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RETROFIT OF COMMERCIAL REFRIGERATION EQUIPMENT

1. At the Twenty-fifth Meeting, the Executive Committee had on its agenda a paper on the retrofit of commercial refrigeration equipment (UNEP/OzL.Pro/ExCom/25/58). The Committee decided to defer consideration of the paper to the Twenty-sixth Meeting (Decision 25/51).

2. The paper 'Commercial Refrigeration End-User Conversion' is reproduced as Annex I.

ANNEX I

COMMERCIAL REFRIGERATION END-USER CONVERSION

Background

1. At its 21st Meeting, the Executive Committee decided 'to request the World Bank, in conjunction with the Fund Secretariat, to prepare draft guidelines for the consideration of the Executive Committee at its Twenty-second Meeting.' (Decision 21/23 (b)). At the 22nd Meeting, the Executive Committee decided to take note, *inter alia*, of the following policy issues forwarded to it by the Sub-Committee on Project Review: guidelines for retrofitting projects in the commercial refrigeration sub-sector. (Decision 22/9 (b)).

2. The Sub-Committee on Project Review considered an Executive Summary of the Draft Guidelines at its 11th Meeting (Montreal, 18-19 September 1997).[1]

3. The Sub-Committee requested the World Bank to revise the guidelines in the light of the comments made by members of the Sub-Committee and to submit it, through the Secretariat, for the consideration of the Executive Committee at its Twenty-third Meeting, on the understanding that a more complete examination of the sector by the Secretariat, in cooperation with the implementing agencies covering, *inter alia*, projects for users with an installed capacity of less than 10 tonnes, should be prepared, with the objective of a document being available for the Executive Committee at its Twenty-fourth meeting. The further work would take into account a report being prepared on the Mexican experience in this subsector, which would be completed by the end of 1997.

4. The Sub-Committee *inter alia* expressed a view that consideration should be given to associated policy issues to ensure that users did not revert to using ODS after the conversion of their equipment, especially where such substances were still cheap and/or where enforcement capacities are lacking. The Sub-Committee also requested that the information obtained during the development of refrigerant management plans be used to analyze the commercial refrigeration sector per se.

Commercial Refrigeration Sub-Sector

5. The commercial refrigeration sub-sector consists of compressor and commercial refrigerator manufacturers, end users of the equipment and service shops. This paper is concerned with conversion and CFC phase-out by the end-users.

6. The commercial refrigeration sub-sector in Article-5 countries is predominantly associated with the preservation and distribution of food (the food chain). The enterprises involved range form small food stores using display cabinets or freezers containing less than a kilogram of refrigerant to large supermarket chains and industrial cold-storage facilities for food processing

[1] The report of the Sub-Committee's deliberations is contained in UNEP/OzL.Pro/ExCom/23/10.

with complex refrigeration systems containing several tens of tonnes of refrigerant. Compressor sizes range from fractional horsepower (similar in size to those in domestic refrigerators) up to 100 horsepower. The expected useful life of the smaller refrigeration system compressors is generally less than fifteen years while larger units may last form 15 - 25 years.

7. The equipment used in commercial refrigeration can be grouped under the following two broad categories:

(a) Central systems, where the compressors are located in a machinery room separated form the cooling system. These systems are used generally in medium to large retailing applications, in cold rooms usually associated with food processing, or for industrial refrigeration.

(b) Non-central systems, which may be subdivided into two types:

(i) "Separated systems" where the compressor and the condenser are separated from the refrigerated cabinet. This type of system is typically used for food and beverage conservation. The equipment is usually installed by a contractor who may be involved in both manufacture and servicing and who may construct or assemble from a few hundred up to several thousand units per year.

(ii) Unitary equipment where the cooling system is incorporated within the equipment, including compressor and condenser. Such integral equipment is charged with refrigerant in the factory during manufacture. These are the smallest types of equipment and are frequently of similar construction to domestic refrigerators and freezers.

ODS Consumption and Sub-Sector Profile

8. Based on the 1994 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee[2], estimated quantities of CFC-12 and R-502[3] (a blend of HCFC-22 and CFC-115) installed in commercial refrigeration systems in Article 5 countries in 1994 were approximately 16,100 MT and 13,100 MT, respectively. The total installed capacity is therefore equal to 29,200 MT or 19,800 ODP tonnes (with an estimate of 16,600 ODP tonnes in central and remote refrigeration systems and 3,200 ODP tonnes in unitary equipment).

9. Most large volume CFC consuming countries have a diversified commercial refrigeration sector comprised of a commercial refrigeration equipment manufacturing industry, large supermarkets and cold-stores and numerous small end-users and servicing shops frequently in the

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[2] UNEP Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee, *1994 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee*, 1995.

[3] 48.8% of HCFC-22 and 51.2% of CFC-115, with an ODP value of 0.283.

informal sector. The small end-users mostly use unitary systems equipped with hermetic compressors which are less prone to leaks.

10. In low volume ODS consuming countries (LVCs), the major source of ODS consumption is in refrigeration servicing, especially in servicing commercial refrigeration equipment. The largest number of commercial refrigerators are unitary systems, however, the largest CFC inventory is found in central systems.

ODS Emissions

11. Commercial refrigeration systems typically have much higher leakage rates than other refrigeration systems. Annual loss ranging from 20 percent of system capacity under very good circumstances to over 100 percent of the charge is experienced in centralized commercial refrigeration systems. A typical figure often used for estimation purposes is 50 percent loss per annum. In many Article 5 countries, commercial refrigeration servicing is often carried out in the informal sector. Even under more organized circumstances, the quality of service technician training can be non-existent to poor. Venting refrigerant to the atmosphere and using refrigerant for washing and flushing is common.

12. With an average leakage rate of 50%, the total demand for CFC-12 and R-502 refrigerant in Article 5 countries may be approximately 8,300 ODP tonnes per annum[4] (not including consumption in unitary systems). -This highlights the importance of having refrigerant management plans as well as implementation of such plans in order to assist in managing the changes which will occur eventually as a result of the Montreal Protocol controls.

Current Policies of the Parties and the Executive Committee

13. The Fourth Meeting of the Parties urged all the Parties to take all practicable measures to prevent releases of controlled substances into the atmosphere, (UNEP/OzL.Pro/4/15, Decision IV/24, para. 4) including, *inter alia*:

(a) to recover controlled substances in Annex A, Annex B and Annex C of the Protocol, for purposes of recycling, reclamation or destruction, that are contained in the following equipment during servicing and maintenance as well as prior to equipment dismantling or disposal:

  (i) stationery commercial and industrial refrigeration and air-conditioning equipment;
  (ii) mobile refrigeration and mobile air-conditioning equipment;
  (iii) fire protection systems;
  (iv) cleaning machinery containing solvents;

[4] Through analysis of a selection of country programmes, it indicates that CFC consumption in this sector could be as high as 26,000 MT.

(b) to minimize refrigerant leakage from commercial and industrial air-conditioning and refrigeration systems during manufacture, installation, operation and servicing;

(c) to destroy unneeded ozone depleting substances where economically feasible and environmentally appropriate to do so.

14. At its Thirteenth Meeting, the Executive Committee recommended that countries should be given appropriate advice and training so they could appreciate the implications of a phaseout of ODS in that sector (retrofitting of refrigeration equipment) (UNEP/OzL.Pro/ExCom/13/47, para 102).

15. The Fourteenth Meeting of the Executive Committee approved a project for retrofitting existing CFC-based commercial refrigeration equipment in the fishing industry in Mauritania, since this industry is vital to the economy of the country. The Committee also decided that projects for the conversion of commercial refrigeration units in Article 5 countries should be assessed on a case-by-case basis taking into consideration the importance of the commercial refrigeration subsector in the economy of the country. Projects which are clearly cost-effective should be considered in their own right (UNEP/OzL.Pro/ExCom/14/15, para 47).

16. The Eighteenth Meeting of the Executive Committee decided to consider the provision of recovery/recycling equipment to commercial refrigeration companies in projects related to servicing and recovery/recycling in the refrigeration sector in the future (UNEP/OzL.Pro/ExCom/18/75, Annex V, para 8).

17. The Twenty-third Executive Committee Meeting approved Guidelines for the Preparation of Refrigerant Management Plans (RMPs) with the understanding that the overall objective of an RMP is to develop and plan a strategy that will manage the use and phase out of refrigerants for servicing refrigeration and air-conditioning equipment in an Article 5 country.

Priority and Timing of Projects

Montreal Protocol Control Measures

18. CFC consumption in the commercial refrigeration end-user subsector constitutes the largest share of the remaining ODS consumption in the refrigeration sector in many Article 5 countries. Commercial refrigeration end-user conversion projects would likely be a contributing element in assisting both LVCs and larger ODS consuming countries meeting the 2005 target of 50% CFC consumption reduction and subsequent obligations.

19. The 1996 TEAP report pointed out that investment projects can address from 30 to 60 percent of the ODS consumption to be phased-out in a given country. If a project addresses consumption beyond the level of 30 percent, it is likely to be dealing with servicing and other operations undertaken by small and medium-sized enterprises (SMEs). As of March 1998,

several Article 5 countries have already received funding from the Multilateral Fund to phase out more than 30 percent of the base-year consumption in the refrigeration sector, and current CFC consumption in several countries has already reduced by more than 30 percent compared to their peak CFC consumption in the past year.

Sustainability of Commercial Refrigeration End-User Conversion projects

20. The retrofitting of end-users' refrigeration equipment in developed countries is well established and successful primarily because of the scarcity and high cost of CFCs which substantially exceed the cost of alternatives and because improved maintenance practices have reduced the loss of the new, more costly refrigerant.

21. Several countries have already received support for recovery and recycling activities. However, the viability of the recovery and recycling schemes depends largely on the amount of recovered refrigerant and the price differential, if any, between new and reclaimed refrigerant. In most developed countries, such schemes are only becoming financially as end-users are converting their systems on a wider scale. To date, only one retrofit project from low-volume consuming Article 5 countries was approved.

22. In developed countries leakage rates of 20 to 30 percent are being experienced, through improved system construction and maintenance, in response to the higher costs of CFCs and replacement refrigerants. Leakage rates of 50 percent experienced in Article 5 countries could be reduced by similar measures over time. However, availability of cheap CFCs in sufficient quantities constitutes a substantial disincentive to develop better emission control standards and to convert to more expensive non-ODS refrigerants.

23. Whatever initial reductions in CFC use are achieved through better system maintenance, the remaining CFC consumption can only be phased out through changing the refrigerant, which may require some retrofitting or replacement of equipment. Training will be important as technologies for retrofitting refrigeration systems are varied and failure to use the correct methodologies can result in equipment failure.

24. A number of Article 5 countries have indicated an intention to phase-out ODS in advance of the Montreal Protocol schedule. Therefore, it might be necessary for such Article 5 countries to develop national refrigeration management plans including the following elements: (i) implementation of emission control programmes; (ii) increased utilization of recovery, reclamation and recycling practice during servicing of CFC-based equipment; (iii) retrofitting existing equipment; and (iv) replacement of existing equipment with zero or low ODP equipment. It might also be necessary for such countries to develop and enforce controls on imports and/or consumption. Experience in Article 2 countries, some of which have been in a position to devote substantial resources to the task, has indicated that enforcement of restrictions on CFC imports has been problematical unless the basic demand is reduced or removed.

25. However, in the future, especially after phase-out activities have commenced in the production sector, there could be rapid changes in the availability of CFC refrigerants. There will be a need to ensure that measures can be taken quickly at that time to respond to those changes, including through the implementation of end user conversion projects . A preconditon will be the availability of the necessary technical information and expertise in maintaining both existing CFC systems and in non-CFC technologies.

26. Active government action through consultative discussions with the industry and public, voluntary agreements between the industry and government, and regulatory measures have resulted in early phaseout of ODS consumption in several manufacturing sectors in some Article 5 countries. Overseas market demand for exports and to some extent local demand for non-ODS or environmentally friendly products has been a contributing factor. These measures could also have an impact on end-user conversions, but are likely to be less significant as exports are not a factor.

27. Based on the above experience, it could be concluded that sustainability of commercial refrigeration end-user conversion projects would depend on the following factors:

(a) price of CFCs and their availability compared to their alternatives;
(b) the ability to enforce regulatory measures on imports either existing or to be implemented in countries concerned;
(c) to a lesser extent, the marketing benefits for enterprises arising from being seen as environmentally friendly (if the costs involved are not excessive).

Commercially Available Technical Options

28. In addition to emission control measures (repairing leaks), and use of recovery, reclamation, and recycling practices during servicing, the replacement of refrigerant either through equipment retrofit or equipment replacement is needed to phase-out the use of CFCs.

Equipment Replacement

29. This option involves replacement of the refrigeration system (including the compressor) with new components which are designed for HFC-134a or HFC-based blends (e.g. R-404A, R-407C, R-410 and R-507). Hydrocarbon and ammonia are also considered as potential candidates for large centralized refrigeration systems. They are far more expensive.

30. This option will usually be selected when existing equipment is in poor condition or nearing the end of its useful life. In such cases, the Executive Committee guidelines for technological upgrade should be applied accordingly. Therefore, the eligible amount for funding from the Multilateral Fund would be very small.

Equipment Retrofit

31. The options available are:

- retrofit existing equipment to HFC-134a or an HFC-based blend (R-404A);
- retrofit existing equipment to a low ODP HCFC-based refrigerant blends such as R-408A or R-401A (MP 39) with an ODP of 0.037;

32. Retrofits to hydrocarbon refrigerant have reportedly been undertaken in Cuba and several African nations. This has been mainly in domestic refrigeration. No major equipment supplier has as yet authorized hydrocarbon retrofits for existing CFC or HCFC equipment. Retrofitting to hydrocarbons in circumstances where equipment leakage rates may be 20 - 50% is unacceptable on safety grounds.

Estimated Cost Effectiveness of CFC Reduction Measures

33. The only example analysed to date to illustrate possible cost effectiveness figures for end-user conversions is the three projects undertaken in Mexico by the World Bank. The Gigante project is one of the three implemented by the Bank under a US $4 million line-of-grant approved by the Executive Committee for Mexico at its Fifth Meeting in 1991. At that time, relevant guidelines and policies (e.g. eligibility criteria) for this sector were not yet established. This individual project was not reviewed by the Secretariat or considered by the Executive Committee.

34. The enterprise concerned is Gigante, a large supermarket chain with over 200 stores, 53 of which are in the Mexico City division. The total installed capacity of refrigerant in the stores in the Mexico City division exceeds 33 ODP tonnes. The options exercised to phase out this consumption were (i) emission control; (ii) retrofit with service blends (HCFCs); and (iii) compressor replacement. The results of the conversion are described fully in Annex I.

35. The Mexican experience reveals cost-effectiveness per kg of ODS phaseout ranging from US$ 50/kg - US$ 165/kg, compared with a US$ 35/kg - US$ 85/kg range being reported in developed countries.

36. It can be seen that the cost of repairing leaks is high compared to the saving in ODS consumption. A key issue in considering these costs will be whether they are fully eligible as incremental costs or whether they constitute an improvement in the baseline condition of the enterprise. This issue will have to be considered in the development of the guidelines. Given the additional cost of the refrigerant blends, leak reduction is a cost effective expenditure for the enterprise and part of its costs may be essential in practice for economic reasons.

Implications for the Multilateral Fund

37. Using the consumption figures reported by TEAP for the commercial refrigeration end-user sub-sector in Article 5 countries (i.e., 16,600 ODP tonnes in central plants and 3,200 ODP tonnes in unitary equipment), the total cost of phase-out for end-users, based on the cost-effectiveness of the range of options in the Mexican project, would be about US $830 million to US $2.74 billion, with a cost of around US $1 billion for the mix of options actually used in the project. However, the range of US $581 million to US $1.4 billion would be the total cost of phase-out if the reported cost range for developed countries is used. It should be noted that the total costs may be greater than the compensation eligible under the Executive Committee's rules and policies for the calculation of incremental costs.

38. The World Bank's Ozone Operation Resource Group recognizing the relative lack of technical and cost information on end-user conversions, is planning to study this matter further as soon as technical and cost information is available to it.

Conclusions

39. The Executive Committee may wish to give a guidance on:

(a) circumstances under which the Committee could consider projects from Article 5 countries to retrofit commercial refrigeration appliances; and

(b) how should the incremental costs of such projects be calculated.

ANNEX I

A. Estimating Cost Effectiveness of CFC Reduction Measures: Conclusions based on the Experience of the Most Important Mexican Chain

1. Lessons from Mexico's Projects: The first lesson is that defining the optimal mix of reduction measures (replacement, retrofit, conservation) should start with a thorough evaluation of the operating condition of all systems. A detailed inventory of the installed refrigeration systems proved extremely valuable for understanding the situation of the existing systems. A second lesson is that choosing a replacement/retrofit/conservation mix at the stage of project proposal is very different than the mix that emerges when the project is implemented. As the company embarks on its implementation, a focused and careful examination of each system uncovers situations not known before and requires adjustments to the original mix. A third lesson is that labor costs have been higher than anticipated because specialized refrigeration contractors are needed to implement conversions properly.

2. Cost-effectiveness was calculated using GIGANTE's actual mix (15% replacement, 58% retrofit (HCFC blends) and 27% conservation). Appendix I shows the cost-effectiveness break-down assuming that GIGANTE bears financing burden of all labor costs.

3. In addition to technical considerations discussed in Section B of this Annex, costs are a major factor in determining a mix of options that is both affordable and technically sound from the company's perspective. The experience in implementing the GIGANTE project indicates that labor costs are much higher than anticipated and that fixing leaks required higher materials costs (e.g., gaskets, valves, etc.) than anticipated. There is also great variance from system to system. For the purposes of this draft guideline, average costs for each option were developed based on data supplied by the Government of Mexico, actual cost data from GIGANTE, and World Bank estimates based on developed country experience, the costs of each option (excluding labor) are as follows:

- **conservation: $330 per system;**
- **retrofit to HCFC blends: $550 per system;**
- **retrofit to HFC blends: $1,314 per system;**
- **replacement: $2,730 per system.**

4. The $2,730 figure is a reference figure based on a 7 to 11 HP compressor (including oil, refrigerant, filters, and other accessories). While GIGANTE has documented replacements costing up to $4,851 per system, $2,730 is believed to be a reasonable average value. The retrofit figures of $550 and $1,314 per system are based on retrofits to HCFC and HFC blends.

5. The $330 per system (which excludes labor costs) is an estimate derived from labor costs estimates provided by the Government of Mexico and costs of materials used in applying conservation measures by GIGANTE.

6. Accounting for the Recovered Charge as a Project Benefit: In calculating the denominator of the cost effectiveness (CE) ratio, the standard MPMF method is to account for the annual consumption eliminated or reduced by the project. In an hypothetical scenario where GIGANTE had fully converted all its systems to non-CFC options, the recovered charge would be available for re-use elsewhere. The Government of Mexico has proposed to recognize such recovered in the CE denominator because the recovered charge could be used by another user and; thus, reduce the country's overall future consumption. To account for Mexico's concern, Appendix I incorporates two sets of CE values for each scenario and refers to them as CE options A and B: (1) annual reduction calculated in the standard MPMF method; and (2) annual reduction plus the change recovered from converted systems.

7. To place these results in perspective with regard to how financing requirements from the MFMP would be affected and to assess the environmental benefits, the following table applies these CE values and computes the ODP reductions that would have resulted using GIGANTE's 1,023 systems in its Mexico City Division.

SCENARIOS GIGANTE	COMPANY PAYS LABOR COSTS (See Appendix I)
100% Conservation	
Cost	$337,590
Impact	6,752 kg
Cost-Effectiveness	$50/kg
70% Conservation, 20% HCFC Blends, and 10% Replacement	
Cost	$674,219
Impact Option A	9,669 kg
Impact Option B	19,795 kg
Cost-Effectiveness Option A	$69.73/kg
Cost-Effectiveness Option B	$34.06/kg
Actual Project (15% replaced 58% retrofitted and 27% conservation)	
Cost	$828,291
Impact Option A	13,775 kg
Impact Option B	38,182 kg
Cost-Effectiveness Option A	$60.13/kg
Cost-Effectiveness Option B	$21.69/kg

8. Summary of Results: The main finding is the relatively low sensitivity of the cost-effectiveness value to the mix between conversion options, but the high environmental difference it makes in terms of CFC emission and the elimination of residual demand for CFCs. The 70% conservation has about the same CE value as the actual GIGANTE project but produces a CFC reduction of about 30% lower. In a context of limited financial resources, but also stringent CFC control deadlines in 2005 and 2007, both factors should inform project eligibility decisions.

9. The main point to be considered is that from a company's perspective, a viable project needs to provide financing for at least a reasonable proportion of the up-front investment costs. While a precise figure on GIGANTE's actual investment is not available because the company also embarked in a store improvement program. The Mexican government

estimates that this company has contributed at least an equivalent amount to the $500,000 provided by the Multilateral Fund in implementing the project, including incremental operational costs. Thus, the costs shown in the above table provide a reasonable approximation of actual costs.

B. The Experience of Mexico's GIGANTE Supermarket Chain in Developing the Project Concept and Generating Key Information.

10. This section presents the experience of the GIGANTE supermarket conversion project to illustrate the decision-making process followed by the company in determining conversion options and to generate unit cost data based on the most current data available to the World Bank at this time.

Detailed System Inventory and Characterization of its Condition

11. In early 1994, the Mexican Supermarket chain, GIGANTE, engaged Mexico's environment agency (Instituto National de Ecologia - INE) in discussions about the company's consumption of ozone depleting substances (ODS) prompted by its awareness about the Montreal Protocol. Given the significant consumption levels and the likely longer-term demand for CFCs in this end-sue segment of the commercial refrigeration sector, the government decided to explore options for reducing reliance on CFC refrigerants. Project preparation work for GIGANTE and two other supermarket chains (CHEDRAUI and AURRERA) unfolded in late 1994 and early 1995. Because the GIGANTE case is better documented at this time, it is used here for illustration purposes.

12. GIGANTE's claim comprising over 200 supermarkets initiated an in-depth assessment of its Mexico City Division to answer questions raised about the company's consumption characteristics. GIGANTE represented and example of a nation-wide chain with very large store format with relatively high level of know-how. GIGANTE developed a very comprehensive database of the systems in its 53 sore Mexico Division. This database contained a complete characterization of each system, including information on:

- number of refrigeration systems in each store;
- type of refrigerants in each system;
- application (fish, meat, pharmacy, etc.);
- type of oil (mineral, POEs, etc.)
- temperature application (low, medium, and high)
- capacity (refrigeration charges)
- remote or self-contained;
- annual consumption of refrigerants;
- diameter of the tubing;
- date of installation;
- brand and model, serial number of compressor and type (reciprocating, open etc.);

- specifications of compressor motor.

Based on the above data and the company's assessment of the performance and reliability of each system, all systems were classified into three groups:

GIGANTE's Refrigeration Units in 53 Stores (Mexico Division)

TYPE OF REFRIGERANT	GOOD <10 years	NOMINAL 10-15 years	POOR >15 years	NUMBER OF UNITS	VOLUME OF REFRIGERANT CHARGE (KG.)
R-12	273	513	60	846	27,918
R-502	158	18	1	177	5,841
TOTAL	431	531	61	1023	33,759

Notes: (1) R-22 refrigerant systems have not been included in this table.
(2) Average charge is 33 kg. of refrigerant per unit.

13. While the table above correlates system age with condition, this is a generalization to provide a sense of the average conditions found by GIGANTE. There were exceptions because, in addition to system age, two important determinants affect a refrigeration system's condition: (1) the general environment under which the system must operate (climate, power surges, etc.); and, (2) the quality and frequency of servicing and maintenance. Under the right circumstances, both of these factors can either vastly extend the service life of an older system or can significantly shorten the functional life of a relatively new machine. An older refrigeration system that is seeing relatively light duty and is well maintained, for example, can greatly outlast its projected service life and exceeds 25 years.

Defining the Right Mix: Replacement, Retrofit, and Conservation

14. The breakdown shown in the table above highlights the overall condition of GIGANTE's refrigeration equipment at the time of project development and served as the key piece of information to determine the balance of three options selected by GIGANTE:
- retrofit of existing systems to zero or low-ODP refrigerants,
- replacement of existing compressors and associated system adjustments,
- fixing leaks and recycling recovered refrigerant.

15. On average, systems in poor condition were older and showed compressor problems, and had high leaks and required high maintenance. From a purely technical and performance standpoint (without regard to costs), these systems were the logical candidates for the

compressor replacement option. Systems in nominal operating conditions (i.e., that were running satisfactorily most of the time but sometimes presented problems) would be either retrofitted, and in some circumstances (type of temperature range, etc.), the compressor could be replaced and render a more reliable and effective system. Systems in generally good operating condition were good candidates for conservation measures.

16. Where replacement of the compressor is required the choice is to replace the CFC-12 and R-502 refrigerants with HCF-134a and/or with R-404a. In GIGANTE's original project concepts both refrigerants were contemplated; HFC-134a or R-404A would replace CFC-12 in medium temperatures while R-404A would replace R-502 in low temperature applications. In the process of implementing its project GIGANTE determined that R-404A was a more efficient definitive option because HFC-134a requires a higher capacity compressor under the equivalent conditions. In addition, since R-404A cans be used in medium and low temperature applications, the company can eliminate of the choices and standardize on one refrigerant.

17. Converting via retrofit requires choosing an appropriate substitute "blend" to replace CFC-12 or R-502. The choice of substitutes depends to a large extent on the temperature requirement of the application. Some refrigerants are much better suited for low temperatures while others are more effective in medium temperatures. For CFC-12 in medium temperatures, R-401A (MP-39) and R-409A (FX-56) were selected while for low temperature needs R-502 would be substituted by R-402A (HP-80) and R-408 (FX-10).

18. The conservation option requires changing of deteriorated parts (i.e., malfunctioning parts) and improved servicing. The recovered refrigerant is handled more carefully and is recycled for reuse when feasible.

19. While the lowest cost solution appears to be to implement CFC conservation measures (e.g., to allocate all 431 units in food condition to conservation). However, from an environmental standpoint, the downside of that approach is that the installed capacity is not eliminated and the residual consumption of CFCs persists. The conversion options on the other hand cost more, but they provide the environmental benefit of eliminating the installed capacity.

COST-BENEFIT OF TECHNICAL OPTIONS		
OPTION	COST IMPLICATION	ENVIRONMENTAL BENEFIT
Retrofit	Moderate Cost	All or almost all ODP is eliminated
Replacement	Highest Cost	All ODP is eliminated
Conservation	Lowest Cost	Marginal Reduction of ODP Consumption, but consumption continues

20. The Government of Mexico is concerned about the country's stated policy of a year 2000 phaseout and is thus promoting eliminating residual demand for CFCs. Considering the government's objectives and the support received from the Multilateral Fund, GIGANTE chose not only to minimize costs, but to arrive at a mix that maximized conversion (retrofit and replace) that the company could afford. The company's total 1,023 total units were allocated as follows:

- 593 systems for retrofit;
- 150 systems for replacement;
- 280 systems for conservation.

21. This means that GIGANTE allocated 72.6% of its systems to the conversion option and 27.4% conservation. The costs associated with GIGANTE's mix are presented in Appendix I.

APPENDIX I

Cost-effectiveness Calculation

Assume: Enterprise A with 100 commercial refrigeration systems. Each of them has a charge size of 33 kg, Option A takes into account only the saving resulting form comparing the baseline consumption with the new stream of ODP leaks. Option B incorporates the ODP savings resulting from recovered ODP charge after the conversion takes place. In this calculation labor costs are assumed to be borne by the enterprise. Thus the costs for each technical option are reduced by the labor cost components as follows: (a) emission controls: $440 - $110 = **$330** ; (b) HCFC blends: $720 - $170 = **$550**; (c) HFC-134a or HFC blends: $1524 - $210 = **$1314**; and (d) compressor replacement: $3,500 - $770 = **$2,730**.

Emission Control Option (100%)

Capital costs: $330/system x 100 system	$33,000
CFC consumption	
Before: 33 kg/system x 100 systems x 50% leakage rate	1,650 kg
After: 33 kg/system x 100 systems x 30% leakage rate	990 kg
CFC Savings	660 kg
Cost effectiveness	**$50/kg**

Retrofit with HCFC Blends (100%)

CFC consumption	
Before: 33 kg/system x 100 systems x 50% leakage rate	1,650 kg
After: 33 kg/system x 100 systems x 30% leakage rate x 0.04*	39.6 kg
Option A-ODP Savings without charge	1,610 kg
Option B-ODP savings with charge**	4,910 kg
Capital costs HCFC Blend retrofit: $550/system x 100 systems	$ 55,000

Cost effectiveness Option A	**$34.16/kg**
Cost effectiveness Option B	**$11.12/kg**

* ODP of HCFC = 0.04

** Recovered CFC form retrofitted units: 33 kg/system x 100 systems = 3300 kg

<u>Retrofit with HFC Blends (100%)</u>

CFC consumption: Replacing 30% of existing units	
Before: 33 kg/system x 100 systems x 50% leakage rate	1,650 kg
After: 33 kg/system x 100 systems x 0.0*	0 kg

Option A-ODP Savings without charge	1,650 kg
Option B-ODP savings with charge**	4,950 kg

Capital costs of retrofit to Blends: $1314/system x 100 systems	$131,400

Cost effectiveness Option A	$79.09/kg
Cost effectiveness Option B	$26.55/kg

* ODP of HCFC = 0.0

** Including recovered CFC form retrofitted units: 33 kg/system x 100 systems = 3300 kg

<u>Replace Compressors (100%)</u>

CFC consumption:	
Before: 33 kg/system x 100 systems x 50% leakage rate	1,650 kg
After: 33 kg/system x 100 systems x 0.0*	0 kg

Option A-ODP Savings without charge	1,650 kg
Option B-ODP savings with charge**	4,950 kg

Capital costs of retrofit to Blends: $2730/system x 100 systems	$273,000

Cost effectiveness Option A	$165.45/kg
Cost effectiveness Option B	$55.15/kg

*   ODP of HFC = 0.0
**   Including recovered CFC form retrofitted units: 33 kg/system x 100 systems = 3300 kg

Gigante's Scenario: Replacement (15%) + Emission Control (27%)

CFC consumption:	
Before: 33 kg/system x 100 systems x 50% leakage rate	1,650 kg
After: 33 kg/system x 27 systems x 30% leakage rate	267.3 kg
33 kg/system x 58 systems x 30% leakage rate x 0.04*	23 kg
Option A-ODP Savings without charge	1,359.7 kg
Option B-ODP savings with charge**	3768.7 kg
Capital costs of emission control: $330/system x 27 systems	$ 8,910
Capital costs of retrofitting: $550/system x 58 systems	$ 31,900
Capital costs of replacing compressor: $2,730/system x 15 systems	$ 40,950
Total	$ 81,760
Cost effectiveness Option A	$60.13/kg
Cost effectiveness Option B	$21.69/kg

*   ODP of HCFC Blend = 0.04
**   Recovered CFC form retrofitted and replaced units: 33 kg/system x (15+58) systems = 2,409 kg