indicated that the Implementing Agencies provided the only source of information about how the Multilateral Fund policies were likely to affect them.
- Most of the enterprises were encouraged to convert from CFCs to alternatives by the NOU and the Implementing Agencies.
- Most of the enterprises did not have the expertise to perform the necessary analysis to determine the economic impact of conversion to CFC alternatives on their companies. Furthermore, neither the NOU nor the Implementing Agencies explained the economic ramifications of the conversion to the enterprises.
- Malaysian chemical suppliers have not been aggressively promoting polyurethane systems that can be used with hydrocarbons. Chemical suppliers do not maintain stocks of these chemicals because of the small demand.
- Cyclopentane and other hydrocarbons used as CFC alternatives are not produced in Malaysia.
- Importers of hydrocarbon CFC alternatives need special permits for warehouses and storage tanks.

- Rigid foam producers wishing to use hydrocarbon CFC alternatives must make long-term arrangements with the suppliers; otherwise, the waiting period for receipt of products is about 3–4 months. The long delivery period discourages the use of hydrocarbon CFC alternatives.
- The enterprises considered the commercially available alternatives before making the selection. However, the selection was invariably based on the technical advice received from the Implementing Agencies.
- The relatively large panel producers were interested in using hydrocarbon CFC alternatives. However, because of the location of their factories, they could not obtain permits for that use from fire marshals.
- All the enterprises using HCFCs indicated that they will convert to zero ODP alternatives when they become commercially viable in Malaysia.
- Most of the enterprises purchase preblended systems.
- All enterprises consuming less than 50 t/yr of CFC-11 indicated that their operations were too small to justify the large capital needed for use of hydrocarbon blowing agents.

3.9.4 Findings from the Questionnaires

With the assistance of the Secretariat and the Implementing Agencies, 135 questionnaires were sent to enterprises in 22 countries in addition to the ones sent to enterprises in Argentina, Egypt, and Malaysia. Wakim received 63 completed questionnaires from enterprises in 7 Article 5 countries; however, 50 of these came from large, small, and medium enterprises included in basket projects in Mexico. A summary of the common responses follows.

- Most of the enterprises indicated that the Implementing Agencies provided the only source of information about how the Multilateral Fund policies were likely to affect them.
- The majority of the respondents indicated that the Multilateral Fund policies helped them proceed with the conversion to CFC alternatives by supplying capital grants and technical support. However, the respondents did not indicate that the policies influenced their decision to select any particular CFC alternative.
- Most of the enterprises were encouraged to convert from CFCs to alternatives by their NOU and the Implementing Agencies.

3.10 FINDINGS AND CONCLUSIONS

Our analysis indicates that the market conditions faced by enterprises in Article 5 countries differ significantly from those experienced by enterprises in other countries. Furthermore, market conditions also differ among the individual Article 5 countries as well. Therefore, to ensure that the findings were applicable at the producing enterprise level, it was necessary to take into consideration local conditions in each of the countries. A summary of our findings and conclusions follows.

3.10.1 Factors Affecting the Choice of Alternative Technologies

Wakim's analysis indicates that a major factor affecting the enterprises' choices of CFC alternatives was the advice received from their NOUs, UNDP and UNIDO experts, and suppliers of polyurethane systems and blowing agents. The enterprises became aware that the alternative technologies used globally include HCFCs, pentanes—cyclopentane, n-pentane, and iso-pentane—CO_2, and HFCs. They also received information about other emerging alternatives, which include HFC-245fa, HFC-365mfc, blends of HFCs, methyl formate, 2-chloropropane, and others. However, some of the emerging alternatives such as HFC-245fa and HFC-365mfc will not become available commercially until 2003, and market introduction in Article 5 countries is expected to be delayed beyond that date.

The enterprises also understood that the various CFC alternatives had advantages and disadvantages. Some alternatives had zero ODP, others had an ODP potential of 10% or less compared with that of CFC-11. Some alternatives had fire-retardant properties similar to those of CFC-11; others were flammable and required modification of plant and equipment before they could be used in the factory. They also discovered that invariably these alternatives produced rigid foams whose properties differ from those of foam produced with CFC-11.

Our analysis indicates that the enterprises interviewed were genuinely interested in proceeding with one conversion step and in selecting an alternative with zero ODP potential. However, the enterprises had to make pragmatic decisions in accordance with local market realities, such as whether or not:

- The alternative was available commercially in the local market
- The enterprise could obtain a permit to use the alternative in the factory
- The foam produced with the alternative was acceptable in the market
- The price of the alternative was commercially viable.

These local market realities had a major influence on each enterprise's choice of a CFC alternative; this was especially the case for small and medium size enterprises. For example, if an alternative and the compatible isocyanate and polyol systems were not available in the local market at the time conversion was being considered, the enterprise did not choose that alternative. Furthermore, the majority of small and medium enterprises used preblended systems. Therefore, an enterprise selected a CFC alternative only if the local suppliers kept stocks of the systems and offered the necessary technical support. Our analysis indicates that, in the early to late 1990s, several systems compatible with CFC alternatives were available in Europe, Japan, and North America, but were not promoted by suppliers in Article 5 countries such as Argentina, Egypt, and Malaysia.

Another factor that influenced the choice of a CFC alternative was the location of the enterprise's factory. For example, for factories in heavily populated areas or residential areas, fire marshals and local authorities would not grant permits to use flammable liquids in foam manufacturing. Our analysis indicates that a number of enterprises could not use pentanes because their factory locations made it impossible to obtain permits to use flammable liquids.

An enterprise's ability to choose CFC alternatives was also influenced by the type of application. For example, enterprises engaged in spray-in-place rigid foams could not use flammable liquids. Therefore, they could not select pentanes as blowing agents in this application.

An enterprise's choice of a CFC alternative was also influenced by the properties of the foams produced with the particular alternative. For example, enterprises producing foam for insulation could not use water-based systems; no water-based systems were available to the enterprises interviewed in this study that would produce foam with acceptable insulation properties. Similarly, enterprises producing foams requiring dimensional stability found that the selection of CFC alternatives for that application was limited.

Another factor that influenced an enterprise's choice of a CFC alternative was the price of the alternative. Enterprises compared the prices of the alternatives available with each other and with that for CFC-11 and chose the least expensive product. Obviously, the enterprises that received Multilateral Fund grants to convert to CFC alternatives were not supposed to use CFC-11. However, the availability in some Article 5 countries of CFC-11 from China, India, and some European countries at prices of about US$1.20/kg—well below the prices of low ODP or zero ODP alternatives—created a situation that worried the NOUs in these countries. Because they would save significant amounts of money, some enterprises could restart production, using CFC-11, thus breaking the agreement reached with the Multilateral Fund. Our analysis indicates that representatives of the NOUs interviewed during the field visits were developing strategies to deal with this potential problem.

3.10.2 Economic Consequences of Converting to Alternative Technologies

Our analysis included an assessment of the economic consequences of conversion to CFC alternatives for enterprises in Article 5 countries. To assess the magnitude of these consequences and the role played by the Multilateral Fund in alleviating their effects on enterprises, we conducted six case studies of enterprises that were representative of different global regions and different CFC alternatives, and that had received approval from 1993 to 1999. The case study sample was also chosen to represent small (consuming less than 20 t/yr of CFC-11, medium (consuming 20-49 t/yr), and large (consuming 50 t/yr or more) enterprises. Therefore, they also illustrate the impact of economies of scale on the projects.

We then estimated the short- and long-term economic consequences at the enterprise level. To do so, we performed spot checks on the data supplied by the enterprises in collaboration with an Implementing Agency, and confirmed that the data were reasonable and reflected actual conditions in the marketplace at the time they were prepared. The data typically included the cost of raw materials, energy, utilities, capital costs, labor costs, and other relevant expenses.

We conducted cost-benefit analyses by assuming a plant life of 4 years (short term) and 10 years (long term). In estimating the NPV of the economic benefits or losses realized by the enterprise from converting to CFC alternatives, we used two scenarios for annual discount rates—8% and 12%.

Our analysis indicates that the large majority of enterprises we surveyed did not assess the economic consequences for their companies associated with the conversion to CFC-11 alternatives.

The enterprises that converted to CFC alternatives invariably had to deal with one-time ICC and recurring IOC. An analysis of the consequences of these costs on enterprises selected from the case studies follows.

3.10.3 Incremental Capital Costs

The enterprises we assessed typically spent ICC on machinery and equipment, storage tanks and pipes, safety and fire prevention installations, technology transfer and technical assistance, and commissioning and startup. The ICC incurred by the selected enterprises for converting to CFC-11 alternatives ranged from about US$54,000 to about US$759,000. Tables C 1 through C 3 in Appendix C and Tables D 1 through D 3 in Appendix D present detailed breakdowns of the ICCs for the six enterprises.

ICC are typically capitalized and depreciated over the life of the project. Enterprises usually recover the capital cost of the equipment by considering depreciation as a running cost and by adding it to the manufacturing cost of products. Enterprises also add the ICC to the capital investment base and expect to realize a return on the investment.

The size of the ICC depends on the productive capacity of the enterprise, the type of equipment selected—high-pressure machines vs. low-pressure machines—and the CFC alternative selected. Using a flammable blowing agent, such as pentanes, requires special machines, instrumentation, and factory modifications to ensure employee safety and to prevent fires in the factory. The special machines and factory modifications increase the ICC significantly as can be seen from the following case study.

FMCP, a small Malaysian enterprise, consumed an average of 13.3 t/yr of CFC-11 from 1996 to 1998. With the assistance of UNDP, FMCP compared the ICC needed to convert its factory from CFC-11 to HCFC-141b or cyclopentane. The data indicated that the ICC needed to convert FMCP's factory to HCFC-141b and maintain the same production capacity was US$78,100. The ICC needed to convert the same factory to cyclopentane was US$507,100. (Appendix Table C 1 presents a detailed breakdown of the ICC.) Relying on these calculations, FMCP, with the concurrence of the NOU and UNDP, selected HCFC-141b and settled for an ICC of US$78,000.

The analysis of the data presented by FMCP indicates that small and medium enterprises consuming less than 50 t/yr of CFC-11 will find it difficult to select pentanes as CFC alternatives and justify the large capital investment needed for the conversion.

Another enterprise, Calofrig Asilaciones Jacobi (Calofrig), a large Argentinean enterprise that consumed 72 tonnes of CFC-11 in 1996, selected cyclopentane as a CFC alternative. With the assistance of UNDP, Calofrig prepared its project documentation in February 1997, and the Executive Committee approved the project later in 1997. Calofrig and UNDP estimated the ICC for the conversion at US$759,000. (Appendix Table D 2 presents a detailed breakdown of the ICC for the Calofrig case.)

Our analysis indicates that the ICCs discussed above constitute major financial commitments by the enterprises. Therefore, the grants supplied by the Multilateral Fund were crucial for these enterprises to be able to proceed with the conversion to CFC alternatives. Our analysis also indicates that the size of the enterprise, in terms of CFC-11 phased out per year, is a major determinant in selecting CFC alternatives. All the enterprises we interviewed indicated that they desired to convert to an alternative with zero ODP. Currently, the only commercially available zero ODP alternatives are pentanes. However, the market reality is that small and medium size enterprises can justify the large ICC, needed to convert to flammable alternatives only in special and rare cases. The results of the survey—which indicate that HCFC-141b was the alternative to CFC-11 that was chosen most frequently—demonstrate that the enterprises opted for HCFC-141b's relatively low ICC and simple handling procedures, as compared with the considerably higher ICC and more complicated handling that would have been needed with flammable blowing agents.

3.10.4 Incremental Operating Costs

The IOC reflect changes in costs, attributable to the conversion to CFC alternatives, and arising from changes in starting materials, additives, and the volumes of chemicals needed to compensate for foam properties and maintain the same level of production. The changes in costs could theoretically entail either increases or reduction of the IOC.

Our analysis of the data obtained in the field visits indicates that in all cases, when the level of production was maintained at the same level, IOC increased, regardless of the CFC alternative used. This increase in IOC occurred in Article 5 countries for two reasons: (1) the prices of HCFC-141b have been relatively high, and (2) those of CFC-11 have been depressed. HCFC-141b was recently introduced into the market, and in setting a price for the chemical, producers have sought to recover their development and commercialization costs. Table 10 presents the HCFC-141b prices paid by the enterprises and reported in the project reports.

Table 10
HCFC-141b Prices

Year	HCFC-141b (US$/kg)
1993	5.45
1994	4.00
1998	3.40
1999	3.40

The data indicate that HCFC-141b prices dropped by about 38% from 1993 to 1998 and 1999.

The producers of CFC-11 have kept the prices low to capture and maintain market share from other blowing agents such as HCFC-141b. This is particularly true for Article 5 countries because these markets are the only export markets left. The data supplied by the NOUs in the field visits indicate that by early 2001, CFC-11 imported from China, India, and some European countries was priced as low as US$1.20/kg at the port of entry. After subtracting the cost of freight, insurance, packaging, and handling, the CFC-11 prices realized by the producers at their factory gate would be somewhat lower—probably around US$1.00 to US$1.10/kg. The analysis indicates that the industry is in general agreement, both at the producer level and consumer level, that CFC-11 prices are depressed.

The increase in IOC in Article 5 countries, in particular the increase that would be associated with the selection of pentanes, compared with CFC-11, as the blowing agent, means that enterprises cannot realize savings that could be used to justify the necessary capital expenditures required to change to pentanes.

Changes in raw material prices leading to changes in IOCs occur frequently in the chemical industry, including the rigid foam sector. Typically, producers respond to these changes by passing the increases through to their customers in an orderly manner and as market conditions allow. It takes enterprises some time to respond to major cost changes and to bring their operations back to profitability, with a period of as long as 1 to 2 years needed to adjust to the changes.

Our analyses of changes in the IOCs of the enterprises selected for the case studies are presented in Appendices C 4 through 6 and Appendices D 4 through 6. The increases in IOC ranged from –US$1,004 to about US$37,300. The reduction of US$1,004 was obtained by an enterprise that selected pentanes as a CFC alternative. However, the reduction in IOC resulted from an annual drop of 14,400 kg of foam production that coincided with the conversion to pentanes. When production was maintained at the same level, the annual IOC with pentanes increased to US$36,320.

We then estimated the increases of IOC for 4 years (short term) and 10 years (long term) using the methodology and constraints approved by the Executive Committee and adopted by the Multilateral Fund. For example, the level of production for an enterprise was assumed to remain unchanged over the 4- or 10-year period. And in fact, the analysis indicates that production increased at only a few enterprises. Instead, production declined significantly in many enterprises as a result of a slow or declining national economy. Indeed, several enterprises went out of business shortly after receiving the Multilateral Fund grants. In another example, the IOC for an enterprise was assumed to remain unchanged for the 4- or 10-year period. This assumption is based on raw material prices, including those of CFC alternatives, remaining unchanged. The analysis indicates that prices of HCFC-141b (Table 10) declined by about 38% from 1993 to 1999—a decline that is typical of pricing trends once a product is introduced and competition increases in the marketplace.

The NPVs were then calculated using discount rates of 8% and 12%. These rates were chosen to establish a high case and a low case with a discount rate of 10% assumed to represent cost of capital in Article 5 countries. The detailed analyses of the NPVs for the case studies are presented in Appendix Tables C 7 through C 9 and D 7 through D 9. In all cases, no capital outlay of cash is included at the beginning of the project in the NPV calculations because the Multilateral Fund grants paid for the ICC. Similarly, and for the same reason, depreciation is not added to the cost of production in estimating the IOC.

Because of the constraints imposed on the IOC, the calculated NPVs are predictable. The NPV for 4 years for all projects is less than that for 10 years. The NPVs calculated using a discount rate of 8% is greater than that for 12% for IOC of all projects.

Wakim's analysis indicates that the NPVs mentioned above do not represent the NPV of the actual cash flows experienced by the enterprises. Take, for example, an enterprise that received a grant in 1993. It received a grant based on the NPV of an IOC calculated for a fixed price of US$5.45/ kg of HCFC-141b for the duration of the project or 2 years as allowed by Multilateral Fund policy. In reality, the price of HCFC-141b dropped to US$4.0/kg in 1994 and US$3.40/kg in 1999. Therefore, the IOC was overestimated in year 2 and the enterprise was overcompensated for the IOC actually incurred. From this finding, it is reasonable to conclude that a grant estimated by calculating the NPVs for 4 or 10 years, using the fixed original price of HCFC-141b, rather than the actual declining market prices, will greatly overestimate the increased IOC of the enterprise.

Predicting the behavior of chemical markets is a risky business, and formulating a policy that is expected to mirror global market behavior is open to criticism from all sides. Industry deals with this dilemma by conducting financial analyses on a project-by-project basis and by holding those who make the assumptions accountable for the bottom line of a project. If the project is profitable, they receive rewards; if it fails, they are deemed responsible. This leads us to the conclusion that limiting the IOC calculations to 2 years, as is currently stipulated by the Multilateral Fund policy, gives results that resemble actual conditions at the enterprise level, as opposed to using longer periods. Furthermore, the 2-year period gives an enterprise sufficient time to adjust its selling prices to reflect raw material prices.

3.10.5 The Influence of Fund Policies on the Choice of Alternative Technologies

Wakim also reviewed the Multilateral Fund rules that govern funding to enterprises in Article 5 countries for converting to CFC alternatives in rigid foam applications to determine how the rules may have influenced the choice of alternatives. The review indicated that the funding rules for ICC and IOC evolved as the Secretariat and the Implementing Agencies gained experience over time. Therefore, the funding rules that were applicable to projects approved in the early 1990s, for example, were different from those used for projects approved in later years. A significant development resulting from the evolving rules for funding ICC and IOC occurred at the sixteenth meeting of the Executive Committee when the Committee established a list of cost-effectiveness thresholds for most sectors and several subsectors, including a cost-effectiveness threshold of US$7.83/kg/yr of ozone-depleting substances (ODS) phased out in rigid foam applications. This decision essentially limited the funds available for conversion to CFC alternatives by small enterprises.

Wakim's discussions in the field visits and information gathered from the responses to the mailed questionnaires indicate that the enterprises depended exclusively on the Implementing Agencies as the source of information about the funding policies. The information also indicates that the enterprises did not have a clear picture of the actual policies or how those policies affected them. For example, the large majority of the enterprises we interviewed indicated that they did not perform an analysis to determine the economic impact on their companies of converting to CFC alternatives. Therefore, these enterprises proceeded with the conversion without knowing the short- or long-term effects of the conversion on the financial position of their companies.

Our analysis of how the Multilateral Fund policies affected the conversion to CFC alternatives by enterprises in Article 5 countries follows.

3.10.6 Conversion to CFC Alternatives

The enterprises were informed by their countries' NOUs and by representatives of the Implementing Agencies available in their countries that all consumers of CFCs must replace CFCs with products that do not deplete ozone from the atmosphere. They were also informed that the Multilateral Fund would compensate them for the conversion.

The enterprises indicated that they would convert to CFC alternatives to obey the laws and regulations proposed by their governments. The availability of funds from the Multilateral Fund was an incentive for many enterprises to speed the conversion process and stop using CFCs well in advance of the enactment of laws by their governments.

The enterprises were also informed that the Multilateral Fund would provide technical assistance for converting to CFC alternatives.

The enterprises were aware that the ultimate goals of the Multilateral Fund and of their national governments were to eliminate the use of CFCs and replace them with products with zero ODP.

3.10.7 Selection of CFC Alternatives

Wakim's review of the Multilateral Fund policies indicates that the funding rules for ICC and IOC evolved over time. The funding rules applicable to projects that were approved in the early 1990s, for example, were different from those used for projects approved in later years, including as noted above, the cost-effectiveness threshold. This decision essentially limited the level of funds available for conversion to CFC alternatives and linked them to the volume of CFC-11 consumed by the enterprise. It did not account for changes that could arise for small enterprises. Although most large projects have been completed, a number of small enterprises have as yet to be presented for consideration by the Executive Committee; most are likely to be part of umbrella projects.

Our analysis indicates that the enterprises depended on the Implementing Agencies as the source of information about the funding policies. It also indicates that the enterprises did not have a clear picture of the policies or how these policies affected them. For example, most of the enterprises relied on the Implementing Agencies to estimate the ICC and IOC resulting from the conversion to CFC alternatives. Most of the enterprises proceeded with the conversion without knowing the short- or long-term effects of the conversion on their financial positions.

Our analysis indicates that the Multilateral Fund policies affected the conversion to CFC alternatives by enterprises in Article 5 countries in the following ways.

3.10.8 Conversion to CFC Alternatives

On realizing that they had to convert to CFC alternatives, the enterprises indicated that they would obey the new laws and regulations proposed by their governments. The availability of funds and technical assistance from the Multilateral Fund was an incentive for many enterprises to speed the conversion process and to stop using CFCs well in advance of the enactment of laws by their governments.

3.10.9 Selection of CFC Alternatives

The Multilateral Fund policies affected the selection of CFC alternatives by proxy. The Implementing Agencies, which represented the Multilateral Fund as far as the enterprises were concerned, were the major sources of information about the available alternatives and of recommendations for the most appropriate choices for the enterprises. However, the final selection of the alternatives was a pragmatic decision made by the enterprises and was dictated to a large extent by market realities, such as whether or not:

- The alternative was available commercially in the local market
- The enterprise could obtain a permit to use the alternative in the factory
- The foam produced with the alternative was acceptable in the market
- The price of the alternative was commercially viable.

Therefore, the funding rules of the Multilateral Fund had little, if any, impact on the choices made by the enterprises.

3.10.10 Incremental Capital Cost

The Multilateral Fund policy is intended to cover the ICC incurred by an enterprise as a result of conversion to a CFC alternative. The enterprise was expected to maintain the same production level as before the conversion. In the early 1990s, the enterprises, with the assistance of the Implementing Agencies, estimated the ICC and presented the project proposal to the Secretariat for review. On the Secretariat's agreement with the Implementing Agency's request, the proposal was presented to the Executive Committee for approval and reimbursement of the estimated amount.

The Executive Committee, in its sixteenth meeting, established a cost-effectiveness threshold of US$7.83/kg of ODS phased out annually for incremental costs—capital and operating—for rigid foam projects. That threshold worked quite well for most of the projects approved in the years immediately following the sixteenth meeting; and moderately well for many subsequent projects.

However, some enterprises claim that they have had to spend significant amounts to complete the conversion to CFC alternatives because the grants did not cover the ICC incurred. The claims have been made by small and large enterprises; the large enterprises that made the claim selected cyclopentane as the CFC alternative. The analysis indicates that the main causes of the increased expenditures in these enterprises arose from the costs of safety and fire-fighting equipment requested by the fire marshals or local authorities.

The analysis indicates that the Multilateral Fund's funding rules for ICC did not affect enterprises' selection of CFC alternatives. However, some enterprises had to spend their own money to pay for part of the conversion.

3.10.11 Incremental Operating Cost

The Multilateral Fund policy is intended to cover increases in IOC incurred by an enterprise as a result of the conversion to a CFC alternative. The Executive Committee stipulated the use of the NPV of 2 years of IOC in estimating project costs.

The analysis indicates that the IOC of most enterprises in Article 5 countries increased as a result of converting to CFC alternatives. Data collected during the field visits indicate that CFC-11 imported from China, India, and some European countries is delivered to Article 5 countries at prices as low as US$1.20/kg. Currently, the prices of most CFC alternatives available in Article 5 countries are higher than the price of CFC-11.

Our analysis indicated that the Multilateral Fund rules for funding IOC did not affect the selection of CFC alternatives made by the enterprises interviewed. The enterprises appreciate that the funding rules are intended to assist them during the transition from CFCs to alternatives and not to establish an arbitrary pricing system based on ongoing subsidies. Most of the enterprises indicated that a period of 2 years was sufficient for them to make the necessary adjustments. During that transition period, the enterprises learned how to use the new systems and CFC alternatives efficiently and adjusted their prices so that they could generate enough profit and stay in business.

project.xls MULTILATERAL FUND PROJECTS BY YEAR OF APPROVAL

Blowing Agent	Total	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991
HCFC-141b	319	36	102	46	73	27	10	14	5	4	2
HCFC-22	13	0	0	1	0	1	8	2	0	1	0
HCFC-22/142b	2	0	0	0	1	0	0	0	0	1	0
50% Reduced CFC	13	0	0	0	0	4	2	1	6	0	0
Water/CO2	18	3	5	2	3	0	0	4	1	0	0
Cyclopentane	11	1	0	3	0	1	2	4	0	0	0
Pentanes	15	1	2	3	2	3	2	2	0	0	0
HFC-134a	2	0	0	1	0	1	0	0	0	0	0
Liquid CO2	1	0	0	1	0	0	0	0	0	0	0
Totals	394	41	109	57	79	37	24	27	12	6	2

project.xls

APPROVED HYDROCARBON PROJECTS BY COUNTRY

Hydrocarbon/	Pentanes		Cyclopentanes		ODP Tons		
Country	Number	ODP Tons	Number	ODP Tons	C5 Projects	All Projects	C5 as %
Algeria	2	192	0	0	192		
Argentina	3	176	1	45	221		
Brazil	0	0	1	46	46		
China	5	543	4	526	1069		
Egypt	0	0	3	123	123		
Iran	2	1270	0	0	1270		
Syria	1	65	1	61	126		
Turkey	2	291	1	155	446		
Total	15	2,537	11	956	3,493	17,762	19.67

DECISIONS OF THE EXECUTIVE COMMITTEE

The following decisions of the Executive Committee are related to the rigid foam sub-sector and might have bearing on the choice of alternatives:

(A) Relevant decisions of the Executive Committee on HCFCs

(B) Cost-effectiveness

- Threshold values ((*UNEP/OzL.Pro/ExCom/16/20 (paras. 32c, 32**d)***
- Partial funding (Decision 17/10)
- Cost-effectiveness for rigid PU foam projects and discounting for safety costs (no discounting is allowed) (Decision 20/45)

(C) Decisions on safety issues and related costs in hydrocarbon technology

- Safety related costs of hydrocarbon technology (Decision 23/18)
- Hydrocarbon safety (Decision 25/47)

(D) Other relevant decisions

- Duration of incremental costs (Decision 18/8)
- Technological upgrade (Decision 18/25)
- The admissibility of using operating costs to fund non -incremental capital costs (Decision 20/6)
- Foam density (Decision 31/44)
- Report on evaluation of foam projects (Decision 33/2)

The decisions are reproduced below.

(A) Relevant decisions of the Executive Committee on HCFCs

The Executive Committee requested Implementing Agencies to take the following issue into consideration when preparing projects:

(a) as HCFCs were not controlled substances for Article 5 countries, incremental costs for conversion of HCFC-141b plants were not eligible for funding;
(b) Implementing Agencies should note a presumption against HCFCs when preparing projects; and
(c) where HCFC projects were proposed, the choice of this technology should be fully justified and include an estimate of the potential future costs of second-stage conversion.

(UNEP/OzL.Pro/ExCom/15/45, para. 129).
(UNEP/OzL.Pro/ExCom/17/60, Decision 17/17 para. 26).

The Twentieth Meeting of the Executive Committee, decided:
(b) to request the Implementing Agencies to ensure that adequate information on all alternative technologies was provided to enterprises converting from CFCs;
(c) to reaffirm paragraph (b) of its decision 19/2 which stated that, in cases where conversion to HCFCs was recommended, the Implementing Agencies should be requested to provide a full explanation of the reasons why such conversion was recommended, together with supporting documentation that the criteria laid down by the Executive Committee for transitional substances had been met, and should make it clear that the enterprises concerned had agreed to bear the cost of subsequent conversion to non-HCFC substances.

(UNEP/OzL.Pro/ExCom/20/72, Decision 20/48, para 72 (b, c).

The Executive Committee at its Twenty-seventh Meeting expressed its appreciation for the increased information/justification provided for the selection of HCFCs and noted that that was the level of information originally expected, and that at least that level was expected in the future; stressed to the Implementing Agencies that it considered this to be more than a paper exercise, and urged the Agencies to take seriously the obligations related to providing information on alternatives available; and decided, in recognition of Article 2F of the Montreal Protocol, to request that Implementing Agencies provide, for all future projects or groups of projects for HCFCs from any country, a letter from the Government concerned. In the letter, the country should:

(a) verify that it had reviewed the specific situations involved with the project(s) as well as its HCFC commitments under Article 2F;
(b) state if it had nonetheless determined that, at the present time, the projects needed to use HCFCs for an interim period;
(c) state that it understood that no funding would be available for the future conversion from HCFCs for these companies.

(UNEP/OzL.Pro/ExCom/27/48, Decision 27/13 (para. 35).

(B) Cost-effectiveness

Threshold values

The Sixteenth Meeting of the Executive Committee adopted the following sector and sub-sector cost-effectiveness threshold values to be applied to projects submitted to the Seventeenth Meeting, and to review them at its Eighteenth Meeting:

Foam Sector	US $/kg ODP
General	9.53
Flexible polyurethane	6.23
Integral skin	16.86
Polystyrene/polyethylene	8.22
Rigid polyurethane	7.83

(UNEP/OzL.Pro/ExCom/16/20 (paras. 32c, 32d)

Partial funding

18. The Executive Committee noted that a number of projects with cost-effectiveness values above the cost-effectiveness threshold had been submitted for partial funding of total project costs (e.g. the enterprise only sought funding for that proportion of the incremental costs that met or approached the cost-effectiveness threshold) and decided that:

(a) Partial funding should be allowed and encouraged since it was fully consistent with previous decisions by the Executive Committee to maximize the effectiveness of the Fund's resources in phasing out ODS; (**Decision 17/10**)

Cost-effectiveness for rigid PU foam projects and discounting for safety costs (no discounting is allowed)

68. The Executive Committee took note of document UNEP/OzL.Pro/ExCom/20/65 and the recommendation by the Sub-Committee on Project Review (UNEP/OzL.Pro/ExCom/20/5, para. 54) and decided:

(a) To approve the recommendations in the Secretariat's document on safety-related costs in projects using hydrocarbon technologies, namely:

(iii) With regard to rigid polyurethane foam projects, there was no need for the introduction of a discounting factor to account for the additional safety costs for hydrocarbon technology, because the above statistical analysis showed that on average, projects using hydrocarbon technology were already below the cost-effectiveness threshold for the sector, and thus would not be disadvantaged for consideration for funding;

(Decision 20/45)

(C) Decisions on safety issues and related costs in hydrocarbon technology

Safety-related costs of hydrocarbon technology

39. Taking into account the recommendation of the Sub-Committee (UNEP/OzL.Pro/ExCom/23/10/Add.1, paragraph 37), the Executive Committee decided that:

(a) Safety standards should follow international standards, where these are higher than standards in the country concerned. The practical application of established standards should be based on industry norms and practice in European countries.

(b) Projects should be prepared and reviewed on the basis of this principle.

(Decision 23/18)

Hydrocarbon safety

84. Having taken note of the comments and recommendation of the Sub-Committee on Project Review (UNEP/OzL.Pro/ExCom/25/17, paragraphs 83 to 87), the Executive Committee decided to approve the Hydrocarbon Safety Cost Study to be used as guidance for the implementing agencies, for enterprises in Article 5 countries in the preparation of investment projects and for the Secretariat in reviewing the submitted projects.

(Decision 25/47)

(D) Other relevant decisions

Duration of operating costs

20. The Executive Committee decided:

(a) to approve a time-frame of up to two years for the calculation of incremental operating costs of all rigid polyurethane foam projects other than those relating to the domestic refrigeration sector; and

(Decision 18/8)

Technological upgrade

56. The Executive Committee considered the issue of the technological upgrade associated with implementation of non-ODS conversion projects, as presented in document UNEP/OzL.Pro/ExCom/18/73. Technological upgrades were defined as additional advantages which the enterprises may obtain, such as superior quality in their products, increased production capacity or flexibility, reduced energy consumption and labour and/or other advantages as a result of conversion to non-ODS (or low-ODS) technology. Methodologies for the identification and quantification of technological upgrades were presented in the policy paper.

57. The Executive Committee decided:

(b) that costs associated with avoidable technological upgrades should not be considered as eligible incremental costs and therefore should not be funded by the Multilateral Fund;

(c) that the methodologies for quantification of technological upgrades outlined in UNEP/OzL.Pro/ExCom/18/73 will be used as guidance in the calculation of incremental costs. **(Decision 18/25)**

The admissibility of using operating costs to fund non -incremental capital costs

17. Having considered the recommendations of the Sub-Committee on Project Review on the admissibility of using operating costs to fund non-incremental capital costs (UNEP/OzL.Pro/ExCom/20/5, para. 15), the Executive Committee decided:

(a) That where the Secretariat, in reviewing a project that did not claim all the eligible operating costs in order to keep its cost-effectiveness within the established threshold, determined that part of the capital costs were ineligible, the value of those ineligible costs could be compensated by an increase in the eligible operating costs provided that:

(i) The original eligible operating costs were claimed for less than the allowable period;

(ii) The compensation did not result in the allowable period being exceeded; and

(iii) The overall cost of the project remained within the threshold established for the sector or subsector;

(b) Transfers from operating costs to capital costs during implementation of such a project could only occur to fund cost overruns for eligible capital equipment items that had been included in the project approval, in which case, a report would have to be submitted to the Executive Committee providing an explanation and justification for the transfer. **(Decision 20/6)**

Foam density

68. Having considered the comments of the Sub-Committee on Project Review (UNEP/OzL.Pro/ExCom/31/21, paras. 64-66), the Executive Committee decided:

(a) To adopt the conclusions and the recommendations of the technical study on foam density, as contained in annex VII to the present report (Page 7 of this Appendix), for a period of one year for the calculation of incremental operating costs;

(b) To request the Secretariat to arrange for work on the subject to be resumed, in order to improve the conclusions. This resumed work, may include, inter alia, consideration of the costs and viability of LCD technology for small and medium-sized enterprises, within the context of existing guidelines and cost-effectiveness thresholds. **(Decision 31/44)**

Report on the evaluation of foam projects

18. Having considered the comments and the recommendation of the Sub-Committee on Monitoring, Evaluation and Finance (UNEP/OzL.Pro/ExCom/33/3, para. 13), the Executive Committee decided:

(d) Further to request that, in accordance with the relevant guidelines, the funding received be partly or fully returned to the Multilateral Fund in cases where technology was changed without informing the Secretariat and without approval by the Executive Committee;

(f) To request the implementing agencies to ensure that recipient enterprises were fully aware of their obligation to cease using CFCs upon conversion and to make a commitment to that effect in the project documentation;

(g) appropriate use, or refund, of unused contingency funds, and to keep funding requests for equipment and trials to levels essential to ensuring the conversion. In cases of serious funding irregularities, such as when project funds were used to purchase non-eligible items, the implementing agency concerned might be requested by the Executive Committee to return funding to the Multilateral Fund; **(Decision 33/2)**

Annex VII to the Report of the 31st Meeting of the Excom
Conclusions and recommendations of the World Bank OORG Foam Density Report 2000

1. The information and guidance contained in the World Bank OORG Foam Density Report 2000 of 25 June 2000 should be shared with all the implementing agencies.

2. Rigid polyurethane insulation foam projects should be based on the definitions of market segments as defined in Table 1.

3. For each MLF project the overall densities of the foams in the baseline case and with the alternative technologies should be determined using ISO 845. This will enable the data bank to be expanded and enhanced.

4. The density changes applied in rigid polyurethane insulating foam projects should follow the values listed in Table 3.

5. Where enterprises are operating, in the baseline case, at lower densities than those listed in Table 3 the percentage increases in density should be applied.

6. For rigid polyurethane foam projects where incremental operating costs are given for two years the first year should be based on the "start-up" density and the second year on the "mature" density. For those projects where incremental operating costs are met for six months then the "start-up" density should be used.

7. For flexible molded foam, where the technology to replace CFC-11 is invariably $C0_2$ (water) blown there is no increase in density. However, formulations might need to be changed to maintain performance/OEM specifications, but no general rules can be drawn up regarding formulation changes.

8. For integral skin products, this segment is best considered on a case-by-case basis.

9. The Working Group should be reconvened when it is deemed necessary so that it can update its findings.

And some concluding remarks:

This study is extremely important for the cost effective phase-out of ODS in foam projects. The TOR was broad in concept and this report attempts to present the findings in a clear and concise fashion.

The data input was based on two sources. The first was from a study of data from MLF projects provided by UNDP and The World Bank. The second was the experience (a total of 146 years) and on-going learning of the members of the Foams Working Group. Both sources are invaluable.

It is inevitable that further information would have enhanced the data bank but is unlikely to have changed the conclusions.

TABLE 1 – RIGID POLYURETHANE FOAM SEGMENTATION

SEGMENT	SUB-SEGMENT	COMMENTS
THERMOWARE	Picnic boxes	e.g. as made by Rubbermaid and Coleman
	Insulated food dishes & bottles	
PIPE INSULATION	Pipe sections	Molded sections
		Sections cut from blocks
	Pipe-in-pipe	For DCH (District heating pipes)
DISCONTINUOUS BOARDS & BLOCKS	Boards	
	Blocks	Used for several applications including pipe sections & panels
CONTINUOUS BOARDS & BLOCKS	Flexible-faced laminates/boardstock	Major insulation product in developed countries
	Blocks	Rigid slabstock used for pipe sections and panels, etc.
DOMESTIC REFRIGERATORS & FREEZERS		
COMMERCIAL REFRIGERATORS & FREEZERS	Vending machines	Self-service can drink dispensers
	Visi-coolers	Glass-fronted drink coolers
	Display cases	Used in retail outlets
	Chest freezers	Used in retail outlets
	Walk-in/step-in coolers/freezers	Storage in supermarkets, typically made from discontinuously-made sandwich panels
CONTINUOUS PANELS		For cladding, warehouses, cold stores, industrial buildings
DISCONTINUOUS PANELS		Uses as for continuous panels plus doors and commercial refrigeration
SPRAY FOAMS	Walls	Interior & exterior walls
	Roofs	For new and renovation applications
	Pipes and Tanks	For hot and cold applications

For non-insulating polyurethane foams the sub-segments are:

TABLE 2 – FLEXIBLE MOLDED FOAM SEGMENTATION

SEGMENT	SUB-SEGMENTS	COMMENTS
FLEXIBLE MOLDED FOAM – TRANSPORTATION	Seat backs	All follow specifications of the OEMs
	Seat cushions	
	Headrests	
	Saddles	For motorcycles
FLEXIBLE MOLDED FOAM – FURNITURE		
FLEXIBLE INTEGRAL SKIN FOAMS – TRANSPORTATION	Steering Wheels, armrests	
	Fascias	
	Bicycle saddles	
RIGID INTEGRAL SKIN	Furniture	Typically wood imitation moldings
	Electrical and electronic cases	

TABLE 3 – DENSITIES FOR RIGID POLYURETHANE FOAMS

SEGMENT	SUB-SEGMENT	BASELINE DENSITY	ALTERNATIVE TECHNOLOGY	START-UP DENSITY (Δ %)	MATURE DENSITY (Δ %)
THERMOWARE	Picnic boxes	32-34	HCFC 141b	35-37 (9)	32-34 (0)
	Insulated dishes	32-34	HCFC 141b	35-37 (9)	32-34 (0)
PIPE INSULATION	Pipe sections	33-35	HCFC 141b	35-37 (6)	34-36 (3)
	Pipe-in-pipe	70-80	HCFC 141b & pentane	70-80 (0)	70-80 (0)
DISCONTINUOUS BOARDS & BLOCKS	Boards	35-37	HCFC 141b	38-40 (8)	36-38 (3)
	Blocks	33-34	HCFC 141b	36-37 (9)	34-35 (3)
CONTINUOUS BOARDS	Boards	30-32	HCFC 141b, pentane	33-35 (10) 35-37 (16)	31-33 (3) 34-36 (13)
DOMESTIC REFRIGERATOR/ FREEZERS		31-33	Cyclopentane Cyclo/iso pentane HCFC 141b	36-38 (16) 34-36 (10) 35-37 (13)	34-36 (10) 34-35 (8) 33-35 (6)
COMMERCIAL REFRIGERATORS & FREEZERS	Vending machines	33-35	HCFC 141b	36-38 (9)	35-37 (6)
	Visi-coolers	33-35	HCFC 141b	36-38 (9)	35-37 (6)
	Display cases	36-38	HCFC 141b	38-40 (5)	37-39 (3)
	Chest freezers	36-38	HCFC 141b	38-40 (5)	37-39 (3)
	Walk-in/step-in coolers/freezers	41-44	HCFC 141b	43-45 (4)	41-44 (0)
CONTINUOUS PANELS		40-42	HCFC 141b, Pentane	42-44 (5)	40-42 (0)
DISCONTINUOUS PANELS		41-44	HCFC 141b, Pentane, HFC 134a	43-45 (4)	41-44 (0)
SPRAY FOAMS	Walls	32-35	HCFC 141b	34-37 (6)	33-36 (3)
	Roofs	48-50	HCFC 141b	48-50 (0)	48-50 (0)
	Pipes & tanks	32-35	HCFC 141b	34-37 (6)	33-36 (3)

COMPARISON OF CAPITAL COSTS FOR CONVERSION TO CFC ALTERNATIVES AT FMCP IN MALAYSIA
Cyclopentane vs. HCFC-141b

Equipment & Other One Time Costs	HCFC-141b U.S.$	Cyclopentane U.S.$
OMS FM 110 Low Pressure foaming dispenser	40,000	
Air Compressor and compressed air supply system	8,000	8,000
Electrical System Supply upgrade within foaming area	3,000	15,000
HP-foaming machine for cyclopentane, duty 120 kg/min		150,000
Polyol/ABA Pre-mixer including buffer tank		85,000
Gas Detection system for the foaming area		35,000
Safety Extract Ventilation System for the foaming area		35,000
Modifications to the press including grounding		10,000
Encapsulation of foaming areas		10,000
Anti-static floor covering for foaming areas		5,000
Sprinkler fire protection system for foaming areas		20,000
Pipe-work Installation for the mixing head		10,000
Cyclopentnae Storage Tank (5 cubic meters)		15,000
Pump, Valves, & Pipe-work from cyclopentane tank to pre-mixer		10,000
Emergency Power Generator		10,000
Independent Safety Inspections		15,000
Training	5,000	5,000
Production Trials & Formulation Optimization	5,000	8,000
Technology Transfer & Technical Assistance	10,000	15,000
Contingency (10%)	7,100	46,100
TOTAL	$78,100	$507,100

Source: Project of the Government of Malaysia
Implementing Agency: UNDP
Prepared in March 1999
Presented to the 28th Meeting of the Executive Committee

Average annual ODS used at enterprise was 13.3 tons (1996-1998)

CAPITAL COSTS FOR CONVERSION TO CFC ALTERNATIVES
AT PANGKAT REFRIGERATION INDUSTRIES IN MALAYSIA
HCFC-141b

Equipment & Other One Time Costs	HCFC-141b U.S.$
Foaming Machine	150,000
Mixing Head Beam	20,000
Freight and Installation	15,000
Start-up and Trials	5,000
Technology Transfer and Training	15,000
Contingency & Rounding	20,000
TOTAL	225,000

Source: Project of the Government of Malaysia
Implementing Agency: UNDP
Prepared in June 1994
Approved in July 1994

Estimated annual ODS use at enterprise was 20 tons in 1994

CAPITAL COSTS FOR CONVERSION TO CFC ALTERNATIVES
AT CYCLE WORLD SDN. IN MALAYSIA
HCFC-141b

Equipment & Other One Time Costs	HCFC-141b U.S.$
Foam Equipment	110,000
Premix Station	65,000
Freight and Installation	15,000
Start-up and Trials	5,000
Technology Transfer and Training	15,000
Contingency & Rounding	23,000
TOTAL	233,000

Source: Project of the Government of Malaysia
Implementing Agency: UNDP
Prepared in December 1993
Approved in March 1994

Annual ODS use at enterprise was 45 tons in 1993

COMPARISON OF INCREMENTAL OPERATING COSTS FOR CONVERSION TO CFC ALTERNATIVES AT FMCP IN MALAYSIA
Cyclopentane and HCFC-141b vs. CFC-11

Raw Material Consumption per kg of Foam	CFC-11 Kg	HCFC-141b Kg	Cyclopentane Kg
MDI	0.500	0.520	0.594
Polyol	0.370	0.378	0.350
Blowing Agent	0.130	0.102	0.056
Total	1.000	1.000	1.000
Prices	US$/kg	US$/kg	US$/kg
MDI	1.85	1.85	1.85
Polyol	1.85	1.95	1.95
Blowing Agent	1.75	3.50	2.00
Cost per Kg of Foam Produced	US$	US$	US$
MDI	0.925	0.962	1.099
Polyol	0.685	0.737	0.683
Blowing Agent	0.228	0.357	0.112
Total	1.837	2.056	1.893
Average Annual Foam Production, Kg	102,564	102,564	102,564
Average Annual Cost	$188,410	$210,882	$194,195
Incremental Operating Cost over CFC-11 Base		$22,472	$5,785

Source: Project of the Government of Malaysia
Implementing Agency: UNDP
Prepared in March 1999
Presented to the 28th Meeting of the Executive Committee

Average annual ODS used at enterprise was 13.3 tons (1996-1998)
Net phase out of 12.2 ODP tons

INCREASE OF INCREMENTAL OPERATING COSTS FOR CONVERSION FROM CFC-11
AT PANGKAT REFRIGERATION INDUSTRIES IN MALAYSIA
HCFC-141b vs. CFC-11

Annual Raw Material Consumption	CFC-11 Tons	HCFC-141b Tons
MDI	(A)	13.50
Polyol	(B)	(B)
Blowing Agent	20.00	7.50
Total	20.00	21.00
Prices	US$/kg	US$/kg
MDI	1.85	1.85
Polyol	(N/A)	(N/A)
Blowing Agent	2.00	4.00
Annual Costs to Produce Rigid Foam	US$	US$
MDI	(N/A)	24,975
Polyol	(N/A)	(N/A)
Blowing Agent	40,000	30,000
Annual Cost	40,000	54,975
Incremental Operating Cost over CFC-11 Base		14,975

(A) Base MDI consumption
(B) Polyol consumption not affected
(N/A) Not applicable

Source: Project of the Government of Malaysia
Implementing Agency: UNDP
Prepared in June 1994
Approved in July 1994

Estimated annual ODS use at enterprise was 20 tons in 1994

INCREASE OF INCREMENTAL OPERATING COSTS FOR CONVERSION FROM CFC-11
AT CYCLE WORLD SDN. IN MALAYSIA
HCFC-141b vs. CFC-11

Annual Raw Material Consumption	CFC-11 Tons	HCFC-141b Tons
MDI	(A)	32.00
Polyol	(B)	(B)
Blowing Agent	45.00	18.00
Total	45.00	50.00
Prices	US$/kg	US$/kg
MDI	1.85	1.85
Polyol	(N/A)	(N/A)
Blowing Agent	2.10	5.45
Annual Costs to Produce Rigid Foam	US$	US$
MDI	(N/A)	59,200
Polyol	(N/A)	(N/A)
Blowing Agent	94,500	98,100
Annual Cost	94,500	157,300
Gross Increase of Incremental Operating Cost		62,800
Less Savings on cleaning agents and others		25,500
Incremental Operating Cost over CFC-11 Base		37,300

(A) Base MDI consumption
(B) Polyol consumption not affected
(N/A) Not applicable

Source: Project of the Government of Malaysia
Implementing Agency: UNDP
Prepared in December 1993
Approved in March 1994

Annual ODS use at enterprise was 45 tons in 1993

NET PRESENT VALUE OF INCREASE OF INCREMENTAL OPERATING COSTS
AT FMCP IN MALAYSIA
HCFC-141b vs. CFC-11

Discount Rate: 8% Deflator = 0.92

Year	1	2	3	4	5	6	7	8	9	10
Amount	22,472									
Discounted	22,472	20,674	19,020	17,498	16,099	14,811	13,626	12,536	11,533	10,610

NPV of 4 Years of Increase in IOC, $: 79,664
NPV of 10 Years of Increase in IOC, $: 158,879

Discount Rate: 12% Deflator = 0.88

Year	1	2	3	4	5	6	7	8	9	10
Amount	22,472									
Discounted	22,472	19,775	17,402	15,314	13,476	11,859	10,436	9,184	8,082	7,112

NPV of 4 Years of Increase in IOC, $: 74,963
NPV of 10 Years of Increase in IOC, $: 135,111

NET PRESENT VALUE OF INCREASE OF INCREMENTAL OPERATING COSTS
AT FMCP IN MALAYSIA
Cyclopentane vs. CFC-11

Discount Rate: 8% Deflator = 0.92

Year	1	2	3	4	5	6	7	8	9	10
Amount	5,785									
Discounted	5,785	5,322	4,896	4,504	4,144	3,813	3,508	3,227	2,969	2,731

NPV of 4 Years of Increase in IOC, $: 20,507
NPV of 10 Years of Increase in IOC, $: 40,898

Discount Rate: 12% Deflator = 0.88

Year	1	2	3	4	5	6	7	8	9	10
Amount	5,785									
Discounted	5,785	5,090	4,480	3,942	3,469	3,053	2,686	2,364	2,080	1,831

NPV of 4 Years of Increase in IOC, $: 19,297
NPV of 10 Years of Increase in IOC, $: 34,780

NET PRESENT VALUE OF INCREASE OF INCREMENTAL OPERATING COSTS
AT PANGKAT REFRIGERATION INDUSTRIES IN MALAYSIA
HCFC-141b vs. CFC-11

Discount Rate: 8% Deflator = 0.92

Year	1	2	3	4	5	6	7	8	9	10
Amount	14,975									
Discounted	14,975	13,777	12,675	11,661	10,728	9,870	9,080	8,354	7,685	7,071

NPV of 4 Years of Increase in IOC, $: 53,088
NPV of 10 Years of Increase in IOC, $: 105,875

Discount Rate: 12% Deflator = 0.88

Year	1	2	3	4	5	6	7	8	9	10
Amount	14,975									
Discounted	14,975	13,178	11,597	10,205	8,980	7,903	6,954	6,120	5,386	4,739

NPV of 4 Years of Increase in IOC, $: 49,955
NPV of 10 Years of Increase in IOC, $: 90,037

NET PRESENT VALUE OF INCREASE OF INCREMENTAL OPERATING COSTS
AT CYCLE WORLD SDN. IN MALAYSIA
HCFC-141b vs. CFC-11

Discount Rate: 8% Deflator = 0.92

Year	1	2	3	4	5	6	7	8	9	10
Amount	37,300									
Discounted	37,300	34,316	31,571	29,045	26,721	24,584	22,617	20,808	19,143	17,612

NPV of 4 Years of Increase in IOC, $: 132,232
NPV of 10 Years of Increase in IOC, $: 263,716

Discount Rate: 12% Deflator = 0.88

Year	1	2	3	4	5	6	7	8	9	10
Amount	37,300									
Discounted	37,300	32,824	28,885	25,419	22,369	19,684	17,322	15,244	13,414	11,805

NPV of 4 Years of Increase in IOC, $: 124,428
NPV of 10 Years of Increase in IOC, $: 224,266

CAPITAL COSTS FOR CONVERSION TO CFC ALTERNATIVES
AT POLWER S.R.L. IN ARGENTINA
HCFC-141b

Equipment & Other One Time Costs	HCFC-141b U.S.$
New Foaming Machine for Block Foam Production	30,000
Retrofit Existing Gusmer Equipment (14 years old)	5,000
Technology Transfer & Technical Assistance	5,000
Commissioning, Startup, and Trials	10,000
Contingency	3,500
TOTAL	53,500

Source: Project of the Government of Argentina
Implementing Agency: UNIDO
Prepared in April 1999
Presented to the 28th Meeting of the Executive Committee

Average annual ODS used at enterprise was 30.2 tons (1996-1998)

CAPITAL COSTS FOR CONVERSION TO CFC ALTERNATIVES
AT CALOFRIG AISLACIONES JACOBI IN ARGENTINA
Pentanes

Equipment & Other One Time Costs	Pentanes U.S.$
Equipment for Block Production Plant	
Foaming Machine, High Pressure, 120 kg	180,000
Premix Unit, Supply Pumps and Installation	80,000
Storage Tank, Piping and Pumps for Pentane, Explosion Proof	40,000
Ventilation for Injector and Press	20,000
Gas and Leak Detectors, Monitoring System	30,000
Local Works (Building modification, etc.)	20,000
SUB-TOTAL	370,000
Equipment for Panel Production Plant	
Foaming Unit: Re-conversion of high pressure unit	70,000
Premix Unit, Supply Pumps and Installation	80,000
Storage Tank, Piping and Pumps for Pentane, Explosion Proof	40,000
Ventilation for Injector and Press	30,000
Gas and Leak Detectors, Monitoring System	30,000
Local Works (Building modification, etc.)	20,000
SUB-TOTAL	270,000
Technology Transfer and Training	
International consultant and technology transfer	20,000
Safety audit	10,000
Tests and trials	20,000
SUB-TOTAL	50,000
Contingency and Rounding	69,000
TOTAL	759,000

Source: Project of the Government of Argentina
Implementing Agency: UNDP
Prepared in February 1997
Approved in 1997

Estimated annual ODS use at enterprise was 72 tons in 1996

CAPITAL COSTS FOR CONVERSION TO CFC ALTERNATIVES
AT OBRAS DE INGENIERIA IN ARGENTINA
HCFC-141b

Equipment & Other One Time Costs	HCFC-141b U.S.$
High Pressure Spray Foam Dispensers (3 units)	60,000
Start-up and Trials	5,000
Technology Transfer and Training	10,000
TOTAL	75,000

Source: Project of the Government of Argentina
Implementing Agency: UNDP
Prepared in September 1998
Approved in 1999

Annual ODS use at enterprise was 18.5 tons in 1998

COMPARISON OF INCREMENTAL OPERATING COSTS FOR CONVERSION TO CFC
AT POLWER S.R.L. IN ARGENTINA
HCFC-141b vs. CFC-11

Raw Material Consumption per kg of Foam	CFC-11 Kg	HCFC-141b Kg
MDI	0.500	0.566
Polyol	0.370	0.377
Blowing Agent	0.130	0.057
Total	1.000	1.000
Prices	US$/kg	US$/kg
MDI	3.11	3.11
Polyol	3.11	3.11
Blowing Agent	2.11	3.40
Cost per Kg of Foam Produced	US$	US$
MDI	1.555	1.760
Polyol	1.151	1.172
Blowing Agent	0.274	0.194
Total	2.980	3.127
Average Annual Foam Production, Kg	226,693	226,693
Average Annual Cost	$675,545	$708,762
Incremental Operating Cost over CFC-11 Base		$33,217

Source: Project of the Government of Argentina
Implementing Agency: UNIDO
Prepared in April 1999
Presented to the 28th Meeting of the Executive Committee

Average annual ODS used at enterprise was 30.2 tons (1996-1998)

INCREASE OF INCREMENTAL OPERATING COSTS FOR CONVERSION FROM CFC-11
AT CALOFRIG AISLACIONES JACOBI IN ARGENTINA
Pentanes vs. CFC-11

Annual Raw Material Consumption	CFC-11 kg	Pentanes kg
MDI	0.500	0.550
Polyol	0.360	0.390
Blowing Agent	0.140	0.060
Total	1.000	1.000
Prices	US$/kg	US$/kg
MDI	2.60	2.60
Polyol	2.60	2.86
Blowing Agent	2.10	1.00
Annual Costs to Produce Rigid Foam	US$	US$
MDI	1.300	1.430
Polyol	0.936	1.115
Blowing Agent	0.294	0.060
Average Cost per kg	2.530	2.605
Annual Production, kg	484,262	469,862
Annual Operating Cost	1,225,183	1,224,178
Incremental Operating Cost over CFC-11 Base		($1,004)

Source: Project of the Government of Argentina
Implementing Agency: UNDP
Prepared in February 1997
Approved in 1997

Estimated annual ODS use at enterprise was 72 tons in 1996

INCREASE OF INCREMENTAL OPERATING COSTS FOR CONVERSION FROM CFC-11
AT OBRAS DE INGENIERIA IN ARGENTINA
HCFC-141b vs. CFC-11

Annual Raw Material Consumption	CFC-11 Tons	HCFC-141b Tons
MDI	(A)	(A)
Polyol	(B)	(B)
Blowing Agent	18.50	18.50
Total	18.50	18.50
Prices	US$/kg	US$/kg
MDI	(N/A)	(N/A)
Polyol	(N/A)	(N/A)
Blowing Agent	2.11	3.40
Annual Costs to Produce Rigid Foam	US$	US$
MDI	(N/A)	(N/A)
Polyol	(N/A)	(N/A)
Blowing Agent	39,035	62,900
Annual Cost	39,035	62,900
Increase of Incremental Operating Cost		23,865

(A) Base MDI consumption
(B) Polyol consumption not affected
(N/A) Not applicable

Source: Project of the Government of Argentina
Implementing Agency: UNDP
Prepared in September 1998
Approved in 1999

Annual ODS use at enterprise was 18.5 tons in 1998

NET PRESENT VALUE OF INCREASE OF INCREMENTAL OPERATING COSTS
AT POLWER S.R.L. IN ARGENTINA
HCFC-141b vs. CFC-11

Discount Rate: 8% Deflator = 0.92

Year	1	2	3	4	5	6	7	8	9	10
Amount	33,217									
Discounted	33,217	30,560	28,115	25,866	23,797	21,893	20,141	18,530	17,048	15,684

NPV of 4 Years of Increase in IOC: 117,758
NPV of 10 Years of Increase in IOC: 234,851

Discount Rate: 12% Deflator = 0.88

Year	1	2	3	4	5	6	7	8	9	10
Amount	33,217									
Discounted	33,217	29,231	25,723	22,637	19,920	17,530	15,426	13,575	11,946	10,513

NPV of 4 Years of Increase in IOC: 110,809
NPV of 10 Years of Increase in IOC: 199,719

NET PRESENT VALUE OF INCREASE OF INCREMENTAL OPERATING COSTS
AT CALOFRIG AISLACIONES JACOBI IN ARGENTINA
Pentanes vs. CFC-11

Discount Rate: 8% Deflator = 0.92

Year	1	2	3	4	5	6	7	8	9	10
Amount	-1,004									
Discounted	-1,004	-924	-850	-782	-720	-662	-609	-560	-515	-474

NPV of 4 Years of Increase in IOC, $: -3,561
NPV of 10 Years of Increase in IOC, $: -7,101

Discount Rate: 12% Deflator = 0.88

Year	1	2	3	4	5	6	7	8	9	10
Amount	-1,004									
Discounted	-1,004	-884	-778	-684	-602	-530	-466	-410	-361	-318

NPV of 4 Years of Increase in IOC, $: -3,351
NPV of 10 Years of Increase in IOC, $: -6,039

NET PRESENT VALUE OF INCREASE OF INCREMENTAL OPERATING COSTS
AT OBRAS DE INGENIERIA IN ARGENTINA
HCFC-141b vs. CFC-11

Discount Rate: 8% Deflator = 0.92

Year	1	2	3	4	5	6	7	8	9	10
Amount	23,865									
Discounted	23,865	21,956	20,199	18,583	17,097	15,729	14,471	13,313	12,248	11,268

NPV of 4 Years of Increase in IOC, $: 84,604
NPV of 10 Years of Increase in IOC, $: 168,729

Discount Rate: 12% Deflator = 0.88

Year	1	2	3	4	5	6	7	8	9	10
Amount	23,865									
Discounted	23,865	21,001	18,481	16,263	14,312	12,594	11,083	9,753	8,583	7,553

NPV of 4 Years of Increase in IOC, $: 79,611
NPV of 10 Years of Increase in IOC, $: 143,488

ANALYSIS OF CASE STUDIES

CONTENTS

ALTERNATIVES TO CFCS IN RIGID FOAM APPLICATIONS

MULTILATERAL FUND RIGID FOAM PROJECTS

The Multilateral Fund has sponsored 409 projects aimed at phasing out CFC use in rigid foam applications globally. Table 1 summarizes the CFC volumes covered in these projects.

Table 1
Funds Dispersed for CFC Phase-Out In Rigid Foam Applications

Region	Total CFC (tonnes)	CFC Phased Out (tonnes)	Funds Disbursed (U.S. dollars)
Africa	828.9	579.0	$ 4,850,929
Asia Pacific	12,303.4	5,092.2	$28,226,468
Europe	807.8	497.8	$ 2,936,094
Latin America and the Caribbean	4,151.7	1,842.6	$11,853,358
Total	18,091.8	8,011.6	$47,866,849

The Asia Pacific region accounted for 68% of the 18,092 tonnes of CFC that are to be phased out; the Latin America and the Caribbean region accounted for 23%. About 44% of the total CFC tonnage has already been phased out.

Of the 10,080 tonnes of CFCs that remain to be phased out, the Asia Pacific region accounts for about 72%, followed by Latin America and the Caribbean at 23%.

At the Secretariat's offices in Montreal, Wakim reviewed the files of 394 projects in 31 Article 5 countries. The 394 projects accounted for 17,762 tonnes of CFCs with ozone-depleting potential (ODP) to be phased out. Wakim also reviewed evaluations conducted by the Secretariat to determine the technical and financial cost-benefit effectiveness of the conversion to CFC alternatives by enterprises in Article 5 countries.

Appendix A sets forth the projects approved by the Executive Committee of the Multilateral Fund. Table A 1 lists the number of projects approved by year and by blowing agent. Of the 394 projects approved from 1991 through 2000, 108 were approved from 1991 through 1996. The number of projects approved annually then increased, reaching 109 in 1999, but declining to 41 in 2000. Table A 2 lists the approved projects in which hydrocarbons—pentanes and cyclopentanes—were used; 15 projects were approved for using pentane, accounting for 2,537 ODP tonnes; and 11 projects were approved for cyclopentane, accounting for 956 ODP tonnes. The ODP tonnes replaced by hydrocarbons accounted for 20% of the total ODPs to be phased out.

To address the major issues identified by the Executive Committee, Wakim decided, in consultation with the Secretariat of the Multilateral Fund, to conduct a field survey in Argentina, Egypt, and Malaysia, as representative of Latin America, Africa and the Middle East, and the Asia Pacific regions, respectively. Furthermore, at the request of the Secretariat, Wakim expanded the scope of the study by sending the survey questionnaire to an additional 135 enterprises, which have received funding from the Multilateral Fund, in 22 Article 5 countries. The rational behind the expansion of project scope was to solicit feedback from a significant number of representative enterprises—small, medium size, and large enterprises—that have received Multilateral Fund funds in most of the Article 5 Countries.

To assist the enterprises submit their feedback, the questionnaire was circulated in English, French, and Spanish, as appropriate; Appendix G provides copies of the questionnaire in English. Table 2 indicates the number of recipients of the questionnaire by country and Implementing Agency.

Table 2
Recipients of the Survey Questionnaire

Country	IBRD	UNDP	UNIDO	Total
Algeria	0	0	2	2
Brazil	2	20	1	23
Chile	1	0	0	1
China	17	19	0	36
Colombia	1	1	0	2
Dominican Republic	0	1	0	1
India	4	10	0	14
Indonesia	3	4	0	7
Iran	0	1	2	3
Jordan	1	0	0	1
Libya	0	1	0	1
Macedonia	0	0	1	1
Mexico	1	9	0	10
Morocco	0	2	0	2
Nigeria	0	3	0	3
Pakistan	2	0	0	2
Philippines	0	3	0	3
Syria	0	0	2	2
Thailand	4	7	0	11
Tunisia	2	0	0	2
Turkey	3	0	2	5
Venezuela	0	0	3	3
Total	41	81	13	135

Alternatives Technologies to the Use of CFCs in Rigid Foam

With the phasing out of CFCs, rigid foam producers needed to select an alternative blowing agent. They sought alternatives that met site-specific processing characteristics and the performance properties desired for the rigid foam. Two particular rigid foam performance characteristics ranked high among the priorities of the producers surveyed in this study: (1) thermal conductivity to ensure energy conservation, and (2) fire performance and fire resistance to met Underwriters Laboratories specifications.

Wakim reviewed the alternative technologies used for producing rigid foam in lieu of CFCs. The major alternative technologies used globally include hydrochlorofluorocarbons (HCFCs), pentanes—cyclopentane, n-pentane, and iso-pentane—carbon dioxide (CO_2), and hydrofluorocarbons (HFCs). Other emerging alternatives include HFC-245fa, HFC-365mfc, blends of HFCs and of HCFCs, methyl formate, 2-chloropropane, and others. In addition, physical foaming processes that do not require a chemical blowing agent, employing vacuum, etc., could be used; however, their applications are being identified thus far limited. We also compared the acceptability of liquid technologies vs. gaseous technologies. Table 3 provides a partial listing of the characteristics of selected blowing agents.

Table 3
Physical Properties of Typical Blowing Agents

Blowing Agent	ODP	K-factor Gas[a]		Boiling Point, °C
CFC-11	1.00	0.06		+ 24
HCFC-141b	0.11	0.066		+ 32
HCFC-22	0.05	0.073		– 41
HCF-142b	0.065	0.080		– 9
HFC-134a	0	0.095		– 27
HFC-245fa	0	0.085		+ 15
HFC-365mfc	0	0.074		+ 40
n-Pentane	0	0.104		+ 36
iso-Pentane	0	0.097		+ 28
Cyclopentane	0	0.083		+ 49
Carbon dioxide	0	0.113		– 78
[a]Btu-in./ft^2-hr per degree at 25°C				

The survey indicated that, in rigid foam applications, HCFC-141b is the main alternative for CFC-11, followed by pentanes. The use of water/CO_2 as a blowing agent, which is attractive because it has zero ODP potential, has not progressed significantly because of application problems in the field. With the impending phase-out of HCFC-141b, researchers are developing low-ODP—0.05–0.07, as compared with CFC-11 of

1—blowing agents for use as interim products until competitive HFCs become commercially available. The emerging low-ODP blowing agents include blends of HCFCs such as HCFC-22 and HCFC-142b and others. The HFCs include HFC-245fa and its blends, HFC-134a and its blends, and HFC-365mfc and its blends.

The use of pentanes is proven commercially and is used in several developed and Article 5 countries. However, pentanes and other hydrocarbons are flammable; thus major factory retrofits are required to ensure safe handling and to prevent fires that could result from hydrocarbon emissions during manufacturing. The high capital investments required for such factory retrofits make this option unattractive for small and medium size enterprises. Furthermore, the use of pentanes requires flame retardants to make the rigid foam comply with Underwriters Laboratories fire specifications. The high cost of the flame retardants negates part of pentanes' financial advantage over other blowing agents. To mitigate the high cost of the flame retardants, researchers are developing new fire-retardant formulations that meet the Underwriters Laboratories specifications without making the products uncompetitive.

Water-based systems are desirable because they represent an alternative with a zero ODP solution and entail minimal health and safety risks. However, water-blown foam systems result in manufacturing and use problems such as poor adhesion to substrates, poor flow patterns, increased foam friability, and questionable insulation values. Furthermore, these systems suffer from poor polyol storage stability because of hydrolysis. Consequently, the suppliers of these systems continue to conduct research to resolve these shortcomings so that the systems can become viable alternatives to CFCs and HCFCs as the latter are phased out in the near future.

Capital and Operating Costs for Rigid Foam Projects

In consultation with the Secretariat, Argentina, Egypt, and Malaysia were chosen as representative of Article 5 countries with enterprises receiving grants from the Multilateral Fund. Wakim's field visits in the three countries were designed to include enterprises that had selected the different commercially available CFC alternatives, and received approval for their projects in different years. Therefore, the case studies are representative of different global regions, different CFC alternatives, and different years for Implementing the projects.

To ensure that the short- and long-term economic consequences for enterprises converting to CFC alternatives were truly captured at the enterprise level, we used the values the enterprise reported for raw materials, energy, utilities, capital costs, labor costs, and other relevant expenses.

The large majority of the enterprises we surveyed use preblended systems. A small percentage purchases the preblended systems without the blowing agent and then adds the blowing agent separately. A still smaller percentage purchases components and blends the systems on site. Enterprises that use pentanes or other hydrocarbons always purchase the blowing agents separately and add them to the polyurethane systems on site—an approach that minimizes the risk of fire and explosion while the products are being shipped to the manufacturing site.

By using the local price in the country of the enterprise, we took into account changes—benefits or losses—in the costs of raw materials arising from the use of preblended systems. In addition, having to blend one or more components on site requires capital equipment and therefore added capital cost. In such cases, we captured the effect of the increased capital cost on the total cost of production of the rigid foam. This approach was necessary, particularly for projects for which the Multilateral Fund did not pay the total cost of equipment needed for the conversion.

In conducting the cost-benefit analyses, we assumed a plant life of 4 years (short term) and 10 years (long term). Accordingly, in estimating depreciation, we used a straight-line approach coinciding with the life of the plant; namely, 4 or 10 years. Various enterprises, in response to questions in the survey, estimated that the life of the foam dispensers varied from 5 to 10 years. Therefore, scenarios that assume a plant life of 4 years or 10 years are quite close to the real-life situation experienced by the enterprises we surveyed.

In estimating the NPV of the economic benefits or losses realized by the enterprise from conversion to CFC alternatives, we used two scenarios for the annual discount rate—8% and 12%, respectively.

The methodology we used to calculate the IOC is similar to that described in the Multilateral Fund policies. We calculated IOC by subtracting the cost of chemicals required to manufacture the products produced with CFC technology from the cost of chemicals required to manufacture the same amount of products with CFC alternative technology. The difference—gain or loss—was used as the basis for the number of years allowed in estimating the NPV of the compensation. In practically all of the rigid foam projects covered in this study, an Implementing Agency representative assisted the enterprise prepare the project document that was submitted for approval to the Executive Committee.

Case Studies

This section presents selected case studies for enterprises in Argentina and Malaysia that illustrate the short- and long-term economic consequences for enterprises that have converted to CFC alternatives in rigid foam. The selected enterprises represent small (consuming 0–19 t/yr of CFC-11), medium (consuming 20–49 t/yr), and large (consuming 50 t/yr or more). Therefore, the selected enterprises can be used to illustrate the effect of economies of scale on the funding for the projects.

The case studies are of projects approved from 1993 to 1999, the period in which the Multilateral Fund approved about 88% of the projects. Therefore, the selected projects represent the large majority of approved projects. Furthermore, the time span is sufficiently long to illustrate changes in the interpretation of the Multilateral Fund's policies over time.

We also attempted to select cases from projects implemented by all the Implementing Agencies. However, we were able to find sufficient details only for projects implemented by UNDP and UNIDO.

Detailed analysis of the economic impact on the enterprises of the conversion to CFC alternatives is presented in Appendix C (Tables C 1 through C 9) and Appendix D (Tables D 1 through D 9).

Case C 1. FMCP

Case C 1 is for a project of the Government of Malaysia prepared in March 1999 with assistance from UNDP and presented to the twenty-eighth meeting of the Executive Committee.

FMCP is a small enterprise, with 20 full time employees and annual sales of US$1.6 million in 1998; it produced about 103 t/yr of rigid insulation foam and consumed about 13.3 t/yr of CFC-11 from 1996 through 1998. FMCP compared its operation while using CFC-11, with the alternatives cyclopentane, HCFC-141b, and water/CO_2. FMCP's selected HCFC-141b as an alternative to CFC-11 for the following reasons:

- Although recognizing the environmental benefits of cyclopentane, FMCP selected HCFC-141b because it produces foams with better insulation value and requires a significantly lower capital investment.
- Commercially available systems used to produce water-blown foams did not meet FMCP's requirements for insulation value and energy efficiency for cold room applications.

In collaboration with the Department of the Environment in Malaysia and FMCP, the UNDP representative compared the capital costs and IOC. Table C 1 summarizes the comparative capital costs, and Table C 4 indicates the IOC.

The data indicate that the capital cost needed to convert from CFC-11 to HCFC-141b was US$78,100; the capital cost needed to convert to cyclopentane was US$507,100. By 1999, the Multilateral Fund policy had established a cost-effectiveness threshold of US$7.83/kg/yr of CFC-11 phased out. Therefore, FMCP would have been entitled to a total compensation—for incremental capital and operating costs—of US$95,526 from the Multilateral Fund for phasing out 12.2 t/yr of CFC-11. (HCFC-141b has an ODP of 0.1 of CFC-11; therefore, conversion to HCFC-141b results in 90% reduction in the ODP of CFC-11.) Essentially, at the cost-effectiveness threshold established in the policy, an enterprise needs to phase out at least 65 t/yr of CFC-11 to cover the required capital investment.

Subtracting the US$78,100 capital cost from the US$95,526 total allowable grant leaves only US$17,426 to cover any increase in IOC.

It unlikely that the Multilateral Fund would want to encourage enterprises to select CFC alternatives that require capital investments that are not commercially viable. This leads to the conclusion that enterprises phasing out less than 65 t/yr of CFC-11 need to conduct a thorough economic cost-benefit analysis before they decide to use cyclopentane—or another flammable hydrocarbon—as an alternative to CFCs.

Table C 4 compares the IOC when HCFC-141b or cyclopentane is used as an alternative to CFC-11. The data indicate that FMCP's annual IOC increased by US$22,472 and by US$5,785 when using HCFC-141b and cyclopentane, respectively.

The analysis indicates that the operating costs, with both HCFC-141b and cyclopentane, were higher than those with CFC-11 in Malaysia when FMCP made its decision. Therefore, FMCP could not realize any savings from using either CFC alternative to recover the depreciation of the capital investment; not to mention realizing any return on the investment.

FMCP selected HCFC-141b as an interim alternative to CFC-11, leading to an increase in IOC of US$22,472. Therefore, the US$17,426 left to cover the increase in incremental operating cost was enough to cover the increase for 9.4 months only. FMCP will convert to a zero ODP alternative, probably an HFC, when commercially acceptable products become available in Malaysia.

Table C 7 presents the analysis of the short- and long-term economic impact of the conversion to CFC alternatives on FMCP: The cost-benefit analysis of converting to HCFC-141b, assuming a plant life of 4 or 10 years and using discount rates of 8% or 12%, indicates that FMCP will incur additional expense. The NPV of the increased IOC at an 8% discount rate is about US$79,000 for a plant life of 4 years and about US$159,000 for a plant life of 10 years. The NPV of the increased IOC at 12% is about US$75,000 for a plant life of 4 years and US$135,000 for a plant life of 10 years.

A similar analysis indicates that the NPV of the increased IOC, for converting to cyclopentane, at a discount rate of 8% is about US$21,000 for a plant life of 4 years and about US$41,000 for a plant life of 10 years. The NPV of the increased IOC at 12% is about US$19,000 for a plant life of 4 years and US$35,000 for a plant life of 10 years.

Case C 2. Pangkat Refrigeration Industries

Case C 2 is for a project of the Government of Malaysia that was prepared in March 1994 with assistance from UNDP/UNOPS and that was approved in July 1994. Pangkat Refrigeration Industries (Pangkat) is a medium enterprise that was expected to consume about 20 tons of CFC-11 in 1994. Pangkat considered pentanes, HFC-134a, HCFC-141b, and a combination of HCFC-141b and water as CFC alternatives. The consultant that helped in the project preparation felt that plant and employee safety would be compromised if pentane were selected. HFC-134a was too expensive. Therefore, Pangkat selected HCFC-141b in combination with water as an interim alternative to CFC-11. Pangkat will convert to a zero ODP alternative, probably an HFC, when commercially acceptable products become available in Malaysia.

The capital costs and IOC were performed by the UNDP representative in collaboration with Pangkat and the Department of the Environment in Malaysia. Table C 5 provides a summary of the capital costs, and Table C 2 summarizes the incremental operating cost.

The data indicate that the capital cost needed for the conversion was US$225,100 (Table C 2). The annual increase in IOC was about US$15,000 (Table C 5).

Table C 8 presents the analysis of the short- and long-term economic impact of the conversion to CFC alternatives on Pangkat: The cost-benefit analysis for converting to HCFC-141b/water, assuming a plant life of 4 or 10 years using discount rates of 8% or 12%, indicates that Pangkat will incur additional expense. The NPV of the increased IOC at an 8% discount rate is about US$53,000 for a plant life of 4 years and about US$106,000 for a plant life of 10 years. The NPV of the increased IOC at 12% is about US$50,000 for a plant life of 4 years and US$90,000 for a plant life of 10 years.

On completion of the project, Pangkat received a grant for US$201,514 to cover capital and IOC costs. The actual cost of the equipment and trials was US$191,855.

Case C 3. Cycle World

Case C 3 is for a project of the Government of Malaysia that was prepared in December 1993 with assistance from UNDP/UNOPS and was approved in March 1994. Cycle World is a medium enterprise that consumed 45 tons of CFC-11 in 1993. Cycle World considered cyclopentane, HFC-134a, HCFC-141b, and a combination of HCFC-141b and water as CFC alternatives. The plant owners felt that plant and employee safety would be compromised if cyclopentane was selected. HFC-134a was too expensive. Therefore, Cycle World selected HCFC-141b in combination with water as an interim alternative to CFC-11. Cycle World will convert to a zero ODP alternative, probably an HFC, when commercially acceptable products become available in Malaysia.

The capital costs and IOC were performed by the UNDP/UNOPS representative in collaboration with Cycle World and the Department of the Environment in Malaysia. Table C 3 provides a summary of the capital costs, and the incremental operating cost are set forth in Table C 6.

The data indicate that the capital cost needed for the conversion was US$233,000 (Table C 3). The annual increase in IOC was about US$37,300 (Table C 6).

Table C 9 presents the analysis of the short- and long-term economic impact of the conversion to CFC alternatives on Cycle World: The cost-benefit analysis for converting to HCFC-141b/water, assuming a plant life of 4 or 10 years using discount rates of 8% or 12%, indicates that Cycle World will incur additional expense. The NPV of the increased IOC at a 8% discount rate is about US$132,000 for a plant life of 4 years, and about US$263,000 for a plant life of 10 years. The NPV of the increased IOC at 12% is about US$124,000 for a plant life of 4 years and US$224,000 for a plant life of 10 years.

On completion of the project, Cycle World received a grant for US$351,979 to cover capital and IOC costs. The grant covered the capital cost of the conversion, plus the NPV for 4 years of ICC.

Case D 1. Polwer

Case D 1 is for a project of the Government of Argentina that was prepared in April 1999 with assistance from UNIDO and was approved at the twenty-eighth meeting of the Executive Committee. Polwer is a medium size enterprise with 14 full-time employees and an average consumption of 30.2 t/yr of CFC-11 from 1996 through 1998. Polwer was aware that cyclopentane, HCFC-141b, a combination of HCFC-141b and water, and CO_2 are potential CFC alternatives. Polwer selected HCFC-141b in combination with water, as an interim alternative to CFC-11. Polwer will convert to a zero ODP alternative, probably an HFC, when commercially acceptable products become available in Argentina.

The capital costs and IOC were performed by the UNIDO representative in collaboration with Polwer and the Department of the Environment in Argentina. Table D 1 provides a summary of the capital costs, and Table D 4 indicates the IOC.

The data indicate that the capital cost needed for the conversion was US$53,500 (Table D 1). The annual increase in IOC was about US$33,217 (Table D 4).

Table D 7 presents an analysis of the short- and long-term economic impact of the conversion to CFC alternatives on Polwer: The cost-benefit analysis of converting to HCFC-141b/water, assuming a plant life of 4 or 10 years using discount rates of 8% or 12%, indicates that Polwer will incur additional expense. The NPV of the increased IOC at 8% discount rate is about US$118,000 for a plant life of 4 years and about US$235,000 for a plant life of 10 years. The NPV of increased IOC at 12% is about US$111,000 for a plant life of 4 years and US$200,000 for a plant life of 10 years.

Case D 2. Calofrig Asilaciones Jacobi

Case D 2 is for a project of the Government of Argentina that was prepared in February 1997 with assistance from UNDP and approved in 1997. Calofrig Asilaciones Jacobi (Calofrig) is a large enterprise that consumed 72 tons of CFC-11 in 1996. Calofrig considered cyclopentane, HCFC-141b, and CO_2; it decided to convert to cyclopentane with zero ODP rather than adopting an interim solution.

The capital costs and IOC were performed by the UNDP representative in collaboration with Calofrig and the Department of the Environment in Argentina. Table D 2 summarizes the capital costs, with the IOC set forth in Table D 5.

The data indicate that the capital cost needed for the conversion was US$759,000 (Table D 2), and that the IOC declined by a nominal US$1,004 (Table D 5). To estimate the IOC with cyclopentane, Calofrig used foam production of 469,862 kg/yr of foam instead of the 484,262 kg/yr produced while using CFC-11. (Typically, we would expect that foam production would increase to compensate for changes in foam density and thermal insulation capability. However, we accepted the data presented by the enterprise at face value.)

Table D 8 presents the analysis of the short- and long-term economic impact of the conversion to CFC alternatives on Calofrig: The IOC of Calofrig will decrease as a result of the conversion to pentanes. The cost-benefit analysis, assuming a plant life of 4 or 10 years using discount rates of 8% or 12%, indicates that Calofrig will realize some savings. The NPV of the savings in IOC at an 8% discount rate is about US$4,000 for a plant life of 4 years, and about US$7,000 for a plant life of 10 years. The NPV of increased IOC at 12% is about US$3,000 for a plant life of 4 years and US$6,000 for a plant life of 10 years.

By 1997, the Multilateral Fund had established a cost-effectiveness ceiling of US$7.83/kg/yr of CFC-11 phased out. Therefore, Calofrig was asked to reduce its request for assistance from the US$759,000 estimated with the help of the UNDP representative to US$563,750 to stay within the allowed budget for the grant.

Case D 3. Obras de Ingenieria

Case D 3 is for a project of the Government of Argentina that was prepared in September 1998 with assistance from UNDP and approved by the Executive Committee. Obras de Ingenieria (Obras) is a small enterprise that consumed 18.5 tons of CFC-11 in 1998. Obras was aware that cyclopentane, HCFC-141b, a combination of HCFC-141b and water, and CO_2 are potential CFC alternatives. Relying on the recommendation of the UNDP representative and the endorsement of the Government of Argentina, Obras selected HCFC-141b as an interim alternative to CFC-11. Obras will convert to a zero ODP alternative, probably an HFC, when commercially acceptable products become available in Argentina.

The capital costs and IOC calculations were performed by the UNDP representative in collaboration with Obras and the Department of the Environment in Argentina. Table D 3 presents a summary of the capital costs, with the IOC set forth in Table D 6.

The data indicate that the capital cost needed for the conversion was US$75,000 (Table D 3). The annual increase in IOC was about US$24,000 (Table D 6). The supplier indicated that the prices of the polyol and MDI that will be used with HCFC-141b will be the same as those used with CFC-11. Furthermore, the new formulation contains the same amount of HCFC-141b as the old one did of CFC-11, and both formulations produce foam with the same density. Therefore, the only price difference arises from the difference in price between HCFC-141b and CFC-11.

Table D 9 sets forth the analysis of the short- and long-term economic impact of the conversion to CFC alternatives on Obras: The cost-benefit analysis of converting to HCFC-141b, assuming a plant life of 4 or 10 years using discount rates of 8% or 12%, indicates that Obras will incur additional expense. The NPV of the increased IOC at 8% discount rate is about US$85,000 for a plant life of 4 years and about US$169,000 for a plant life of 10 years. The NPV of increased IOC at 12% is about US$80,000 for a plant life of 4 years and US$143,000 for a plant life of 10 years.

Terms of reference for a study on alternatives to CFCs in rigid foam applications

The Executive Committee of the Multilateral Fund wishes to undertake a study to examine the economic aspects of conversion from CFCs in the rigid foam subsector. The purpose of the study is to provide transparency and comprehensive information on:

- The factors leading to the choice of alternative technologies in Article 5 countries at the producing enterprise level. Factors to be considered are, inter alia cost, availability of alternatives, the interim or final nature of the alternative, effects of local safety regulations or concerns, availability of Fund assistance, etc.;

- The short-term and long-term economic consequences for firms converting to various alternatives to CFCs.

The objective of the study is to provide to firms in Article 5 countries a greater understanding of the economic impacts of conversion to various alternatives. The Executive Committee should gain a clearer picture of how Fund policies may influence the choice of alternatives.

The following key factors shall be considered in the study:

- The study should cover the full range of alternative technologies to CFCs in the rigid foam sector, i.e. hydrocarbons, water, CO2, HCFCs, HFCs, etc.;

- The study should examine the relevant funding rules of the Multilateral Fund and analyse the impacts on the choice of alternatives and (future) implications for the Multilateral Fund. As a starting point it should consider projects funded to date, their choices of technologies and all completion reports available on those projects;

- The study should carry out an analysis of capital costs associated with the foam projects. This would include the equipment directly needed to make the transitions to the technologies investigated, and the changes necessary to make certain transitions. It should also consider the useful life of foaming and other related equipment that will need to be procured to enable the conversion from CFCs;

- The study should examine the operational cost or benefit associated with the use of the alternative technology selected. Related costs should also include costs for changes in the starting material and additives taking into account the prevalent use of premixed systems and costs for performing changes of the properties of the product (for example density, R-factor, etc.). The focus should be on estimating total operational cost, as well as any costs that may be incurred by the firm that are not compensable under Fund rules. The latter may include costs for relevant country firms that face project costs exceeding the Fund's cost-effectiveness thresholds, project term cost or benefit (beyond the compensable 2 years) of providing the alternative chemical at a level needed to sustain current output, and costs of secondary conversions from HCFCs considering factors related to the timing of compliance with the Montreal Protocol's HCFC provisions, as well as factors related to the useful life, usability, or retrofit potential for the use of current equipment, cost of conversion and evolving market acceptability issues;

- In order to enable enterprises to clearly understand short-term and long-term economic implications they may be facing, the study should make assumptions regarding the cost of CFCs and the various alternatives. With regard to alternatives under advanced development but not currently commercially available, the study should make a range of reasonable assumptions on the basis of probable scenarios ahead. The study should also consider the added cost/benefit of conversion using each of the various technologies. In that regard, it should assume a 4-, 10- and 15-year project lifetime;

- While, to the extent found relevant, the above factors should be considered, they are not meant to be overly limiting. In developing a consistent evaluative methodology, the consultant should contact purveyors of the different technological options. In the conduct of the study, efforts should also be made to utilize local expertise gained in Article 5 countries by the implementing agencies;

- The total cost (both capital and operational) associated with using different alternatives should be presented in terms of net present value using at least two assumptions for a discount rate;

- The study should contain case studies as well as (a) table(s) providing information relevant to different foam applications, alternatives, size of firms and economies of scale (measured by current use of tons of CFCs). Representative samples should be considered from the point of view of the end users. In that regard, total net-present-value costs of using the different options for the different project lifetimes for firms of different sizes should be presented.

The Secretariat of the Multilateral Fund shall contract for the services of a qualified independent consultant experienced in conducting economic evaluations at the enterprise level and familiar with conversions to related technologies to carry out the study.

If possible, the Executive Committee believes it would be desirable to have at least a summary of findings delivered to the Executive Committee at its 32nd meeting.

Alternatives to CFCs in Rigid Foam Applications

1. Background Information

Date:

Company

Ownership

Name and Title of respondent

Address

Address

Country Project No.

Telephone numbers: Voice: Fax:

eMail Address

National Coordinating Agency Implementing Agency

2. Production Facility

	Boardstock	Spray	Appliances	Laminated/Sandwich Panels		
Rigid Foam Type						

3. Dates of Events Leading to Replacement of Ozone Depleting Substances at Your Plant

	Month	Year
Project Preparation Date		
Approval Date		
Conversion Date		

4. Alternative Technologies Available for Replacing Ozone Depleting Substances at Your Plant

Blowing Agent	Available to You	Selected by You	Approved by MLF	Adopted During Conversion
Cyclopentane				
n-Pentane/iso-Pentane				
Water/CO2				
HCFC-141b				
HFC-134a				
Others				

5. List the Factors that Influenced Your Selection in Question 4 in order of Decreasing Importance

6. Were You Aware that HCFC's Were Contolled Substances That Will be Phased Out When you made Your Selection of an Alternative?

7. Were You Aware that Low Pressure Foam Dispensers Could be Retrofitted for Use With HCFC-141b?

8. List the Organizations that Assisted You in Making Your Selection in Question 4

National Coordinating Agencies

Alternatives to CFCs in Rigid Foam Applications

Implementing Agencies ______
Equipment Suppliers ______
Chemical Suppliers ______
Consulting Firms ______
Others ______

9. List the Multilateral Fund Policies that Influenced Your Selection in Question 4

______

10. If You Listed any Multilateral Fund Policies in Question 9, Describe How the Policies Influenced Your Selection in Question 4

______

11. Incremental Capital Costs for Conversion to CFC Alternatives

	No. of Units	Cost/Unit	Total Cost
CONVERSION COST	1,000 $	1,000 $	1,000 $
Foam Dispensers			
Blending Equip.			
Storage Tanks			
Retrofit Costs			
Metering Systems			
Technology Transfer/Training			
Commissioning/Start-up Trials			
Other			
TOTAL	-		
Company Funds	-		
MLF Funds	-		

12. Based on Your Experience, What is a Typical Operating Life for a Low Pressure Foam Dispenser?

______

13. Based on Your Experience, What is a Typical Operating Life for a High Pressure Foam Dispenser?

______

14. Incremental Operating Costs for Conversion to CFC Alternatives

Kilograms Raw Materials Consumed per Year

	Conversion - 3 Year	C - 2 Year	C - 1 Year	Conversion Year	C + 1 Year	C + 2 Year	C + 3 Year
Example	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**

Alternatives to CFCs
in Rigid Foam Applications

CFC-11							
HCFC 141b							
Cyclopentane							
n-Pentane							
Iso-Pentane							
Water/CO2							
HFC-134a							
Other							
A-Side							
MDI							
B-Side							
Polyol							
Other							
Total							

Average Price of Raw Materials, $/ Kg

	Conversion - 3 Year	C - 2 Year	C - 1 Year	Conversion Year	C + 1 Year	C + 2 Year	C + 3 Year
CFC-11							
HCFC 141b							
Cyclopentane							
n-Pentane							
Iso-Pentane							
Water/CO2							
HFC-134a							
Other							
A-Side							
MDI							
B-Side							
Polyol							
Other							

15. Foam Characteristics Before and After Conversion to CFC Alternatives

Foam Characteristic		CFC-11 Agent	Interim Agent	Final Agent
Density, Kg/M3				
K-Factor				
Other				