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ESPAÑOL
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COMITÉ EJECUTIVO DEL FONDO MULTILATERAL
PARA LA APLICACIÓN DEL
PROTOCOLO DE MONTREAL
Cuadragésima Séptima Reunión
Montreal, 21 al 25 de noviembre de 2005

PROPUESTAS DE PROYECTOS: PROYECTOS DE DEMOSTRACIÓN DE ENFRIADORES

• Proyecto de demostración para la gestión integrada del subsector de enfriadores centrífugos en Brasil, relativo a la aplicación de tecnologías sin CFC que emplean eficientemente la energía para sustituir los enfriadores basados en CFC	PNUD
• Proyecto de demostración regional para la gestión integrada del subsector de enfriadores centrífugos en el Caribe, relativo a la aplicación de tecnologías sin CFC que emplean eficientemente la energía para sustituir los enfriadores basados en CFC	PNUD
• Proyecto de demostración para la gestión integrada del subsector de enfriadores centrífugos en Colombia, relativo a la aplicación de tecnologías sin CFC que emplean eficientemente la energía para sustituir los enfriadores basados en CFC	PNUD
• Proyecto de demostración para la gestión integrada del subsector de enfriadores centrífugos en Cuba, relativo a la aplicación de tecnologías sin CFC que emplean eficientemente la energía para sustituir los enfriadores basados en CFC	PNUD y Canadá
• Proyecto de demostración sobre la sustitución de enfriadores centrífugos de CFC en Bahrein y Siria	ONUDI
• Proyecto de demostración sobre la sustitución de enfriadores centrífugos de CFC en Croacia, Serbia y Montenegro, Rumania y Macedonia	ONUDI
• Proyecto mundial de sustitución de enfriadores	Banco Mundial

ANTECEDENTES

1. En la 46ª Reunión del Comité Ejecutivo se examinó un estudio sobre los criterios y modalidades para proyectos de demostración de enfriadores que figuraba en el documento UNEP/OzL.Pro/ExCom/46/37, y había preparado de conformidad con la decisión XVI/13 de la Decimosexta Reunión de las Partes y la Decisión 45/4 d) de la 45ª Reunión del Comité Ejecutivo.

2. Después del debate, el Comité Ejecutivo decidió asignar una ventana de financiación de 15,2 millones $EUA a proyectos de demostración adicionales en el subsector de enfriadores. Se solicitó al PNUD, la ONUDI y al Banco Mundial, así como a los organismos bilaterales interesados, que presentaran a la 47ª Reunión del Comité Ejecutivo propuestas de proyectos que pudieran reproducirse en otros países a fin de demostrar la viabilidad y las modalidades de sustituir los enfriadores centrífugos en el futuro mediante la utilización de recursos externos al Fondo Multilateral (Decisión 46/33). Se alentó a los organismos a que presentasen dichos proyectos sobre una base regional para permitir la inclusión del mayor número posible de países. El Comité Ejecutivo convino también en las condiciones aplicables a dichos proyectos.

3. Se han recibido proyectos del PNUD, la ONUDI y el Banco Mundial así como de Canadá en calidad de organismo bilateral en cooperación con el PNUD. El cuadro que figura a continuación contiene una descripción general de los proyectos recibidos. Cada organismo ha optado por un enfoque diferente para los proyectos de enfriadores, salvo en el caso del proyecto conjunto de Canadá y el PNUD que es similar al del PNUD.

4. El presente documento contiene una descripción general y una comparación de las características de los proyectos presentados. En el Anexo I a este documento figuran ejemplos de los proyectos de cada organismo, según lo indicado en el cuadro siguiente. Todas las propuestas de proyectos que se muestran en el cuadro pueden descargarse del sitio web de la Secretaría.

País	**Región**	**Organismo**	**Título**	**Adjunto como ejemplo**
Brasil	América Latina y el Caribe	PNUD	Proyecto de demostración para la gestión integrada del subsector de enfriadores centrífugos en Brasil, relativo a la aplicación de tecnologías sin CFC que emplean eficientemente la energía para sustituir los enfriadores basados en CFC	Sí
Barbados República Dominicana Jamaica Trinidad y Tobago	América Latina y el Caribe	PNUD	Proyecto de demostración regional para la gestión integrada del subsector de enfriadores centrífugos en el Caribe, relativo a la aplicación de tecnologías sin CFC que emplean eficientemente la energía para sustituir los enfriadores basados en CFC	
Colombia	América Latina y el Caribe	PNUD	Proyecto de demostración para la gestión integrada del subsector de enfriadores centrífugos en Colombia, relativo a la aplicación de tecnologías sin CFC que emplean eficientemente la energía para sustituir los enfriadores basados en CFC	
Cuba	América Latina y el Caribe	Canadá y el PNUD	Proyecto de demostración para la gestión integrada del subsector de enfriadores centrífugos en Cuba, relativo a la aplicación de tecnologías sin CFC que emplean eficientemente la energía para sustituir los enfriadores basados en CFC	

País	Región	Organismo	Título	Adjunto como ejemplo
Bahrein	Asia Occidental y Central y Europa Oriental	ONUDI	Proyecto de demostración sobre la sustitución de enfriadores centrífugos de CFC en Bahrein y Siria	Sí
Siria				
Croacia	Asia Occidental y Central y Europa Oriental	ONUDI	Proyecto de demostración sobre la sustitución de enfriadores centrífugos de CFC en Croacia, Serbia y Montenegro, Rumania y Macedonia	
Ex República Yugoslava de Macedonia				
Rumania				
Serbia y Montenegro				
China	Mundial, principalmente Asia Oriental y Meridional	Banco Mundial	Proyecto mundial de sustitución de enfriadores	Sí
India				
Indonesia				
Malasia				
Filipinas				

5. En su Decisión 46/33, el Comité Ejecutivo pidió al PNUMA que presentara una propuesta de proyecto relativa a la ejecución de actividades pertinentes de información, difusión y sensibilización a escala mundial, con el objetivo de divulgar la experiencia adquirida en los proyectos de demostración en todo el mundo. El PNUMA sometió a la consideración de la 47ª Reunión una propuesta de proyecto a este respecto. Como no se trata de un proyecto de demostración, esta propuesta se analiza en el documento UNEP/OzL.Pro/ExCom/47/20, "Informe de la Secretaría sobre la experiencia adquirida durante la preparación de proyectos y los cambios o enmiendas que es necesario introducir en los criterios y modalidades aprobados en la Decisión 46/33 en lo que respecta a los proyectos de demostración de enfriadores".

6. El análisis en detalle de los proyectos de demostración de enfriadores recibidos se incluirá en un addendum al presente documento.

THIS CONSISTS OF THE THREE PROJECTS LISTED BELOW AS SUBMITTED TO THE SECRETARIAT BY THE AGENCIES

MULTILATERAL FUND FOR THE IMPLEMENTATION OF THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER

PROJECT COVER SHEET

COUNTRY: BRAZIL **IMPLEMENTING AGENCY:** UNDP

PROJECT TITLE: Demonstration project for integrated management of the centrifugal chiller sub-sector in Brazil, focusing on application of energy-efficient CFC-free technologies for replacement of CFC-based chillers

PROJECT IN CURRENT BUSINESS PLAN: Yes

SECTOR: Refrigeration & Air Conditioning
SUB-SECTOR: Chillers

ODS USE IN SUB-SECTOR: Current (2004) 98 MT ODP

PROJECT IMPACT: Reflecting the net ODP value Not applicable MT ODP (* demonstration)

PROJECT DURATION: 3 years (2006 – 2008)

		MLF	Counterpart	Total
PROJECT COSTS & FUNDING:	US$	1,000,000	350,000 (GEF pdf b)	1,350,000
AGENCY SUPPORT COSTS:	US$	75,000	31,500	106,500
TOTAL COSTS:	US$	1,075,000	381,500	1,456,000

LOCAL OWNERSHIP: 100%
EXPORT COMPONENT: 0%

STATUS OF COUNTERPART FUNDING: As described above
PROJECT MONITORING MILESTONES: Included
NATIONAL COORDINATING BODY: MMA/Prozon

PROJECT SUMMARY

This project aims at developing and demonstration of sustainable institutional and financial mechanisms to facilitate integrated management of the centrifugal chiller sub-sector in Brazil, through application of environmentally sound and energy-efficient alternative technologies for replacement of CFC-based centrifugal chillers. Upon completion, the project will have the following primary outcomes: (a) creating conditions favorable for removal of technological, financial and regulatory barriers to early replacement of CFC-based chillers (b) elimination of the residual consumption of Annex-A, Group-I substances (CFCs) in servicing of CFC-based centrifugal chillers Brazil; (c) creation of a stockpile of CFCs recovered from replaced chillers to be used for servicing of those CFC-based chillers, for which replacement is not immediately viable (d) demonstration of energy savings through application of energy-efficient replacement technologies and (e) demonstration of reductions in greenhouse gas emissions through application of energy-efficient replacement technologies. From a sample numbering 64 chiller installations, representing the priorities of the Government of Brazil in terms of ownership and end-use profiles, a representative sample of 15 chillers will be selected for replacement demonstration.

The secondary outcomes of this demonstration project would be: (a) Compilation of a national inventory and conversion priority list of CFC-based chillers; (b) Compilation of a range of cost-effective replacement technology options and (c) Capacity-building of national expertise in implementation of chiller replacement technologies. It is expected that the primary and secondary outcomes of the project would be critically useful in developing a strategy for country-wide replacement of CFC-based chillers through leveraging a combination of funding sources such as commercial finance, carbon finance and other multilateral and bilateral funding sources.

PREPARED BY: UNDP jointly with MMA/Prozon and chiller task force national team **DATE:** 3 October 2005

BRAZIL

DEMONSTRATION PROJECT
FOR INTEGRATED MANAGEMENT OF THE CENTRIFUGAL CHILLER SUB-SECTOR IN BRAZIL, WITH FOCUS ON APPLICATION OF ENERGY-EFFICIENT CFC-FREE TECHNOLOGIES FOR REPLACEMENT OF CFC-BASED CHILLERS

Prepared jointly by

MMA/Prozon
United Nations Development Programme
3 October 2005

CONTENTS

LIST OF ABBREVIATIONS

ARI	American Refrigeration Institute
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigeration and Air-conditioning Engineers
BNDES	National Development Bank of Brazil
BTU	British Thermal Unit
C	Carbon
CDM	Clean Development Mechanism
CFC	Chlorofluorocarbons
CO_2	Carbon dioxide
COP	Coefficient of Performance
DSM	Demand Side Management
EER	Energy Efficiency Ratio
EFLH	Equivalent Full Load Hours
ExCom	Executive Committee of the Multilateral Fund for the Montreal Protocol
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gases
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbons
Hr	Hour
ISO	International Standards Organization
Kcal	Kilocalories
Kg	Kilogram
Kg-C	Kilogram Carbon equivalent emissions
Kw	Kilowatts
Kwh	Kilowatt-hours
Kwh/TR	Kilowatt-hours per ton of refrigeration
MLF	Multilateral Fund for the Implementation of the Montreal Protocol
MP	Montreal Protocol on Substances that deplete the ozone layer
MT	Metric Ton (1,000 kilogram)
ODP	Ozone Depleting Potential
ODS	Ozone Depleting Substances
TEWI	Total Equivalent Warming Impact
TR	Tons of Refrigeration (12,000 BTU/hr or 3,024 kcal/hr)

PROJECT OF THE GOVERNMENT OF BRAZIL

Demonstration Project for Integrated Management of the Centrifugal Chillers Sub-sector in Brazil, focusing on Application of Energy-efficient CFC-free technologies for Replacement of CFC-based chillers

1. SITUATION ANALYSIS – MOP and ExCOM GUIDANCE

Decision XVI/13 of the Meeting of the Parties to the Montreal Protocol (November 2004) requested the Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol (MLF) to consider funding additional demonstration projects[1] in the chillers sub-sector to help demonstrate the value of replacement of CFC-based chillers, as well as to increase awareness of users of the impending phase-out and options that may be available for dealing with their chillers. Decision XVI/13 also requested countries preparing or implementing Refrigerant Management Plans (RMPs) to consider developing measures for the effective use of the ozone-depleting substances recovered from the chillers to meet servicing needs in the sector.

Further to this Decision, the Executive Committee of the Multilateral Fund (ExCom) adopted Decision 45/4 (d) in April 2005, requesting that criteria and modalities for chiller demonstration projects be developed. At the same time, the ExCom set aside a funding window of US $15.2 million dollars for funding in this sub-sector in response to the MOP decision.

At its 46th Meeting (July 2005), the ExCom adopted criteria and modalities for chiller demonstration projects under Decision 46/33. The main aim of the decision is to allow for utilization of the US $15.2 million funding window for additional demonstration projects in the chiller sub-sector, with an understanding that no further funding for chiller replacement would be approved by the ExCom, as per the following guidelines (paraphrased):

(i) That the MLF agencies, as well as interested bilateral agencies, submit project proposals to ExCom 47 (November 2005) that demonstrate replicability and scale-up potential (feasibility of, and modalities for) for replacing centrifugal chillers in the future through use of resources external to the MLF. Agencies were encouraged to submit such projects on a regional basis to allow as many countries as possible to be included;

(ii) To agree to the following conditions for such investment demonstration projects:

1. Countries participating in the demonstration should have enacted and were enforcing legislation to phase out ODS (refer to Section 3.3);
2. As the project is intended to use financial resources outside the Multilateral Fund, the credibility of those financial resources should be indicated at time of submission to the Fund, on the understanding that such financial resources should be secured before disbursement of funds approved under the Fund commences (refer to Section 3.5);
3. The total funding per investment will be determined using an accessible mathematical and/or business model, taking into account relevant decisions of the Executive Committee (refer to Section 5.4);

[1] There are 4 ongoing demo programmes for replacement of CFC chillers at present – Côte d'Ivoire, funded by France; Mexico (managed by the World Bank using UK MLF bilateral contribution + private sector input), Thailand (managed by the World Bank with joint financing through MLF and GEF) and Turkey (managed by the World Bank with MLF funding – CFC chiller phase-out as part of Refrigerant Mgmt Plan)

4. The maximum Multilateral Fund grant for a particular country is US $1,000,000; for regional projects, approval of additional funding on a revolving fund basis could be decided on a case-by-case basis (refer to Section 6.2); and,
5. The project proposal includes a general strategy for managing the entire CFC chiller sub-sector including the cost-effective use and/or disposal of CFCs recovered from chillers in the countries concerned (refer to Annex 3).

2. PROJECT OBJECTIVES – Aims and Outcomes

This project aims to develop and demonstrate sustainable institutional and financial mechanisms to facilitate integrated management of the centrifugal chiller sub-sector in Brazil, through application of environmentally sound and energy-efficient alternative technologies for replacement of CFC-based centrifugal chillers.

2.1. a. The project will have the following primary outcomes:

a) Creating conditions favorable for removal of technological, financial and regulatory/fiscal barriers to conversion to of non-CFC energy efficient chillers;
b) Based on the above, establish a business model for market transformation;
c) Reduction/elimination of the residual consumption of Annex-A, Group-I substances (CFCs) in servicing of CFC-based centrifugal chillers Brazil;
d) In coordination with the ongoing activities being implemented under the National Phase Out Plan, creation of a stockpile of CFCs recovered from replaced chillers to be used for servicing of those CFC-based chillers, for which replacement is not viable;
e) Demonstration of energy cost savings through application of energy-efficient replacement technologies; and,
f) Demonstration of reductions in greenhouse gas emissions through application of energy-efficient replacement technologies, a component that will satisfy the requirements for the associated GEF co-financing request.

2.1.b. The secondary outcomes of this demonstration project would be:

a) Compilation of a national inventory and conversion priority list of CFC-based chillers;
b) Compilation of a range of cost-effective replacement technology options; and,
c) Capacity-building of national expertise in implementation of chiller replacement technologies.

It is expected that the primary and secondary outcomes of the project would be critically useful in developing a replicable strategy for country-wide replacement of all CFC-based chillers through leveraging a combination of funding sources such as commercial finance, carbon finance and other multilateral and bilateral funding sources and counterpart funding from intended recipients.

The project is intended to serve essentially as a demonstration project for funding mechanisms, for institutional and management frameworks and for energy and cost savings through adoption and application of appropriate technologies. To this end, a representative selection of chillers, drawn from a sample set of 64 nationally-owned chiller installations, representing the priorities of the Government of Brazil in terms of ownership and end-use profiles, have been selected for this replacement demonstration.

3. BACKGROUND

3.1 Introduction

Brazil is the fifth largest country in the world, with a population of about 175 million. Brazil has a tropical climate in most areas, except parts of the South, which have a temperate climate. The predominance of lower altitudes throughout the country provides more elevated temperatures, with average annual temperature standing at 28ºC in the northern region and 20ºC in the south. Extreme temperatures, while relatively rare, do occur. At the peak of a Rio de Janeiro summer, temperatures may crest 40ºC.

The contributors to GDP were Agriculture (about 8%), Industry (about 38%) and Services (54%). The real annual GDP growth as of 2004 was about 5%. Over 70% of visitors to Brazil arrive for leisure and tourism. Tourism contributed to over 10 million jobs to the economy. Given the predominantly tropical climate, high contribution of the Services Sector to the GDP, and importance of tourism to the economy, the size of the Refrigeration and Air Conditioning Sector in Brazil is significant, in which building air conditioning systems play an important role.

Chillers are refrigeration systems that cool either a water or a water/antifreeze mixture which is then circulated for use principally in building comfort air-conditioning and industrial processes. For many years, centrifugal chillers were the most common type of cooling system available above 700 kW capacity. Mainly manufactured in the United States, with some manufacturing occurring in Asia and Europe, prior to 1993 centrifugal chillers were offered with CFC-11, CFC-12, R-500 (mixture of CFC-12 and HFC-152a) and HCFC-22 as refrigerants. CFC-11 was the most common.

With the advent of the Montreal Protocol on Substances that Deplete the Ozone Layer, global production of chillers using CFCs or refrigerants containing CFCs essentially came to an end. The average chiller manufactured today uses about 35% less electricity than chillers produced just two decades ago. With the best technology available, operated on HCFC-123 or HFC-134a, new chillers can use up to 50% less electricity than an average chiller from 1976.[2] Energy efficiency savings is therefore a primary environmental consideration and potential economic incentive for conversion to non-CFC chillers.[3] Replacing CFC based chillers also contributes to reduced greenhouse gas emissions, both from an energy consumption perspective and from reduced emissions of CFCs which have high global warming potential[4]. Naturally, the choice of non-CFC refrigerants will affect the aggregate greenhouse gas emissions impact of the substitute technologies.

Brazil has a significant centrifugal chiller population, numbering upwards of 1,250, located mostly in the country's large urban areas. To date, the potential for energy efficiency improvement and energy savings in this sector remains poorly tapped. A number of important external considerations come into play when assessing and determining a realistic payback period, including for example, electricity prices, energy subsidies, legislative/regulatory controls, the condition of the remainder of the circuit (where possible redesign and replacement of heat compressors, pumps, etc. can have a

[2] Report of the TEAP Chiller Task Force, Technical and Economic Assessment Panel of the Montreal Protocol, May 2004.

[3] Ibid. While some alternatives (HFCs) do possess Global Warming Potential (GWP), refrigerants on the whole do not contribute to global warming unless released into the atmosphere. Properly maintained chillers of modern design emit less than 1% of their refrigerant charge each year. The dominant global warming effect caused by chiller operation is therefore, the carbon dioxide emitted during combustion of fossil fuels used to generate the electricity required to drive them.

[4] CFC-11 has a GWP of 5000, while CFC-12 has a GWP of 8500

negative impact on the economic payback period), as well as overall efficiency improvements in the building (e.g. efficient lighting, better insulation).

3.2 Brazil's Montreal Protocol Activities

Brazil ratified both the Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol on Substances that Deplete the Ozone Layer in March 1990. It has also subsequently ratified the London Amendment in October 1992, the Copenhagen Amendment in June 1997, as well as the Montreal and Beijing Amendments in June 2004.

The Brazil Country Programme was prepared with the assistance of the MLF approved at the 6th meeting of ExCom in 1992. It was approved at the 13th meeting of the ExCom in July 1994. The Country Programme proposed measures and actions to be undertaken by the government and industry to facilitate the phase-out of ODS in the various ODS consuming industry sectors and to assist them for complying with the country's commitments and priorities. Interventions included institutional and regulatory measures, marketing and information dissemination, technical assistance, training and investments for technology conversions.

Currently, the most consumed group of controlled substances is the Annex A Group I, which includes the most common CFC, mainly used in the foams and various refrigeration sectors. While a major portion of the consumption by the industrial manufacturing sectors (i.e. domestic, commercial refrigeration producers and foams producers) have been phased out with the assistance of the Multilateral Fund, there is still remaining consumption in the servicing sector, including the chillers maintenance sector.

2004 CFC consumption breakdown by sector reported by the National Phase-out Plan's Programme Management Unit (PMU) is as follows:

Table 1: 2004 Consumption Breakdown by Sector (as reported by National Project Mgmt Unit)

Substance	**Consumption by Sector in ODS Tonnes/Yr**							
	Aerosol	*Foam*	*Fire*	*Refrigeration (*)*	*Solvent applications*	*Process Agent*	*Soil Fumigation*	*Total*
CFC-11	4	11.05	-	28	-	-	-	
CFC-12	43	00	-	1799.46	-	-	-	
CFC-113	-	-	-	-	3	-	-	
CFC-114	9	-	-	-	-	-	-	
CFC-115	-	-	-	-	-	-	-	

(*) Includes the CFC-11 used in domestic refrigeration foams

A National Phase-Out Plan (NPP) for the elimination of CFCs was approved by the ExCom at its 37th Meeting in July 2003. The NPP contains projects to complete the phase out in the manufacturing sectors as well as technical assistance activities to phase out the consumption in the servicing sector.

The main activities currently being implemented under the auspices of the NPP include:
- PU Foam Manufacturing Sector - CFC Conversion Projects
- Commercial Refrigeration Manufacturing Sector - CFC Conversion Projects
- Domestic & Commercial Refrigeration Service Sector:

- Service Technician Training Project
1. CFC-12 Recovery Project
2. CFC-12 Reclaim Centre Project

- MAC Service Sector - CFC-12 R&R Pilot Project
- Industrial Refrigeration and Central Air-Conditioning Service Sector - CFC R&R Project
- Technical Assistance for MDI Transition Strategy
- Investment Project to phase out the use of CFC 12 in Sterilants
- Customs Officer Training

Brazil's chiller owners will face the same commitment obligations as all CFC end users in the country, based on the full and accelerated phase-out commitment made by the Government to the ExCom at its 37th meeting. As per this agreement, US $26.7 million in funding was approved in principle for the phased reduction and complete phase-out of consumption of Annex A, Group I substances in Brazil by 2010.

3.3 Brazil's Montreal Protocol Institutional Framework

The activities related to ozone layer protection and implementation of the Montreal Protocol, are coordinated by PROZON, the Inter-ministerial Executive Committee created which decides on all policy related matters and on overall strategy to be followed in the country to meet the Montreal Protocol control targets. The Ministry of the Environment (MMA) acts as the executive secretariat for PROZON. IBAMA (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renovaveis), the agency responsible for the enforcement of legislation, is part of the MMA. The Committee, coordinated by the Ministry of the Environment, was created by a Decree of the President of Brazil published on 19 December 1995 and updated in March 2003, and includes representation of another six Ministries: Ministry of Development, Industry and Foreign Trade, Ministry of Foreign Relations, Ministry of Science and Technology, Ministry of Economy, Ministry of Health and Ministry of Agriculture.

The licensing system and CONAMA Resolution 267, of 14 September 2000 established the overall regulatory framework for ODS consumption, export, production and use in Brazil. IBAMA hosts the federal ODS registry (all ODS users must register to use and commercialize ODS and IBAMA monitors and enforces the legislation). Fines are applied when irregularities are detected. There have been cases of apprehension of CFCs reported recently in the media. Resolution 267 introduced an import quota for CFC 12 commencing 01 January 2001. Enshrined in CONAMA Resolution 267, it defined a maximum baseline level for CFC 12 imports of 8,259 tonnes that must be progressively reduced according to the following schedule:

Table 2 - Annual Maximum Import Quota for Annex A, Group I CFCs

CFC 12 Maximum Import Quota by Year (tonnes)							
Baseline for CFC 12 Import Quota	Year						
	2001	2002	2003	2004	2005	2006	2007
8,259 tonnes	**7,020**	**5,368**	**3,717**	**2,065**	**1,239**	**413**	**0**

The same legislation clearly states 1 January 2007 as the phase-out date for all CFC imports except for defined "essential uses".

CONAMA Resolution 267 also addresses the control of CFC 11 imports, again with effect from 1 January 2001. There is no import quota quantity specified for CFC 11. Article 3 of this Resolution permits the import of CFC 11 only for consumption by those companies registered with the Brazilian Federal Environmental Agency (IBAMA) with projects to convert to CFC-free technologies that are in the process of implementation or in preparation.

A summary of the ODS related regulatory and policy support established by the Government of Brazil is presented below:

1988	- Enactment of 3 Government Decrees from the Ministry of Health banishing the use of ODS in aerosols: - Government Decree nº 01 - use of labels specifying that the product is CFC free; - Government Decree nº. 534 - prohibition of ODS use in aerosols; - Government Decree nº. 647 -specifies the ODS banned.
1991	- Establishment of the Ozone Working Group - GTO (Decree nº. 929/81)
1993	- Establishment of the ODS consuming companies database by the Brazilian environmental agency - Ibama in Decree nº 27/93.
1994	- Rio Grande do Sul State Law nº. 10.169/94, prohibiting the release of ODS into the atmosphere.
1995	- Enactment by the Brazilian Environmental Agency (Ibama) of Decree nº. 29/95, which made it mandatory for companies to provide ODS consumption data; - Rio de Janeiro State Law nº. 2457/95, prohibiting ODS emissions to the atmosphere; - Establishment of the Inter-ministerial Executive Committee for the Protection of the Ozone Layer (PROZON) by the President of Brazil. Decree dated 19/09/95. - Resolution nº. 13/95 from the National Environment Council (Conama), which established phase-out dates for production and consumption of MP controlled substances
1996	- Official Communication nº. 07/96, establishing deadlines for the foreign trade of equipment containing ODS.
1997	- Green Procurement/ São Paulo State Level Decree nº. 41.629/97, prohibiting government owned institutions to buy equipment and products containing CFC; - Enactment by the National Environment Council (Conama) of Resolution nº. 229/97 that postponed the deadline for the solvents sector phase-out to 01/01/99.
1998	- Official Communication nº. 37/98 that created the Licensing System. Ministry of Industry - Green Procurement Federal Level Decree banning the purchase of CFC equipment and products in government own institutions/buildings (Decree nº. 2783/98).

1999 - Regulatory Instruction for Halons nº 01/99

2000 - National Environment Council – Conama approves legislation updating the phase-out deadlines and creating the ODS import quotas system (Conama Resolution nº267/00).

2003 - Establishment of the new Inter-ministerial Executive Committee for the Protection of the Ozone Layer (PROZON) by the President of Brazil. Decree dated from 03/07/03.

- Establishment of the Ozone Working Group by the Ministry of the Environment (Regulatory Instruction, September/2003).
- Alteration, through Resolution in September 2003, of Article 7 of Conama Resolution 267/00 as to adapt specifications of recovery cylinders to the needs of the National CFC Phase-out Plan.

The activities related to CFCs that have impact on chiller sub sector are the following:

- To monitor closely the CFC-12 import quota reduction schedule as defined in Conama Resolution 267 so as to guarantee compliance. Evaluate market conditions and adequacy of supply;
- To monitor CFC-12 import licence quotas so as to safeguard the availability of CFC-12 according to the permitted import levels, and to provide adequate distribution of the quotas between major importers;
- To revise the CFC-12 import quota allocation system if necessary in order to permit transfers of unused quotas from one authorised importer to another on a quarterly basis;
- To monitor the existing legislation on CFC-11 imports to guarantee the needs of CFC-11 imports for the service of CFC-11 based centrifugal chillers in the central air-conditioning and industrial refrigeration sectors;
- To analyse the impact of the 2007 phase-out schedule for CFC-11 to the needs of the chiller users, establishing a specific import quota for CFC-11 if needed.
- To revise all Federal and State Transport legislation to permit the unhindered transportation of recovered, recycled, and reclaimed CFCs between enterprises and regional CFC recycling/reclamation centres, and vice versa.

3.4 Brazil's Energy Demand Scenario

The total electricity generation in Brazil (2002) was about 340 billion Kwh, over 90% of which was from hydroelectric sources. The total consumption of electricity was 360 billion Kwh, representing a shortfall of about 7%, which was met through import from Paraguay. Due to significant reliance on hydroelectric power generation, the GHG emissions from power generation in Brazil are among the lowest in the world. The carbon intensity of the power sector in Brazil is about 0.3 kg-C/Kwh.

To advance in the implementation of the UNFCCC, the Government of Brazil appointed an Inter-Ministerial Commission for Sustainable Development in June 1994. Since 1985 the Government is supporting a national program (PROCEL) to promote the efficient supply and use of electricity and reduce energy waste. The major historical barriers to Brazilian energy efficiency investments have been an unstable economy and subsidized energy (especially electricity) prices. The recent stabilization of the Brazilian economy has provided the essential foundation for cost reduction investments such as energy efficiency (EE) projects. The movement of energy prices toward cost based pricing and electricity tariffs reflecting peak and off-peak costs provides a growing incentive for energy efficiency investments. The Ministry of Mines and Energy[5] is responsible for the energy sector. As part of the reforms, the state is moving away from commercial activities restricting itself to the policy and regulatory functions. The new, more indirect, role of the government also implied changes in the financing of energy efficiency and R&D.

Law # 9991 of 24 July 2000, mandates electric energy distribution companies to invest in research and development (R&D), and in energy efficiency programmes. They are required to apply annually, as a minimum, the amount of 0.75 % of their operational liquid income to R&D for the electric energy sector; and, a minimum of 0.25 % in programmes of energy efficiency for the end use, noting some variations in percentage as dictated by this law. For instance, the law established that until 31/12/2005 the defined percentages are 0.5% and 0.5% each for R&D and energy efficiency. Investments are to be applied according to ANEEL regulations. ANEEL, the Agencia Nacional de Energia Eletrica, was created by Law 9427 (1996) and is part of the Ministry of Mines and Energy (MME). ANEEL regulates and inspects the production, transmission, distribution and commercialization of electric energy in Brazil.[6] The state-owned utility Eletrobrás has also been implementing the energy savings program PROCEL[7] since 1998.

In 2001, Brazil experienced a significant energy crisis that resulted from two contributing: a) a severe drought, which in turn compromised hydroelectric production capacity; and b) the sheer limitations of the system's generation capacity. National stakeholders interviewed during the project preparation process indicated concern that if significant investment in Brazil's energy production infrastructure were not made, the risk of a similar situation arising by 2008 is considered high.

4. THE CHILLER SECTOR – Replacement Technology Options and Costs

Traditionally, central air conditioning systems used fluorocarbon refrigerants to chill water in a cooling loop. The chilled water produced in a chiller is then circulated throughout the building to air handling units located in various parts of the building, for cooling the air. There are four basic types of water chillers, typically of over 100 tons capacity, used for central air conditioning of buildings:

a) Reciprocating compressor-based (open or semi-hermetic): Capacity up to 200 TR
b) Rotary compressor-based (open or semi-hermetic): Capacity typically up to 400 TR
c) Centrifugal compressor-based (open or semi-hermetic): Capacity typically 200 TR and above
d) Absorption systems (do not use either compressors or fluorocarbon refrigerants): Capacities typically 150 TR and above.

The present discussion and analysis will limit itself to centrifugal chillers (and absorption chillers in context of replacement).

Large-capacity central air conditioning systems, especially those installed in the 1970s to the early 1990s, were predominantly designed with centrifugal compressors and used CFCs as refrigerants. The commonly used refrigerants in centrifugal chillers were CFC-11 (predominant), CFC-12, CFC-500 and HCFC-22 until the initiation of controls of CFCs. Centrifugal Chillers are typically electric

5 *Ministério de Minas e Energia*

6 *Please visit* www.aneel.gov.br/cedoc/lei20009991.pdf *and* www.aneel.gov.br *for more information, as necessary*

7 *Programa Nacional de Conservação de Energia Elétrica (PROCEL)*

motor-driven, but in some applications, driven by engines or turbines.

The initial refrigerant charge in centrifugal chillers is 1-2 kg per TR (ton of refrigeration) depending on the refrigerant used and the system type. Annually, the typical refrigerant loss in an open compressor centrifugal chiller ranges typically around 1-10% of the initial refrigerant charge, depending on the practices followed and the chiller technology and age.

There are three types of centrifugal chillers:

Low-pressure chillers:	CFC-11 as the refrigerant (usually up to 1,000 TR)
Medium-pressure chillers:	CFC-12 or 500 as the refrigerant (300 - 1,500 TR)
High-pressure chillers:	HCFC-22 as the refrigerants (usually from 300 - 8,500 TR)

Centrifugal chillers are also classified as open type (where the compressor and the drive motor are separately mounted) or semi-hermetic (where the compressor and drive motor are encased in a common housing).

4.1 Chiller Energy Efficiency Developments

Energy efficiency of centrifugal chillers is delineated in total energy consumption per ton of refrigeration. The average energy efficiency of centrifugal chillers has evolved as below:

Age of chiller (Years)	Energy Efficiency Range (Kw/ton)
20 or more	0.70 – 1.00
10 – 20	0.65 – 0.80
10 to new	0.49 – 0.65

The above-mentioned figures are based on ARI standard conditions.

The energy efficiency of chillers is not constant, but tends to degrade over its lifetime. It is also a function of the extent of full load and part load operation. The progressively increased energy efficiency of centrifugal chillers is due to several factors, some of which are mentioned below:

a) Mechanical design improvements in the basic chiller components (eg. more efficient impeller design, better heat exchangers, better materials, improved designs of other components, etc.);
b) Improvements in controls and instrumentation (eg. variable speed drives for the drive motor that improve part-load performance);
c) Improvements in auxiliary equipment in the chiller (eg. improved designs of the OAM - Oil, Air and Moisture - Purge Units, expansion devices, etc).

The single most significant contribution to energy efficiency has been the marked improvement in part-load operation of the chillers. Most centrifugal chillers from the 1970s to the early 1990s were designed and selected for peak-load operation based on calculation of building air conditioning loads incorporating considerable safety margins. Typically, buildings experience peak-load conditions only about 25% of the overall operating time. For 50-75% of the time the operating load is typically only 50-75% of the peak load. Thus, from the early 1990s onwards, devices such as variable speed drives in conjunction with other mechanical improvements in the chiller design led to significant increases in energy efficiencies of centrifugal chillers.

In addition to the above, additional energy efficiency gains were obtained through system optimizations as below:

a) Improved designs of peripheral equipment such as cooling towers, chilled water pumps, air handling units, etc.;
b) Improved instrumentation and controls in buildings (motion sensors, variable air flow, enthalpy controllers, etc);
c) Demand-side Management (rationalizing of building air conditioning load calculations, improved building designs such as insulation, window treatments).

4.2 Economic Life of Chillers

Centrifugal chillers are rugged and reliable equipment, containing mostly rotating parts. Being large and heavy, their installation, operation and maintenance is challenging. However, centrifugal chillers are a preferred technology for large applications due to their efficiency and reliability.

In developed countries, due to pressures of emerging technologies as well as those of more stringent energy-efficiency standards, the life of centrifugal chillers was considered to be around 20 years. However, the economic life of centrifugal chillers in developing countries is considered by the owners as much more, sometimes exceeding 30 years, in view of their high initial costs.

4.3 CFC Phase-out in servicing of Chillers

There are three actions for reducing or eliminating CFC usage in servicing of centrifugal chillers:

a) Conservation (no action, continue to operate the chiller until the end of its economic life, ensuring that CFC usage in servicing follows regulatory norms)
b) Retrofitting for use with an approved substitute refrigerant
c) Replacement

The following table summarizes the technical criteria for retrofit or replacement of chillers, based on balance economic life considerations:

Type of Chillers	Balance Economic Life		
	0 – 5 years	5 – 10 years	Over 10 years
CFC-11 based	Replace	Retrofit or Replace	Retrofit or Replace
CFC-12/500 based	Replace	Retrofit or Replace	Retrofit or Replace
HCFC-22 based	No action needed	No action needed	No action needed

Conservation (no action)

Conservation may not be viable in countries or situations where adequate availability of CFCs for servicing is not assured until the end of the economic life. It could however be an option in LVCs.

Retrofitting

CFC-11 based chillers can be retrofitted with HCFC-123 technology. HCFC-123 properties are not very dissimilar from those of CFC-11. HCFC-123 has an ODP of 0.02, GWP of 93 and time-weighted OEL of 50 ppm (in practice, emissions are less than 5 ppm in worst-case scenarios). The availability of HCFC-123 is expected until 2030. However, this is not considered a real drop-in technology due to the aggressive solvent action of HCFC-123. All gaskets, seals, motor winding insulation, etc. need to be replaced with compatible materials in addition to overhauling and other required modifications.

CFC-12/500 based chillers can be retrofitted with HFC-134a technology. HFC-134a has zero ODP, a GWP of 1,300 and low toxicity. HFC-134a is not controlled yet for production closure, thus availability is not an issue. Retrofitting to HFC-134a technology requires gear drive changes to obtain near-original performance. In addition, replacement of lubricants and other mechanical and electrical modifications would be needed.

Noteworthy points:

- Irrespective of the technology, a non-optimized retrofit or the cheapest option, would lead to reduction in capacity and energy efficiency by up to 10-15%
- Retrofit costs could be up to 40-80% of the replacement costs
- In order to maintain energy efficiency after retrofit, additional costs are inevitable. In most cases, non-optimized retrofits are unlikely to improve energy efficiency.
- Depending on the mechanical condition of the chiller, retrofitting may not extend the economic life of the chiller significantly, unless it involves replacement of the compressor and motor.

Energy efficiency gains are a critical consideration in the context of climate performance. Significant energy savings may not be available through retrofitting, unless:

a) The retrofitting involves replacement of the compressor and motor, or
b) Optimization of other chiller components and also of the overall air conditioning system is undertaken

Thus from an energy efficiency standpoint, retrofitting would provide overall environmental benefits only with significant additional investments.

Replacement

The two main alternative technologies for replacement of CFC-based centrifugal chillers with new non-CFC based centrifugal chillers, which are currently commercially viable, are as below:

HCFC-123: HCFC-123 has an ODP of 0.016, GWP of 93 and atmospheric lifetime of 1.4 years. HCFC-123 is non-flammable and considered to be moderately toxic with a WEEL limit of 50 ppm. The physical and thermodynamic properties of HCFC-123 are similar to those of CFC-11 therefore the operating temperatures and pressures in chiller applications are in a similar range. HCFC-123 provides comparable or better COP and IPLV than CFC-based chillers. HCFC-123 technology for chillers is stable, well-researched, and commercially available for low-pressure applications. Thus, HCFC-123 technology as a replacement for CFC-based chillers is considered techno-economically viable and efficient. HCFC-123 being classified as an Annex-C Group-I controlled substance under the Montreal Protocol, will need to be phased-out in developing countries by 2040. Manufacturing of new equipment with HCFC-123 is allowed in the USA until 2020. Thus, regulations on HCFC-123 use may impact its availability in the long-term.

HFC-134a: HFC-134a has zero ODS, a GWP of 1,300 and an atmospheric lifetime of 14 years. HFC-134a has no flammable limits in air and is considered non-toxic with a WEEL limit of 1,000 ppm. The physical and thermodynamic properties of HFC-134a make it a suitable alternative for medium-pressure applications. The energy-efficiency performance of HFC-134a-based chillers based on COP and IPLV levels, is about 5-10% lower than equivalent HCFC-123-based chillers however, the technology is established and commercially available. HFC-134a is not controlled under the Montreal Protocol, but is classified as a GHG under the Kyoto Protocol.

In addition to the above, potential commercially viable technologies or "third generation" technologies are as below:

HFC-152a: HFC-152a has zero ODP, a GWP of 140 and an atmospheric lifetime of 2 years. HFC-152a is flammable but considered non-toxic. The physical and thermodynamic properties of HFC-152a make it a suitable alternative for medium-pressure applications. It provides theoretical energy efficiency performance of about 5% better than HFC-134a. HFC-152a is not controlled under the Montreal Protocol, but is considered a GHG under the Kyoto Protocol. HFC-152a technology is not commercially available due to its flammability classification, however, it is considered technically feasible.

HFC-245ca: HFC-245ca has zero ODP, a GWP of 610 and an atmospheric lifetime of 7 years. Its physical and thermodynamic properties make it suitable as an alternative for low-pressure applications. It provides a theoretical energy efficiency performance marginally lower than HCFC-123. HFC-245ca is not flammable however it has higher vapor pressure than CFC-11 and HCFC-123, and is therefore subject to more stringent pressure vessel regulations. HFC-245ca is classified as a GHG, but is not controlled under the Montreal Protocol. This technology is not yet commercially offered.

Absorption chillers provide a non-centrifugal chiller technology alternative, for replacing CFC-based centrifugal chillers. The absorption refrigeration cycle has been well known for over 100 years. The main advantages of absorption technology are:

- Thermal compression in contrast to mechanical compression, results in much smaller moving or rotating parts, absence of lubricants and therefore lower maintenance costs as compared to centrifugal systems
- Reliable, silent and vibration-free operation
- Significantly reduced reliance on electricity supply and infrastructure
- The technology is environmentally sound with no ODP or GWP and occupationally safe

There are two main types of absorption cycles:

Ammonia-Water: In this system, ammonia is a refrigerant and water is the absorbent. However, since ammonia is toxic, the installations need proper ventilation and safety precautions

Lithium Bromide-Water: In this system, water is the refrigerant and lithium bromide is the absorbent.

Both technologies are commercially available. However, since absorption technology uses thermal compression, it requires an external heating source, such as through direct combustion (oil or natural gas), indirect heating (steam or hot water) or waste heat (flue gases or waste steam).

There are two main subtypes of technologies in Absorption systems: Single-effect and Double-effect. Single-effect absorption chillers are less efficient and are economically viable only if a source of waste heat (steam or flue) is available. Double-effect absorption chillers are usually direct-fired (oil or natural gas). Double-effect absorption chillers, if provided with an additional heat exchanger, usually present an added benefit of producing a hot-water stream, which can be used for heating.

Direct comparisons between centrifugal systems and absorption systems are complex, as the apparent COP of absorption systems is lower than centrifugal systems. However, double-effect direct-fired absorption chillers can also produce hot water, which would otherwise require a separate boiler. If, instead of the normal COP, a resource COP (which takes into account the source-to-site efficiency of the fuel) is used for comparison, then absorption systems depending on application, can provide comparable energy-efficiency performance.

4.4 Selection of Replacement Technology

Taking into account the differences in capacity and operating conditions, the existing CFC-based centrifugal chillers in Brazil provide an average energy efficiency of 0.77 Kw/TR (source: World Bank/ICF – Global Overview of the Chiller Sector – World Bank Financial Agents Workshop, 2004) while commercially available high-efficiency non-CFC chillers consume 0.56 Kw/TR (ARI 550/590) or less. For selection of the replacement non-CFC chiller technology, the project will explore all available technology alternatives and support those replacement options that promise the least ODP and GWP, an energy efficiency rating of not more than 0.56 Kw/TR and the most favorable technical and economic feasibility and environmental and occupational safety. The final selection of the replacement technology would be made based on a case-by-case assessment of specific circumstances of the installations.

5. CHILLER DEMONSTRATION PROJECT DESCRIPTION

The project aims to identify the most cost effective and environmentally friendly options for transforming the market of chillers in Brazil, based on the following objectives (refer to Section 2.1.a):

a) Creating conditions favorable for removal of technological, financial and regulatory/fiscal barriers to conversion to of non-CFC energy efficient chillers;
b) Based on the above, establish a business model for market transformation;
c) Reduction/elimination of the residual consumption of Annex-A, Group-I substances (CFCs) in servicing of CFC-based centrifugal chillers Brazil;
d) In coordination with the ongoing activities being implemented under the National Phase Out Plan, creation of a stockpile of CFCs recovered from replaced chillers to be used for servicing of those CFC-based chillers, for which replacement is not viable;
e) Demonstration of energy cost savings through application of energy-efficient replacement technologies; and,

f) Demonstration of reductions in greenhouse gas emissions through application of energy-efficient replacement technologies, a component that will satisfy the requirements for the associated GEF co-financing request.

The demonstration project addresses both the objectives of the Montreal Protocol on Substances that Deplete the Ozone Layer and the UN Framework Convention on Climate Change. Focus sectors will include hospital and public buildings, office buildings, the hospitality sector (hotels), as well as other commercial/ industrial applications.

5.1 Chiller Population

Estimates based on surveys conducted in 12 states, out of a total of 26, plus the federal district of Brasilia, during preparation of the National CFC Phase-out Plan in 2001 indicated that there were about 700 CFC-based centrifugal chillers used in building air-conditioning and industrial process air conditioning in those 12 states. Extrapolation to other states in the country indicates that the population of CFC centrifugal chillers being used is upwards of 1,250. The survey also indicated that about 28 tons of CFC-11 and 70 tons of CFC-12 were consumed in the servicing of these chillers surveyed. This includes the "top-up" of refrigerant losses during equipment operation, as well as the venting of all, or part of the refrigerant charge during service and repair activities. The use of CFCs for the cleaning of systems during repair, as well as the overcharging of refrigerant, may also contribute to this consumption.

Central air conditioning can be divided into two broad but distinctive categories:

- Large capacity chillers, operated by centrifugal compressors;
- Medium capacity chillers and "self-contained" air-conditioning equipment that mostly operate with reciprocating compressors. These are based almost exclusively on refrigerant HCFC 22.

The use of CFCs is confined to the large centrifugal chillers designed to use CFCs and that were installed pre-1993. New installations since the early 1990's have used centrifugal chillers based on HCFC 123, HFC 134a, or HCFC 22.

The majority of the existing chillers were installed between 1970s and early 1990s. While there has been replacement of older CFC-based chillers with non-CFC chillers during the past 8 years, this was more because of the age and balance economic life of the chillers rather than for environmental reasons. Information provided by national stakeholders during the survey process indicated that retrofits undertaken to date have addressed only non-centrifugal chillers. There are no centrifugal chiller manufacturers in Brazil.

As the average economic life of chillers in Brazil is up to 30 years, a substantial number of CFC-based chillers are expected to have a balance economic life of up to 10 years. Many facilities in the industrial refrigeration sector use ammonia as the refrigerant, while a small number operate with HCFC 22, and some very special facilities use other refrigerants, including CFCs, and hydrocarbons.

In spite of several attempts by the Government to verify with the four suppliers of centrifugal chillers the number of chillers active in the Brazilian market, it has proven extremely difficult to obtain this data from the suppliers, most likely due to market competition. In late August 2005, during the preparatory work for this project, UNDP was able to work out a confidential agreement with suppliers to release the information to UNDP under a confidentiality clause. One supplier has already sent its data and the others are committed to supply theirs shortly. This has enabled UNDP to verify the listed centrifugal chillers, confirm findings from previous surveys, add missing units and select a sample to conduct analyses of the distribution. In addition, it allowed UNDP to progress on site visits and verify information for all 64 chillers used for the energy savings analysis.

Out of an estimated total population that numbers upwards of 1,250 centrifugal CFC chillers in Brazil, a sample of 597 chillers units has been used to represent the characteristics of the consumption of CFC 11 and CFC 12 in the chillers sector, and 64 selected for the purpose of calculating the energy savings analysis.

Table 3 – Representative Sample of Chillers in Brazil (public and private sectors)

State	Private Residential/ Commercial Buildings	Government Buildings	Private Hotels	Public Hospitals	TOTAL
Amazonas	4	2	0	0	6
Para	2	4	0	4	10
Distrito Federal	6	93	2	0	101
Ceara	3	0	0	0	3
Pernambuco	8	2	2	0	12
Bahia	5	2	6	0	13
Minas Gerais	44	0	3	1	48
Esp.Santo	7	0	0	0	7
Rio de Janeiro	149	51	24	14	238
Sao Paulo	127	17	1	8	153
Parana	0	4	0	0	4
Rio Grande do Sul	0	2	0	0	2
Total Sample	**355**	**177**	**38**	**27**	**597**

The major concentration of CFC centrifugal chillers in Brazil is located in the area of Rio de Janeiro, former capital of the country, with high temperatures most part of the year and a large number of governmental, private and commercial buildings still using CFC chillers. The second consumption of CFC in chillers is in the area of Sao Paulo, which represents the wealthiest and most industrialized region of the country. While the population in Sao Paulo is larger than in the Rio area, it is expected that a larger portion of chillers have already been converted or replaced due to the higher income level and the fact that a larger proportion of Sao Paulo's chillers are in the private sector compared to those of Rio de Janeiro. The third area in concentration of centrifugal CFC chillers is the Federal District, where Brasilia, the nation capital, is located, and the major concentration of governmental buildings exists. These three states represent 82.4% of the 597 units considered in the sample.

With regards to the most common chillers using CFC in the country, private, residential and commercial buildings represent 59.4% of the units sampled, followed by governmental buildings that represent 29.6%**.**

While the consumption of CFC in most of their applications in Brazil has been addressed by the National Phase-out Plan approved at the 37th Meeting of the Executive Committee, this plan did not include any activity related to the replacement of CFC-based chillers.

The National Phase-Out Plan contains activities addressed to the industrial refrigeration & central Air-Conditioning (Centrifugal Chillers) servicing sector. These activities, some limited in scope to fit budgets approved, include:

- Development of a Code of Good Practice in Chiller Servicing (Based on the ASHRAE Code and promoted by PROZON in conjunction with ABRAVA).
- A Training Programme in Good Practice for Chiller Service Mechanics based on the Code of Good Practice (Courses tailored to their specific needs, focused on the recovery and recycling of CFCs, the need to check for and eliminate leaks after repair and before re-commissioning, and also including information on retrofit of CFC chillers to use non-CFC refrigerants).
- Recovery & Recycling of CFCs in Chiller Service & Repair Activities. Recovery and recycling equipment to be provided to major selected Chiller Service Companies after mechanics have completed the training course.

5.2 Energy Efficiency Analysis

An analysis was carried out for the 64 selected chiller installations representing a range of ownership profiles and end-use applications covering the following parameters:

- Estimation of direct energy savings and costs from replacement of this chillers with energy-efficient non-CFC chillers
- Indirect reductions in CO_2 emissions due to reduced energy consumption with the replacement chillers
- Reduction in direct GHG emissions due to reduced annual leakage rates with the replacement chillers

<u>Assumptions</u>

a) Equivalent Full Load operation Hours (EFLH) for various applications are as below:

- For Residential & Commercial Buildings: 3,000/year
- Hotels: 4,000/year
- Hospitals: 5,000/year

b) Electricity costs in Brazil as of April 2005 are as below (US$/Kwh):
(Based on exchange rate of US$ 1.00 = BRL 2.43)

- Residential use: 0.120
- Commercial use: 0.100
- Residential/Commercial use (average): 0.110
- Industrial/Public use: 0.064

c) Average Energy Efficiency of Chiller Installations in Brazil is 0.70 Kw/TR
(Source: ICF/WB - Global Overview of Chiller Sector - WB Financial Agents Workshop 2004)

d) Average energy efficiency for all replacement chillers is 0.56 Kw/TR
(Source: ARI Standard 550/590)

e) Carbon intensity of power sector in Brazil is 0.3 kg-C/Kwh. This is used for calculation of the indirect CO2 emission reductions due to energy efficiency gains with the selected replacement technology. *(Source: Energy Information Administration, US Department of Energy)*

f) The existing CFC-based chiller installations can continue to operate for the next 10 years.

g) For calculating direct GHG emissions reductions due to reduced leakage rates/losses with the replacement chillers, the following assumptions are made:

- In the baseline 50% chillers are CFC-11 based and 50% are CFC-12 based. For replacement, 50% chillers would be HCFC-123 based and 50% would be HFC-134a based
- Annual leakage rate in the baseline is 10% of the initial refrigerant charge. For replacement, the annual leakage rate is 2% of the initial refrigerant charge.
- The GWPs are: CFC-11 – 4,000 CFC-12 – 8,500 HCFC-123 – 93 HFC-134a – 1,320

The results of the analysis based on the above assumptions, are tabulated below:

Table 4 : Energy Efficiency Analysis for 64 selected installations

End-use Profiles/Parameters	Private Residential / Commercial Buildings	Private Hotels	Government Hotels	Government Office Buildings	Government Hospitals	Total (or weighted averages)
Number of sample installations	24	8	2	22	8	**64**
Range of dates of installations	1966-1978	1968-1976	1974	1969-1976	1975-1979	**1966-1979**
Carbon intensity of power (Kg-C/Kwh)	0.3	0.3	0.3	0.3	0.3	**0.3**
Baseline Scenario (CFC-based Chillers)						
Available Economic Lifetime (years)	10	10	10	10	10	**10**
Total Installed Capacity (TR)	16,510	2,940	740	18,337	5,850	**44,377**
Total Refrigerant Charge (Kg)	27,223	4,850	1,200	28,958	9,850	**72,081**
Equivalent Full Load Hours (Hrs/year)	3,000	4,000	4,000	3,000	5,000	**3,406**
Energy Costs (US$/Kwh)	0.11	0.10	0.064	0.064	0.064	**0.086**
Energy Efficiency (Kwh/TR)	0.7	0.7	0.7	0.7	0.7	**0.7**
Annual Energy Use (Kwh)	34,671,000	8,232,000	2,072,000	38,507,700	20,475,000	**103,957,700**
Annual Energy Costs (US$)	3,813,810	823,200	132,608	2,464,493	1,310,400	**8,544,511**
Lifetime Energy Costs (US$)	38,138,100	8,232,000	1,326,080	24,644,928	13,104,000	**85,445,108**
Lifetime Indirect CO_2 Emissions (t-C)	100,401	24,696	6,216	115,520	61,425	**308,258**
Lifetime Direct CO_2 Emissions (t-C)	170,188	30,313	7,500	181,000	61,563	**450,564**
Replacement Scenario (non-CFC Chillers)						
Comparable Economic Lifetime (years)	10	10	10	10	10	**10**
Total Installed Capacity (TR)	16,510	2,940	740	18,337	5,850	**41,690**
Total Refrigerant Charge (Kg)	16,510	2,940	740	18,337	5,850	**41,690**
Equivalent Full Load Hours (Hrs/year)	3,000	4,000	4,000	3,000	5,000	**3,406**
Energy Costs (US$/Kwh)	0.11	0.10	0.064	0.064	0.064	**0.086**
Energy Efficiency (Kwh/TR)	0.56	0.56	0.56	0.56	0.56	**0.56**
Annual Energy Use (Kwh)	27,736,800	6,585,600	1,657,600	28,392,000	16,380,000	**80,752,000**
Annual Energy Costs (US$)	3,051,048	658,560	106,086	1,817,088	1,048,320	**6,681,102**
Comparable Lifetime Energy Costs	30,510,480	6,585,600	1,060,864	18,170,880	10,483,200	**66,811,024**

(US$)						
Lifetime Indirect CO_2 Emissions (t-C)	83,210	19,757	4,973	85,176	49,140	**242,796**
Lifetime Direct CO_2 Emissions (t-C)	2,335	416	105	2,593	827	**6,276**
Energy Efficiency Savings						
Lifetime Energy Cost Savings (US$)	7,627,620	1,646,400	265,216	4,542,720	2,620,800	**16,702,756**
Lifetime CO_2 Emission Reductions (t-C)	185,044	34,836	8,638	208,211	73,021	**509,750**
Net/Weighted Average Energy Efficiency Savings per Chiller Installation						
Average installed capacity (TR)						**693**
Annual Energy Savings (Kwh)						**330,450**
Annual Energy Cost Savings (US$)						**28,419**
Lifetime (10-year) Energy Cost Savings (US$)						**284,187**
Lifetime Total CO_2 Emission Reductions (t-C)						**7,960**

This analysis does not take into account the following additional sources of efficiency gains and emission reductions:

- Impact of system optimization
- Demand-side management

5.3 Identification of Barriers to Conversion

Brazil is one of the most critical countries to be considered for chiller replacement due to the sheer number of CFC chillers in use. On the basis of various data, provided by both government sources and manufacturers, including the Brazilian industry association ABRAVA and Trane, a total chiller population of 1250 units has been assumed, with approximately 750 in the private sector and 500 in the public sector. It is quite possible that the total number in Brazil exceeds this conservative assumption.

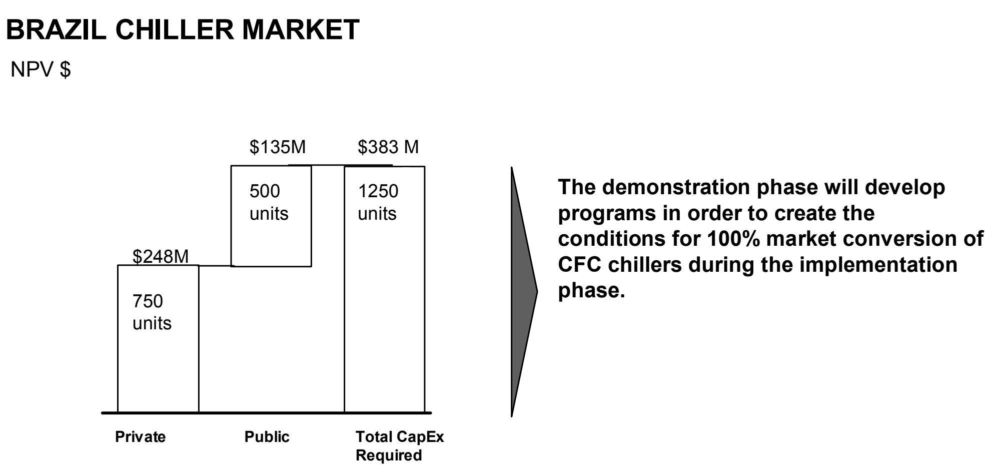
An intense and extensive consultation process with Brazilian stakeholders, undertaken during this preparatory phase, has brought to light a number of obstacles that need to be overcome in Brazil in order to facilitate the replacement of CFC chillers with non-CFC chillers:

- *Lack of awareness of regulation amongst target end users*
  - End users are typically unclear on exactly how government regulation applies to chillers and specific installations/businesses, which creates disincentive to change the CFC chillers prior to the end of their economic lives.
- *High upfront investment / opportunity cost*
  - Public sector
    - The public sector is typically dependent on budget appropriations for its capital expenditure, and therefore unlikely to have upfront capital for chiller replacement
  - Private sector
    - The private sector is more likely to invest in revenue-increasing rather than cost-decreasing activities because of the clear and demonstrable impact of revenue-enhancing activities
    - In addition to the high cost of equipment, private sector chiller owners also have to pay extremely high taxes on imports, amounting to almost 45% of the cost of the equipment

- *Low energy prices*
    - The price of electric power is $.12/Kwh for the public sector and $.14/Kwh (including tax) in the commercial sector. This price is insufficient to create a compelling case for chiller conversion for small chiller owners (<450 TR) in the public sector. Users that receive even lower industrial rates will also not see the incentive for conversion. Many stakeholders in Brazil expect an energy crisis in 2008.
- *Limited access to capital; high costs of financing*
    - o Public sector
        - For states that are in debt, there are heavy restrictions on obtaining new financing
        - The public sector is not allowed to lease chillers under law 8666, and is also not allowed to finance privately.
    - o Private sector
        - Interest rates are extremely high for private sector entities. Due to high estimated business risk, typical private sector entities face an interest rate of approximately 60% on the purchase of new equipment such as chillers. Brazil's prime rate is 19.5%, and inflation was 5% in 2005.

All these factors compounded together (low energy prices, high taxes and high financing costs) create a weak economic case for conversion in Brazil. Although the replacement of CFC chillers with non-CFC chillers results on average in energy savings of over $47,000 and $45,000 annually for public and private sector institutions, respectively, these savings are more than offset by the additional costs of the equipment, taxes and financing costs.

The total financial gap for chiller owners varies by context. Public and private sector owners face different economic conditions.

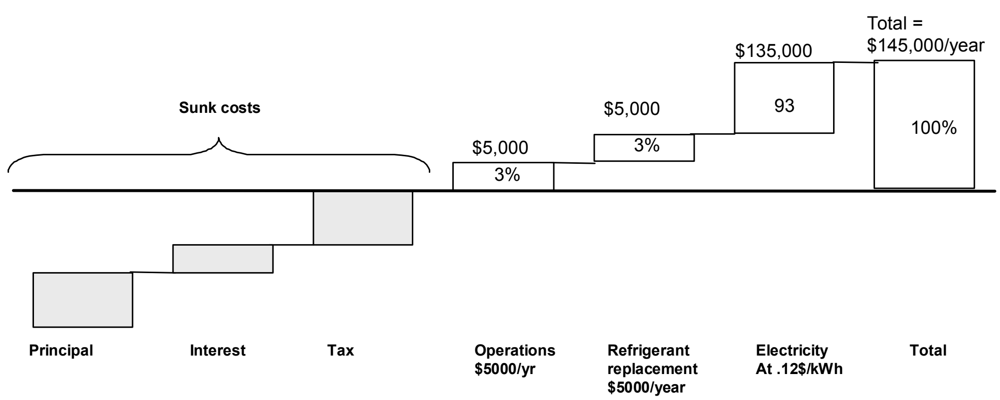


Assumptions: Public sector 57% large chillers (between 700 and 1300TR), 43% small chillers (between 350 and 450 TR). Private sector: 39% large chillers, 61% small chillers, based on market sample of 56 chillers in Brazil. Small chiller price including installation: $450/TR, Large chiller price including installation $340/TR, based on manufacturer estimate.

For public sector entities that have set aside budgets for conversion, there are savings of ~$39,000 per year per chiller to be gained. It makes sense that most of those entities have already made the conversion to a new chiller. However, this situation is not representative of a typical owner. Typical owners of CFC chillers have already paid off the full capital cost of the chiller. They must go through a full budgetary process to purchase a new chiller. Their funding environment may have changed in the 25 years since their purchase and they may not be able to get approval for new capital expenditure, or for increases in their annual spending.

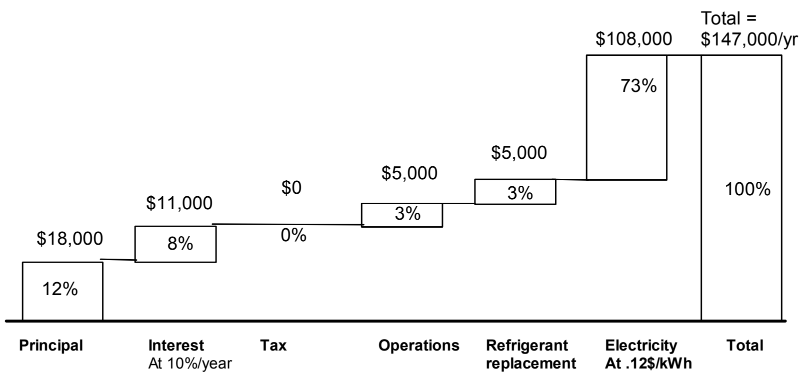
The public sector is divided between small (43%) and large (57%) chiller owners. Smaller chiller owners face higher $/TR equipment costs and lower annual energy savings compared to large chiller owners. As shown in the following figures, smaller chiller owners in the public sector have a funding gap in their ability to convert to non CFC chillers.

ANNUAL OPERATING EXPENSE OF SMALL CFC CHILLER IN THE PUBLIC SECTOR IS $145,000 ON AVERAGE



Assumptions: 400 TR chiller, .7 kW/TR power consumption, 11 hours/ day, fully paid off

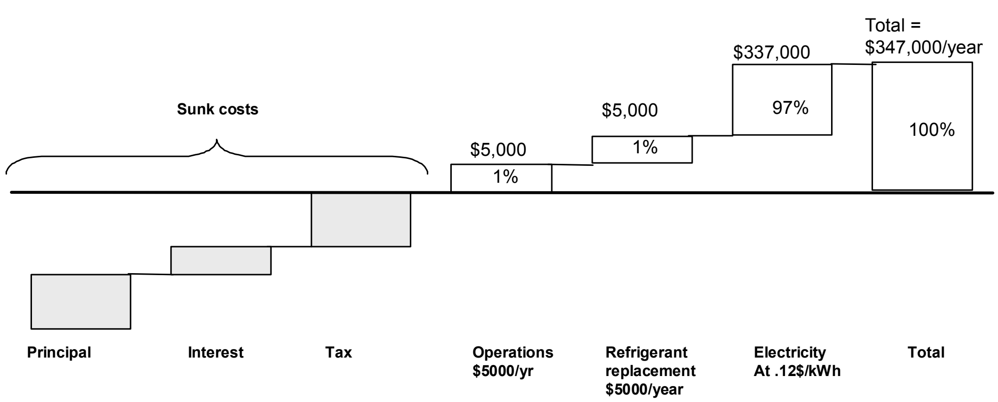
ANNUAL OPERATING EXPENSE OF A NEW SMALL NON-CFC CENTRIFUGAL CHILLER IN THE PUBLIC SECTOR IS HIGHER AT $147,000



Assumptions: 400 TR chiller, .56 kW / TR power consumption, 11 hours/ day, interest rate 10%, aggregate upfront taxes exempted for public sector, down payment 0%, Loan term 10 years, Chiller price $148,000, Installation $32,000.

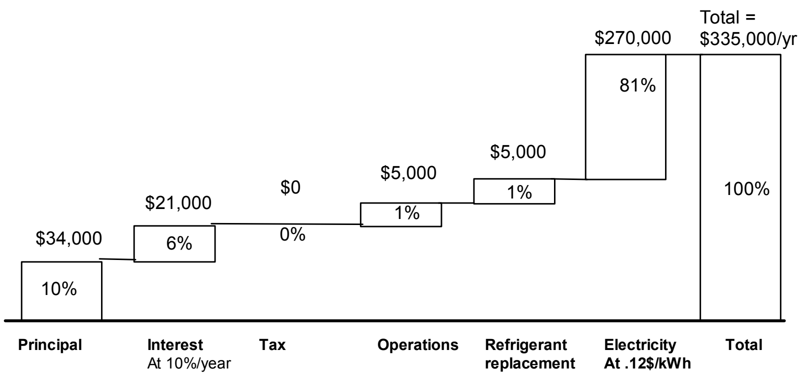
There is little economic incentive for small chiller owners to convert. However, the situation is different for large chiller owners.

ANNUAL OPERATING EXPENSE OF LARGE CFC CHILLER IN THE PUBLIC SECTOR IS $347,000 ON AVERAGE



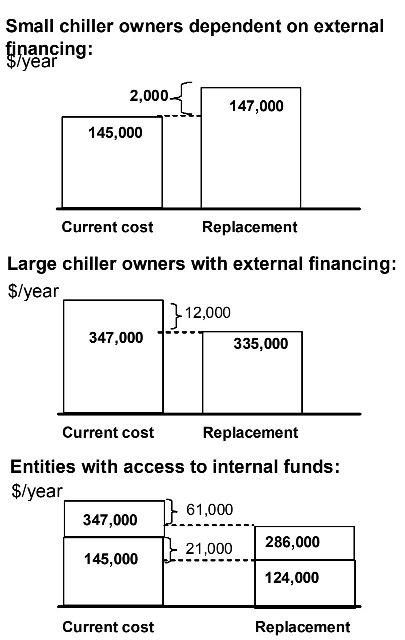
Assumptions: 1000 TR chiller, .7 kW/TR power consumption, 11 hours/ day, fully paid off

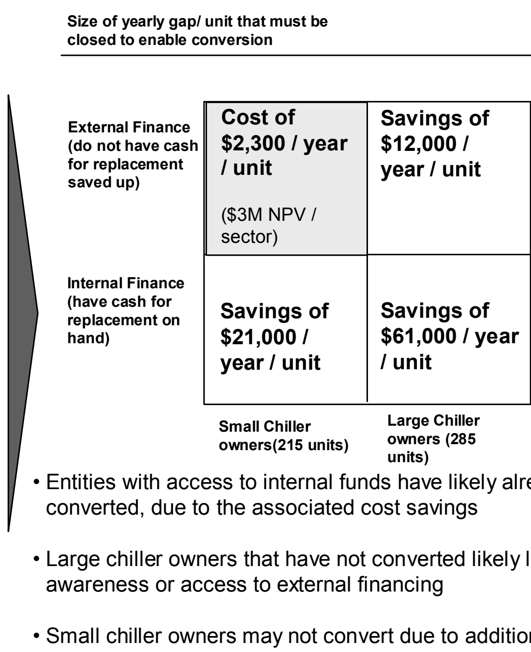
ANNUAL OPERATING EXPENSE OF A NEW LARGE NON-CFC CENTRIFUGAL CHILLER IN THE PUBLIC SECTOR IS LOWER AT $335,000



Assumptions: 1000 TR chiller, .56 kW / TR power consumption, 11 hours/ day, interest rate 10%, aggregate upfront taxes exempted for public sector, down payment 0%, Loan term 10 years, Chiller price $280,000, Installation $60,000.

FINANCIAL GAP OF $2,300 PER UNIT PER YEAR FOR SMALL UNIT OWNERS IMPLIES A TOTAL GAP OF $3 MILLION (NPV) IN THE PUBLIC SECTOR





- Entities with access to internal funds have likely already converted, due to the associated cost savings
- Large chiller owners that have not converted likely lack awareness or access to external financing
- Small chiller owners may not convert due to additional cost. This total gap is estimated to be $3 M for the public sector.

Assumptions: Small chiller: 400 TR , Large chiller 1000 TR, .56 kW / TR power consumption (replacement), .7 kW / TR power consumption (baseline), 11 hours/ day, interest rate 10%, aggregate upfront taxes exempted, down payment 0%, loan term 10 years

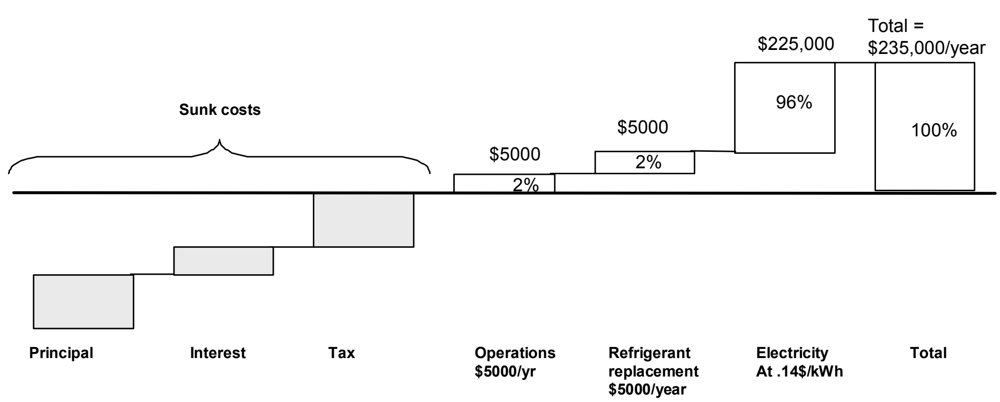
For public sector entities operating small chillers, the operating costs are $145,000 per year, per chiller. For them, it is $2,000 per year more expensive to operate a new non-CFC chiller than a CFC chiller (assuming a 10 year loan period). Using the conservative assumption that all public sector entities will need to take out loans (i.e., have not set aside budgets for) chiller replacement, the total gap for the public sector is estimated to have an NPV of $3 million. This includes the 215 estimated small chiller units in the public sector.

Public sector entities that have large chillers, will find savings of $12,000/ year / unit, including the cost of financing the chillers. As these entities do not have a funding gap, other barriers to conversion including education and access to financing might be at play.

Entities that have used their internal financing will see savings of $21,000/ year and $61,000/ year for small and large chillers respectively. Given these significant savings it is assumed that most entities will have already converted. However lack of education may be a barrier to conversion for these entities as well.

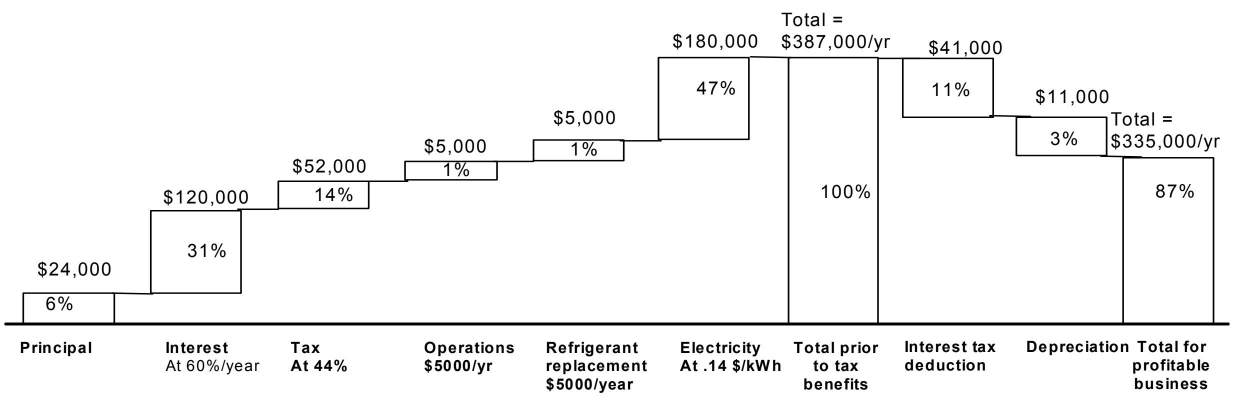
The financial gap is higher for the private sector, given the significant impact of upfront aggregate taxes (nearly 45%) and high interest rates (typically 60%). For private sector entities that have set aside a replacement fund, or have a sufficient cash reserve to fund the conversion, there are savings of ~$45,000 per year per chiller to be gained. It makes sense that most of those entities have already made the conversion to a new chiller. However, this situation is not representative of a typical owner. Typical owners of CFC chillers have already paid off the full capital cost of the chiller. They must acquire the capital needed to purchase a new chiller.

ANNUAL OPERATING EXPENSE OF CFC CHILLERS IN THE PRIVATE SECTOR IS $235,000



Assumptions: 700 TR chiller, .7 kW/TR power consumption, 9 hours/ day, fully paid off

ANNUAL OPERATING EXPENSE OF NON-CFC CHILLERS IN THE PRIVATE SECTOR IS SIGNIFICANTLY HIGHER, AT $335,000

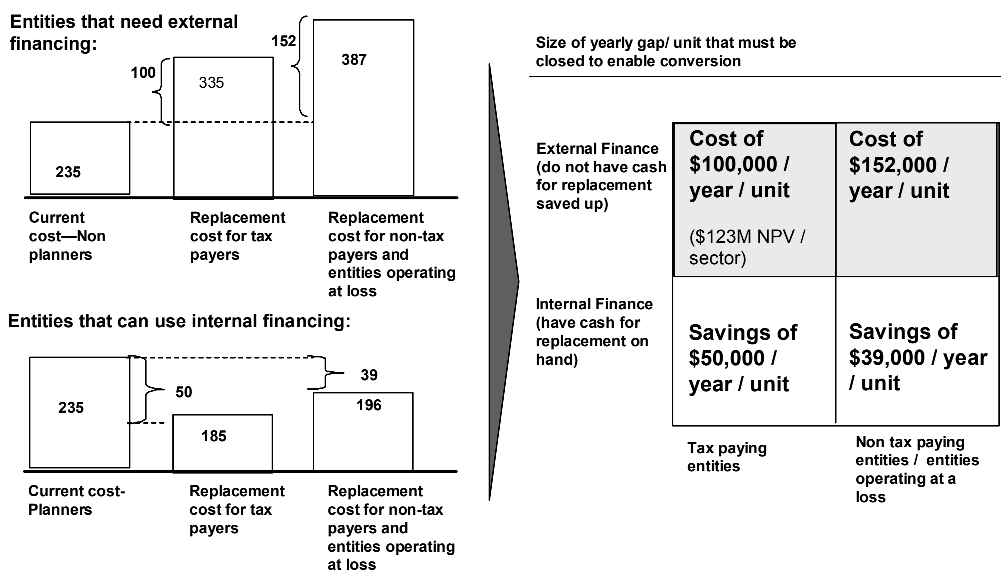


For profit making entities, a non-CFC chiller is $100,000 more expensive than the old equipment on an annual basis

Assumptions: 700 TR chiller, .56 kW / TR avg. power consumption, 9 hours/ day, interest rate 60%, aggregate upfront tax 44%, down payment 0%, Loan term 10 years, Chiller price $196,000, Installation $42,000., income tax rate 34%,

FINANCIAL GAP OF $100,000 PER UNIT PER YEAR IMPLIES A TOTAL GAP OF $123 MILLION (NPV) IN THE PRIVATE SECTOR

$000s



Assumptions: 700 TR chiller, .56 kW / TR power consumption (replacement), .7 kW / TR power consumption (baseline), 9 hours/ day, interest rate 60%, aggregate upfront taxes 44%, down payment 0%, loan term 10 years, chiller price $196,000, installation $42,000.

For private sector entities operating chillers, the operating costs are $236,000 per year per chiller. For them, it is $100,000 per year more expensive to operate a new non-CFC chiller than a CFC chiller (assuming a 10 year loan period). Using the conservative assumption that all remaining private sector chiller operators will need to take out loans (i.e., have not set aside budgets for) chiller replacement, the total gap for the private sector is estimated to have an NPV of $123 million. This includes the 750 estimated chiller units in the private sector.

Private sector entities that cannot take advantage of tax advantages, either because they do not make a profit or have previous losses, their increase in cost is higher at $152,000/ year. These entities would benefit from a lease, outsourcing or performance contracting arrangement, where the tax advantages of the capital expenditure can be captured by the service provider. For this reason they do not increase the overall funding gap, although they do highlight a distinct barrier that makes a case for the aforementioned initiatives to be included in the national strategy.

Entities that have used their internal financing will see savings of $50,000/ year and $39,000/ year for tax paying and non-tax paying respectively. Given these significant savings it is assumed that most entities will have already converted. However lack of education may be a barrier to conversion for these entities as well.

5.4 Sector Wide Strategies and Funding Options

STRATEGIES AND FUNDING OPTIONS

	1 Conduct marketing campaign	2 Reduce cost of equipment & financing	3 Offset risk of conversion
Purpose	Inform chiller owners of benefit of conversion and incentives available	Create time-bound incentive for chiller owners to convert, bringing owners to break-even	Offset risk associated with conversion; i.e., risk of insufficient energy savings, thereby providing non-financial incentives
Examples	*Provide information on:* ❑ Regulation ❑ Economic rationale ❑ Energy availability	*Reduce cost of equipment:* ❑ Demand-side management *Reduce cost of financing:* ❑ Interest rates	*Non-financial incentives:* ❑ Public sector loan fund ❑ Outsourcing

1. CONDUCT INTEGRATED MARKETING CAMPAIGN FOR CHILLER OWNERS (benefits and consequences of their chiller conversion decision)

Discussions with various stakeholders indicate that an effective marketing campaign is the critical first step in addressing barriers to conversion in both the public and private sectors.

This strategy will include the following components:

a. Marketing Program: In the implementation, the marketing campaign targeted to chiller users will be the critical first step; but cannot be assumed to be sufficient. Campaign needs to incorporate financial and non-financial incentives as well. Need to gear campaign towards all the different stakeholders (including consumers). The information campaign directed at chiller owners should highlight:
    - Regulation
        - On import and consumption of CFCs, impacting price and supply of CFCs (phase out by 2007), as well as the consequences of not converting
        - On energy efficiency, stating that all equipment must conform to certain energy specifications, also by 2007. The campaign should also clarify the consequences of not converting
    - High maintenance costs of old chillers
        - Leakage
        - Inefficiencies in old systems
        - Rising costs of R-12
    - Increased energy efficiency and also resulting energy savings
        - Highlight expected energy crisis?
    - Financing options and incentives, including
        - Limited duration tax incentives, etc

b. Involvement of key stakeholders in a single program. These stakeholders should include:
    - Ministry of Environment (Prozon)
    - Equipment manufacturers and suppliers association (such as ABRAVA, ABIMAQ)
    - Ministry of Mines and Energy
    - Ministry of Trade and Industry
    - Electric Utilities
    - Major suppliers and manufacturers of chillers
    - Major associations representing chemical companies and suppliers of CFC alternative chemicals (such as ABIQUIM)
    - Ministry of Finance
    - The banks that will be offering loan funds

c. Identification of catalysts to change, and provision of tools needed to make the conversion happen
    - Manufacturers
    - Lease/service providers
    - Utilities/ Ministry of Energy
    - Industry association (such as ABRAVA / education/training institutions, such as SENAI)

Although the marketing campaign is a critical first step, the financial gap will also need to be addressed in order to make replacement a reality. Aside from the marketing campaign, the strategies needed for the public and private sectors will be tailored to address the unique challenges faced in each sector.

As discussed earlier, the type of strategy needed will depend on whether the institutions have access to internal funds or must take out loans for the financing of the equipment.

Type of institution	*Economic situation*	*Strategy needed*
Institutions that have budgeted funding for replacement chillers, i.e., that have internal financing	The ones that have budgeted will see cost savings ($39,000/year in the public sector, $47,000 in the private sector) when they replace the chillers.	This segment can likely be effectively targeted through *education and marketing* in the demonstration phase, and will most likely require no further strategy.
Institutions that do not have internal capital for replacement chillers, and must rely on external financing.	These institutions are unlikely to convert given the absence of a budget for capital investment.	In addition to marketing, the strategy for this segment is to reduce the overall cost and provide access to financing, such that the increase in yearly costs is negligible or at least manageable.

2. REDUCE THE COST OF THE EQUIPMENT AND FINANCING

PUBLIC SECTOR

As the figures above demonstrate, the funding needed to cover the cost gap for all of Brazil's public sector is estimated at $3 Million out of a total capital cost of $135 Million. The funding to cover the cost gap can come from a combination of sources, each of which will be negotiated during the demonstration phase of the project. Some of the major levers to be utilized are[8]:

- *Loan Program:* If the system is financed, the interest rate will play a major role in annual cost. The interest rate used in this analysis was 10%. Creating a loan program with an 8% interest rate would achieve $3 M towards closing the funding gap. Interest rate can be reduced through programs such as those provided by US Export Import bank.

- *Demand-side management (DSM):* Brazil is facing an impending energy shortage. Conversion of all government chillers (500 units plus) will equate to a load reduction of approximately 197 GWh /year, including peak load hours. At current prices, the Ministry of Energy would avoid $25 M worth of investment in new power generation simply by facilitating this efficiency effort. Offsetting funding from the Ministry of Energy and related utilities for demand side management could therefore help fill the funding gap.

  Brazil faces a unique opportunity to employ DSM, given that Energy Saving Companies (ESCOs) are legislated to put 0.5% of revenues towards projects in themes suggested by the government

[8] Note that this analysis assumes that public sector entities will not be required to pay tax on imported equipment. Upfront taxes including VAT, Importation tax and others result in a charge of 25% in Brazil. If applicable, reducing or eliminating this tax on replacement chillers will be a necessary funding component.

  - The possibility to have chillers as one of the selected themes will be explored in the demonstration phase.
  - This option is complicated by competing incentives; on the one hand, utilities companies prefer to not engage in activities that decrease their revenue; on the other, a decrease in peak load is also interesting to them. In order for DSM to work, there is a need to change the incentive of utilities to increase energy efficiency.
  - The key here will be for the Ministry of Environment and Ministry of Mines & Energy to collaborate closely.

- *Absorption chillers:* For those with capital, and for whom energy self-sufficiency is critical, absorption chillers are an option; this option will be included in the demonstration phase.

- *Pooled purchasing:* Here, a number of the entities looking to convert could join forces and request discounts from the manufacturers.

PRIVATE SECTOR

As with the public sector, institutions in the private sector that have put aside a capital reserve for replacement of chillers can likely be effectively targeted through *marketing* in the demonstration phase, as they will see cost savings of ~$50,000/year/installation when they replace the chillers.

The ones that have not budgeted for replacement, however, will be unlikely to convert unless the upfront cost is eliminated, and the yearly costs are made negligible or at least manageable. The funding for covering the cost gap can come from a combination of sources, each of which will be negotiated during the demonstration phase of the project:

- *Limited duration tax incentives*: Upfront taxes including VAT, Import tax, State taxes and Federal taxes amount to a total charge of ~45% in Brazil. Reducing or eliminating some of these taxes on replacement chillers for a defined period of time will be a necessary funding component. Eliminating this fee would close the funding gap by $61 Million.
- *Private Sector Loan Program*: The interest rate will play a major role in annual cost. The interest rate used in this analysis was 60%. Creating a loan program that could offer an interest rate of 17% would achieve $108 M towards closing the funding gap. Discussions with BNDES indicate a local program called FINAME may be used as one component of this loan program. FINAME provides financing at 17% for some nationally produced equipment.
- *Demand-side management (DSM)*: Brazil is facing an impending energy shortage. Conversion of private sector chillers (about 750 units) will equate to a load reduction of approximately 247 GWh /year, including peak load hours. At current prices, the Ministry of Energy would avoid $37 M worth of investment in new power generation simply by facilitating this efficiency effort. Substitute funding from the Ministry of Energy and related utilities for demand side management could help fill the funding gap.

3. OFFSET THE RISK OF CONVERSION

PUBLIC SECTOR

This strategy is critical for institutions that do not have budgets for capital expenditure. To implement this strategy two financing vehicles are proposed:

- *Public sector loan fund*, which will be operated by a suitable entity to serve the public sector: either a development bank, or a special governmental facility

- *Outsourcing*, entailing the offering of both the equipment and services for a fee to the public sector entity. The fee is based on the costs incurred by the service provider plus a 5% management fee. Outsourcing could be offered either by a manufacturer or by an entirely new entity created for this purpose.

PRIVATE SECTOR

This strategy also focuses on businesses that have not set aside a capital reserve for capital expenditure.

- To implement this strategy, four financing vehicles are proposed:
  - Private sector loan fund (possibly building on FINAME)
    - This loan fund will be operated by a suitable entity to serve the private sector
  - Outsourcing
    - This option entails a manufacturer offering both the equipment and services for a fee to the public sector entity. The fee is based on the costs incurred by the service provider plus a 5% management fee.
  - Performance contracting
  - Leasing

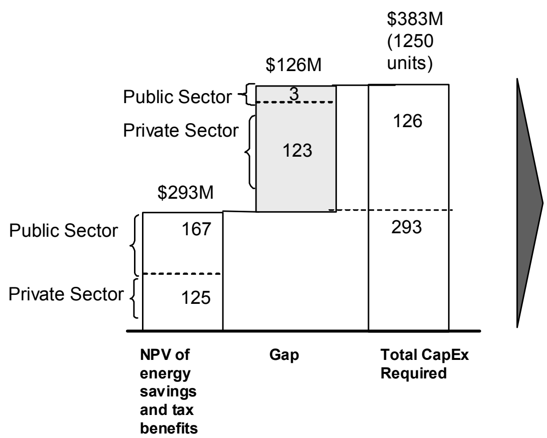
DEMONSTRATION PHASE SUMMARY

Using the strategies and funding options outlined above, the demonstration phase will leverage $2 million to put in place the business models, financing vehicles and educational programs such that during implementation:

- $13 million can be used to catalyze $135 million of capital expenditure, converting 100% of the chillers in the public sector in future; and
- $98 million of obstacles will be overcome and $25 million in financing will be used to catalyze $248 million of capital expenditure, converting 100% of the chillers in the private sector in future.

CHILLER CONVERSION FUNDING GAP IS $3M IN PUBLIC SECTOR AND $123M IN PRIVATE SECTOR

NPV $M

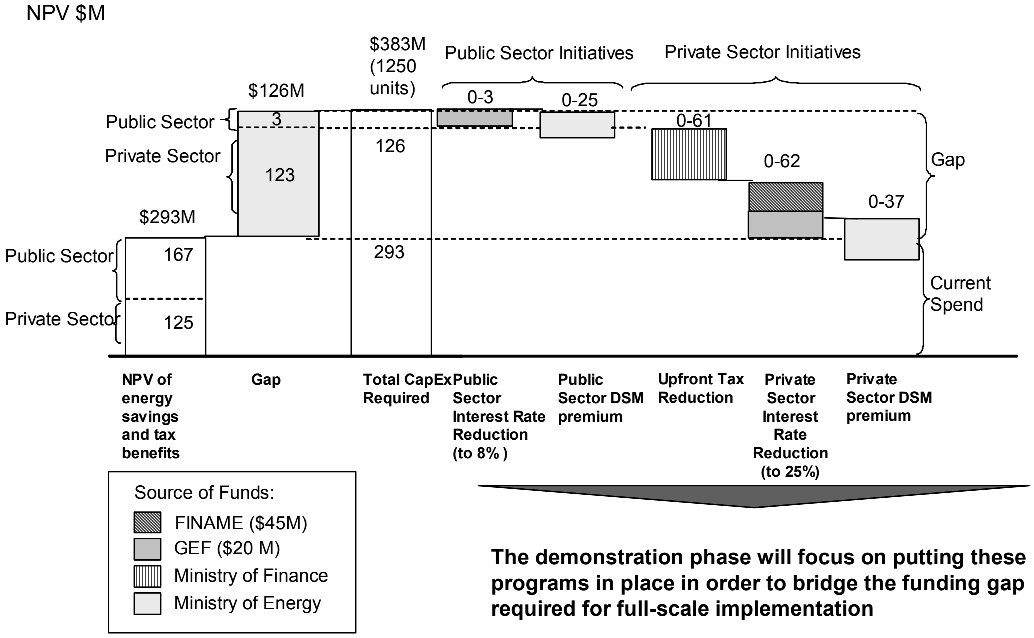


The total impediments to conversion in Brazil amount to $126M. Unless this funding gap is bridged through incentives and policy changes, 100% conversion of chillers will not be likely. The demonstration phase will seek to:

- Validate the proposed business models
- Put in place the conditions needed to implement the strategies
- Conduct the information campaign needed for full-scale implementation

BRAZIL IMPLEMENTATION PHASE GAPS AND INCENTIVES

NPV $M

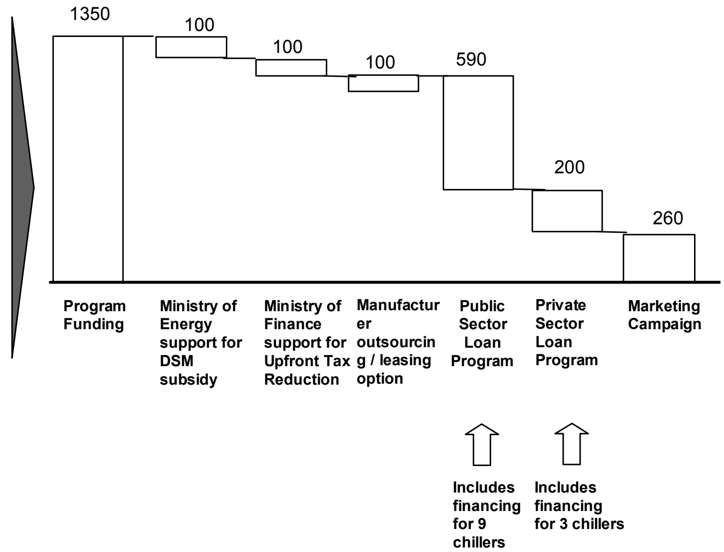


BRAZIL DEMONSTRATION PHASE COMPONENTS AND COSTS

$000s

To create the conditions for full-scale implementation, the demonstration phase will use $1.35 M to:

- Work with Ministry of Energy to gain support for integrated program, both financial and otherwise
- Work with Ministry of Finance to structure time-limited tax incentive
- Work with Manufacturers to create an outsourcing and/or leasing option
- Implement a public sector loan fund vehicle (possibly GEF)
- Implement a private sector loan fund vehicle (possibly to incorporate FINAME and GEF)
- Educate Public and Private Sector about benefits and consequences of chiller decisions



5.5 Project Components and Costs

In order to ensure adequate conditions for complete conversion of chillers in the public and private sectors, several program elements will need to be put in place:

<u>Integrated Marketing Program</u>: The integrated marketing program will last the duration of the demonstration phase, and will include all major stakeholders and all market segments. The program is estimated to cost $258,000.

<u>Demand Side Management</u>: The demand side management program will carry out the tasks needed to create an energy sector subsidy for replacement chillers. The program will involve developing a business case for the Ministry of Energy, as well as providing funding for staff to work with the Ministry of Energy to develop the program. The program is expected to result in a $62 M backing for chiller conversion, and will cost $100,000.

<u>Tax incentive program</u>: This program will carry out the tasks needed to develop a tax incentive program for replacement chillers. It will consist of building a business case for the Ministry of Finance detailing the net revenue impact, and long term economic impact, of a limited duration tax incentive on replacement chillers. The program is expected to result in the removal of $61 M in aggregate upfront taxes on chillers, and will cost $100,000.

<u>Public sector loan program</u>: This program will set up the management of a financing vehicle for the public sector, and will also finance 3 public sector demonstration projects. The key components are identifying the bank partner that will manage the fund, will work with the

bank program to detail the loan structure including interest rate and loan term. This program will implement and demonstrate the effectiveness of a financing vehicle that could be used to channel $13 M of co-financing (possibly GEF) and that will address the need for long-term financing in the public sector. This program will cost $594,000. The demonstration projects that will be implemented through this program will be:

- BNDES - 3 units
- Hospital das Clinicas Sao Paulo - 3 units
- Ministry of Mines & Energy - 3 units

Private sector loan program: This program will set up the management of a financing vehicle for the private sector. This program will also finance one private sector demonstration project with three installation sites. This program will identify the bank-partner that will manage the fund and will work with the bank to detail the loan structure for the program including interest rate and loan term. This program will identify the loan guarantees, national programs and other risk mitigation measures needed to create a loan program with interest rates at 17%. This program will implement and demonstrate the effectiveness of a financing vehicle that could be used to channel $25 M in financing, and the program will cost $198,000. The demonstration projects that will be implemented through this program will be:

- Pao de Acucar (grocery chain) - 3 units

Outsourcing program: This program will set up the management of a chiller outsourcing program for both the public and the private sector, thereby addressing the financing barrier in the chiller market. In the program, we will work with each of the major equipment suppliers, and gain the participation of at least one. The plan is to work with the equipment suppliers to create a financing vehicle necessary for them to be able to offer chiller service on an outsourcing basis. This program will cost $100,000. It will provide a much-needed alternative for public sector entities with restrictions on borrowing, and will be an attractive replacement option for private sector entities that cannot take advantage of tax benefits.

6. IMPLEMENTATION of DEMONSTRATION PHASE

6.1 Management

UNDP will manage the demonstration project using its National Execution Modality (NEX), providing oversight management to the national project management coordinator and team, as well as financial oversight management services. The project, with UNDP acting as facilitator, will work at the ground level to establish the key partnerships required, across sectors, in order to create the right environment in which the long-term sustainable conversion of chillers will be enabled.

6.2 Action Plan and Indicators of Success

COMPONENTS OF DEMONSTRATION PHASE

	Identify and mitigate risks	Validate business models	Assess success	Put in place conditions for implementation	Engage in marketing campaign
Activities	• Assess risks to implementation of demonstration projects, e.g.: - Regulation - Capital • Mitigate risks - Ensure appropriate regulatory environment - Secure funds and counterpart funding	• Engage in discussions with various stakeholders to put in place necessary conditions to test business models (i.e., by demonstrating economic rationale, etc.) • Operationalize models in selected entities across public and private sectors	• Determine success of demonstration projects based on demonstrable implementation progress as well as interviews with chiller owners • Tweak models as necessary	• Work with governments and other stakeholders to put in place conditions necessary for implementation on a larger scale	• Approach various stakeholders to discuss options • Obtain agreement on program overall and specific models to implement • Develop action plan to approach and convert remaining chiller owners
Results expected	• Modifications to legislative environment as needed • Securing of counterpart funds	• Conditions necessary for testing of proposed models	• Critical assessment of success and replicability of demonstration projects	• Legislative conditions and financial arrangements in place for full-scale implementation	• Strategy and action plan to convert all CFC owners • General awareness of program, particularly among chiller owners and manufacturers

The demonstration phase seeks to achieve several goals, and its success will be assessed on the following indicators:

1. Create an enabling environment for implementation
    a. Have the chiller owners in the demo phase all successfully replaced their CFC chillers with non-CFC chillers?
    b. Have the conditions for the various programs been implemented?, including:
        i. Tax
        ii. Loan structure
        iii. DSM
        iv. Outsourcing
2. Develop successful financing vehicles
    a. Are financing vehicles in place for:
        i. Public Sector Loan
        ii. Private Sector Loan
        iii. Outsourcing
    b. Do the financing vehicles eliminate 100% of the down payment?
    c. Are the annual servicing costs in line with the annual operating costs listed in this document?
    d. Are these funding programs available to all of the chillers in the sector?

3. Successfully implement demonstration projects
    e. Were all of the proposed installations, or surrogates, completed?
    f. Did the new chillers achieve the expected energy cost savings?
    g. Do the projects demonstrate an avoidance of significant increase in yearly cost?
    h. Do the projects include a diversity of sectors and applications?
4. Conduct an effective marketing campaign
    a. Have all chiller owners been reached out to?
    b. Do all chiller owners understand the incentives involved with the chiller conversion program?

6.3 Counterpart Funding

The proposed demonstration project under the Multilateral Fund of the Montreal Protocol will contribute to meeting the objectives of the GEF Operational program No. 5, "Removal of Barriers to Energy Efficiency and Energy Conservation" and the GEF Strategic Priority (CC-1) "Transformation of markets for high-volume, commercial, low GHG products or processes".

Stabilizing and reducing Brazil's energy demand in the building sector, through adoption of more energy efficient systems and practices, is no longer considered an option but a necessity. In 1985 the country introduced an official electricity savings program called PROCEL, and since them has implemented electricity conservation actions. Nevertheless, results are modest, poorly documented and annual savings are decreasing in the last few years.

Future expansion of hydroelectric potential required by Brazil faces a number of environmental, economic and social challenges. The bulk of Brazil's hydroelectric reserves lie deep in the Amazon. Concerns regarding environmental protection and conservation, displacement of indigenous peoples and destruction of habitat, and the very high initial capital considerations surrounding expansion deep into the Amazon mean that this resource may remain untapped. As a result, greater dependence on thermal options is expected to be the trend. The GEF component project will contribute to mitigation of greenhouse gases, with the attendant benefit being support of cross-convention synergies.

A Concept Clearance Document for pdf b has been completed for submission to the GEF Secretariat in order to secure pdf b pipeline entry in 2005. UNDP, through its GEF office, is presently in negotiation with the GEF Secretariat. Pdf b financing that would allow for a 0.35:1: co-financing ratio with the funding request being made of the Multilateral Fund's demonstration window is being sought. Ultimately, the GEF pdf b process is expected to result in the preparation of a Full Size project for submission, possibly as early as for consideration at the June 2006 Council meeting. The aim of the FS project will focus on capitalization of financial mechanisms and access to financing that will allow for provision of partial loan guarantees.

6.4 Demonstration Project Budget

Activity	Units	Total cost	Detailed Breakout	Total Req'd	MLF	GEF (pending approval)
Demonstration Phase						
Total demo units installed:			12			
Total funding required ($ 000s):			1,350			
Total Project:					**1,000**	**350**
Pillar III: Create Enabling Conditions						
Working with manufacturers				100	100	
Conduct feasibility assessment of performance contracting in Brazil						
Develop concept			25			
Test program on selected units			25			
Negotiate terms			50			
Working with Ministry of Finance				100	100	
Build business case for limited duration tax incentive			25			
Negotiate terms			25			
Assist Ministry with implementation of tax incentive						
Capacity building			50			
Working with Ministry of Mines and Energy				100	100	
Build business case for energy savings						
Demonstrate how program offsets need for additional capacity			25			
Negotiate terms			25			
Assist Ministry with implementation of new priority theme			50			
Pillar II: Put in Place Financing Mechanisms						
Public sector				594	394	200
Conversion of selected units						
Project:	Units	Total cost	Program loan guarantee			
Government Financial Institution--BNDES	3	459	180			
Government Hospitals --Hospital das Clinicas Sao Paulo	3	1,173	180			
Government Ministry --Mines and Energy	3	459	180			
Transaction costs associated with creating enabling conditions			27			
Set up and manage loan guarantee (staff time)			27			
Private sector				198	48	150
Conversion of selected units						
Project:	Units	total cost	Program loan guarantee			
Supermarket chain: Pao De Acucar	3	714	180			
Transaction costs associated with creating enabling conditions			9			
Set up loan guarantee (staff time)			9			
Pillar I: Conduct Marketing						
Develop Marketing Campaign				258	258	
Develop materials						
Staff time to develop materials (incl. cost of marketing firm)			100			
Cost of materials (publications, billboards, advertisements, etc.)			100			
Target and contact chiller owners			58			

transaction costs	5%
loan guarantee management	5%
loan guarantee per unit	60

ANNEX-1
ENERGY EFFICIENCY ANALYSIS METHODOLOGY

ENERGY EFFICIENCY ANALYSIS IN CHILLER REPLACEMENT

BASELINE SCENARIO		REPLACEMENT SCENARIO	
Installed chiller capacity (TR)	693	Replacement chiller capacity (TR)	693
Refrigerant Charge (Kg)	1,126	Refrigerant Charge (Kg)	693
Annual Leakage Rate (Kg/year)	113	Annual Leakage Rate (Kg/year)	14
Balance Economic Lifetime (Years)	10.00	Comparable Economic Lifetime (Years)	10.00
Energy Efficiency (Kw/TR)	0.70	Energy Efficiency (Kw/TR)	0.56
Energy Costs (US$/Kwh)	0.086	Energy Costs (US$/Kwh)	0.086
Equivalent Full Load operating Hours (EFLH/yr)	3,406	Equivalent Full Load operating Hours (EFLH/yr)	3,406
Annual Energy Use (Kwh)	**1,652,251**	Annual Energy Use (Kwh)	**1,321,800**
Annual Energy Costs (US$)	**142,094**	Annual Energy Costs (US$)	**113,675**
Lifetime Energy Costs (US$)	**1,420,936**	Lifetime Energy Costs (US$)	**1,136,748**
Annual Direct CO_2 Emissions (Tonnes-CO_2)	**706**	Annual Direct CO_2 Emissions (Tonnes-CO_2)	**10**
Annual Indirect CO_2 Emissions (Tonnes-CO_2)	**496**	Annual CO_2 Emissions (Tonnes-CO_2)	**397**
Annual Total CO_2 Emissions (Tonnes-CO_2)	**1,202**	Annual Total CO_2 Emissions (Tonnes-CO_2)	**406**

RESULTS	
Annual Energy Savings (Kwh)	**330,450**
Annual Energy Cost Savings (US$)	**28,419**
Lifetime Energy Cost Savings (US$)	**284,187**
Annual Total CO_2 Emission Reductions (Tonnes-CO_2)	**795**
Lifetime CO_2 Emission Reductions (Tonnes-CO_2)	**7,955**

Notes and assumptions:

1. In the baseline, 50% chillers are CFC-11 based and 50% are CFC-12 based.
2. In replacement, 50% chillers are replaced with HCFC-123 technology and 50% with HFC-134a technology
3. GWPs are CFC-11: 4,000 CFC-12: 8,500 HCFC-123: 93 and HFC-134a: 1,320
4. Baseline annual leakage rate is 10% of the initial refrigerant charge.
5. Annual leakage rate after replacement is 2% of initial refrigerant charge
6. The refrigerant charge in replacement chillers is estimated at 1 Kg/TR

ANNEX-2
REPLICATION OF THE STRATEGY

There is significant potential to achieve energy savings and reduce greenhouse gas emissions from the chillers market in Brazil, while at the same time contributing to the phase out of CFCs in an important emerging economy. GEF funding in the amount of $20 million will be requested to help remove policy, information, finance and technology barriers that are currently standing in the way of the widespread adoption of energy-efficient chillers in Brazil and to spur broader scale replication in neighboring countries.

The goal of the project will be to influence, develop, and transform the market for energy-efficient chillers in Brazil to help chart a less carbon-intensive and more sustainable path in the country, which in turn could positively influence the chillers market in Latin America as a whole. The proposed project conforms to GEF Operational Program 5: Removal of Barriers to Energy Efficiency and Energy Conservation as well as the recently adopted Strategic Objective related to Energy-Efficient Appliances.

An initial problem assessment has identified the following barriers, grouped into four categories.

I. Policy
   a) Absence of energy policy to promote energy efficiency in the chillers sector;
   b) Weakness and/or absence of regulatory framework;
   c) No lead organisation to promote energy efficiency in existing chillers;
   d) Lack of utility involvement;

II. Information
   e) Lack of awareness of energy efficiency benefits among building managers, chillers operators, building owners, national or local authorities, and energy suppliers;
   f) Absence of a strategy to educate and sensitise building managers and building owners on the benefits of energy efficient chillers;

III. Finance
   g) Absence of markets for energy efficiency services for operating chillers;
   h) High initial cost of energy efficiency equipment;

IV. Technology
   i) Lack of specialised trained personnel.

The GEF project will strive to remove all of these barriers through a comprehensive approach that will focus on creating a favorable policy environment, establishing a network between the project and key public and private actors, including chillers users, increasing awareness among key stakeholders, implementing a partial guarantee fund to reduce the risks of investing in the technology, and providing technical assistance to manufacturers. On the policy side, the project will assist the government in developing standards and certification for chillers through a national consultation process bringing together the public and private sectors, as well as civil society at large. Here, it will be important to build public-private partnerships to assist in the phase out of old chillers.

To address information barriers, the GEF intervention will support a nationwide marketing and public education program to highlight the benefits of energy efficient chillers. This program would be targeted to all of the respective stakeholders involved in chillers operation. It will also develop a range of knowledge products about the economic merits and technical options for replacing inefficient chillers that can lead to broader scale replication in other Latin American countries.

On the finance side, a partial guarantee fund will be employed as a cost-effective and market-oriented way of supporting investments in CFC-free, energy-efficient chillers. This approach would aim directly to reduce many of the real and perceived project risks and would effectively ensure a payback period of 3-5 years for building owners who retrofit or replace an old CFC chiller. In addition, the project will explore the possibility of fiscal incentives such as tax waivers to further promote the adoption of energy-efficient chillers.

Finally, technical assistance will be provided to business and industry associations, chillers manufacturers and industry participants. This could involve hands-on 'learning by doing' training and TA activities. By taking a holistic view of the market and targeting both the supply and demand side of the chillers market, the project will boost its chances of success and hence increase its potential impact on reducing greenhouse gas emissions. Replacing CFC based chillers contributes to lower greenhouse gas emissions, both from an energy consumption perspective and from the reduction of CFC emissions, which have a very high global warming potential.

One of the key lessons that has emerged from UNDP-GEF's 14 years of project-level experience is that project and regional networking play an important role in ensuring that the successful features of well-designed projects are incorporated in the design of ongoing and future projects. Through targeted meetings of project managers and country office personnel for specific types of projects, those involved with project management can discuss both technical and administrative issues, share experiences and best practices, and gain a sense of how the portfolio functions at a regional level. For instance, UNDP-GEF convened meetings for its biomass project portfolio in 2002 and 2004, and it organized a similar meeting for projects in the heat sector in 2004.

A similar chillers knowledge network could be envisaged under the auspices of the Brazil project to encourage information sharing, effectively market, and facilitate replication of project activities to other parts of the region. Additionally, the project itself will draw on the experience of, and incorporate lessons from, previous UNDP-GEF refrigerators projects in China and Tunisia, which although focused on residential appliances as opposed to commercial chillers, could still provide useful insights on how to improve awareness and replicate project results elsewhere.

Endorsement and adoption of this project would position Brazil as one of the front leaders in the area of market transformation for energy efficient (EE) technologies, with wide-ranging applications and replication potential, both to other appliances and equipment, as well as in- and outside of Brazil.

ANNEX-3
Disposal of Replaced Baseline CFC-based Chillers and CFCs

Replaced Baseline Chillers

All recipients under the chiller replacement demonstration programme shall provide a Baseline Equipment Disposal Report to MMA/Prozon in the following format upon completion of the replacement:

Name of Owner:	
Address/Location:	
Date of Commissioning of replacement chiller (s)	

Baseline Equipment Make & Model	**Qty**	**Description and type**	**Date Installed**	**Disposal Method**	**Date of Disposal**	**Verified by**

Disposal methods would be one or more of the following, but would ensure that the disposed equipment and parts are rendered unusable with CFCs:

A - Dismantled and stored (electric motors, pumps, controls, accessories)
B - Dismantled and re-used (electric motors, pumps, controls, accessories)
C - Dismantled and disposed as scrap (other parts)
D - Destruction and disposed as scrap (for compressors)

CFCs

All recipients under the chiller replacement demonstration programme shall recover the CFCs from the replaced baseline chillers, maintain a record of the inventory of these CFCs and provide a CFC Disposal Report to MMA/Prozon in the following format upon completion of the replacement:

Name of Owner:	
Address/Location:	
Date of Commissioning of replacement chiller (s)	

CFC Name	**Initial Charge (Kg)**	**Amount Recovered (Kg)**	**Amount Re-usable (Kg)**	**Amount Un-usable (Kg)**	**Storage Location of Re-usable CFCs**	**Storage Location of Un-usable CFCs**	**Verified by**

The disposal of CFC-based baseline centrifugal chillers and CFCs shall comply with the applicable national regulations and be performed in accordance with the relevant national/international standards and practices.

MMA/Prozon will periodically carry out an independent verification of the reports.

ANNEX-4
BRAZIL NATIONAL PHASE-OUT PLAN LETTER of ENDORSEMENT

COUNTRY:	REGIONAL / West Asia
IMPLEMENTING AGENCY:	UNIDO
PROJECT TITLE:	Demonstration Project on the Replacement of CFC Centrifugal Chillers in Bahrain and Syria
PROJECT IN CURRENT BUSINESS PLAN:	No
SECTOR:	Refrigeration
SUB-SECTOR:	Air Conditioning and Process Cooling
PROJECT IMPACT (ODS TO BE ELIMINATED):	8.40 ODP-weighted mt
PROJECT DURATION:	36 months
PROJECT COSTS:	
Incremental Capital Cost:	US$ 2,291,600
Co-financing:	(US$ 467,900)
Contingency (10% of equipment cost):	US$ 189,370
Total Project Cost:	US$ 2,083,070
Requested Grant:	US$ 2,083,070
Implementing Agency Support Cost:	US$ 156,700
Total Cost Of Project To Multilateral Fund:	US$ 2,239,770
Status Of Counterpart Funding:	Commitment confirmed by counterpart
Project Monitoring Milestones Included:	Yes
National Coordinating Agency:	National Ozone Units

PROJECT SUMMARY

The project will phase out 8.40 ODP MT of CFCs by replacing 7 CFC based centrifugal chillers and retrofitting 4 chillers in 2 countries in the West Asian Network; The Kingdom of Bahrain and the Syrian Arab Republic. The sites selected are two public hospitals and a hotel which is state owned. The project includes the costs for retrofitting 4 chillers and for replacing 7 centrifugal chillers supported by 25% counterpart co-financing technical assistance, funds for fostering local initiatives for chiller replacement and funds for organizing a regional workshop at the end of the demonstration project to exchange information on the results of the demonstration project with other countries in the region.

Impact of project on country's Montreal Protocol obligations:

The project will demonstrate the value of early chiller replacement and phase out 8.40 ODP MT of ozone depleting substances in the chiller sub-sector

Prepared by: Ms. R. Ghoneim / Mr. R. Huehren **Date:** September 2005
Reviewed by: Mr. C. Murdoch **Date:** October 2005

1. Project objective

The project aims at demonstrating the value of replacing a number of CFC-based centrifugal chillers into non-CFC alternatives in two West Asian Countries operating under Article 5 of the Montreal Protocol on substances that deplete the ozone layer namely Bahrain and Syria.

- The main objectives of the proposed project are to assist countries:
- To reduce their consumption of ozone depleting substances (ODS) as required under the Montreal Protocol
- To improve the energy efficiency of liquid chillers, demonstrating actual energy savings and reduce greenhouse gas emissions in refrigeration and air conditioning sector resulting from the replacement of 7 old CFC chillers & retrofitting 4 chillers
- The project will specifically facilitate the early replacement of CFC chillers with low-energy efficiency to non-CFC chillers with a high-energy efficiency.

Based on intermediate findings of the demonstration project, UNIDO will develop a replacement policy for the remaining CFC chillers in the 2 countries in cooperation with the competent Government Bodies and stakeholders.

2. Background

The Fourteenth Meeting of the Parties (MOP), in its decision XIV/9, decided to request the Technology and Economic Assessment Panel (TEAP) to collect data and assess the portion of the refrigeration service sector made up by chillers and identify incentives and impediments to the transition to non-CFC equipment and prepare a report; and to request the TEAP to submit the report to the Open-ended Working Group meeting (OEWG) for their consideration. The sixteenth MOP considered the recommendations of the OEWG and decided to request the Executive Committee through decision XVI/13 to fund additional demonstration projects to demonstrate the value of replacement of CFC-based chillers. In the light of decision XVI/13 of the Parties, the Executive Committee decided to establish a funding window amounting to *US $*15.2 million for the chiller sector in 2005 and requested Secretariat to prepare a study on criteria and modalities on how a regional fund for the chiller sector might come into operation to be considered at the Fourty Sixth Meeting.

The Fourty Sixth Meeting of the Executive Committee considered the report of the Secretariat and adopted decision 46/33, which invites the implementing agencies to submit to the Fourty Seventh Meeting of the Executive Committee project proposals to demonstrate the feasibility of and the modalities for replacing centrifugal chillers through the use of resources outside the Multilateral Fund and which could be replicated in other countries.

The general conditions for such investment demonstration projects are:

- Ensure a regional and geographical balance of projects
- Consumption of ODS for servicing of chillers represents a good portion of the overall servicing consumption of a country
- The relevant countries have enacted and are enforcing legislation to phase out ODS
- The project intends to use financial resources outside the Multilateral Fund such as national programmes, GEF funding or other sources. The credibility of those financial resources has to be demonstrated before disbursement of funds approved under the Multilateral Fund can commence;
- The total funding per chiller is determined using a mathematical and/or business model, taking into account relevant decisions of the Executive Committee, such as the share of transitional ownership
- The maximum Multilateral Fund grant for a particular country is US $1,000,000;
- The project proposal includes a general strategy for managing the entire CFC chiller sub-sector in the countries concerned.

3. Introduction

Detailed surveys have been carried out to establish the numbers, types and applications of centrifugal chillers in Kuwait, Yemen, Bahrain and Syria. The details of the surveys for Bahrain and Syria are included in the annexes to this document. Yemen and Kuwait are not covered by this proposal. While the survey in Yemen identified only 2 CFC based chillers in one location, the survey in Kuwait identified more than 250 CFC based chillers, however due to time constraints, it was no possible to finalize the data collection in Kuwait, therefore a project proposal for Kuwait might be prepared and submitted to the ExCom at a later stage.

During the course of the surveys it became clear that lack of information on the economical benefits of chiller replacement is the greatest barrier to progress in this sector. The major barrier is general economic constraints on investment and funding for capital replacement.

This project aims to remove both barriers through awareness raising and provisions with economic incentives.

Results and activities necessary to be implemented includes demonstration projects, awareness rising and reuse of recovered CFC refrigerants

Syria and Bahrain are very well advanced in the implementation of the Montreal Protocol in the refrigeration sector. All manufactures had been converted to ODS free technology.

The service sector is the largest area remaining with significant CFC consumption.

Syria and Bahrain have introduced a licensing system allowing the control of ODS imports. Yemen is about to introduce the licensing system.

Reported CFC consumption in 2004 (kg)

Country	Refrigeration service sector	chiller sector kg
Syria	804.45	4,108
Bahrain	64,800	27,600

Results of the chiller survey in both countries is attached as annexes 1 and 2 to this document.

4. Approach

4.1. General

The key objective of the proposed demonstration projects should be to clearly evaluate and demonstrate the incentives for operators to convert / replace CFC based centrifugal chillers.

As demonstrated by the work carried out by the World Bank in developing its opportunity cost model, it will only be through detailed understanding of these incentives that operators and owners will be persuaded to invest in conversion or replacement activities.

The project is designed to identify all applicable incentives for owners and operators. These fall within 3 principle categories:

- Financial – opportunity cost, energy savings, reduced maintenance
- Operational – process improvement, improved reliability
- Practical – lifecycle replacement, planned reconfiguration,

It has been found in non-article 5 countries that the instigation of basic plant monitoring, including energy consumption, chiller efficiency, operation and control regime often highlights potential process improvements that have significant cost savings potential in terms plant utilisation, energy efficiency and even reduced plant capacity requirements. A key feature of the demonstration project will therefore be to apply rigorous monitoring of chiller installations before and after replacement.

The chiller project will be implemented using strict criteria under which a chiller replacement can be co-funded. The criteria developed and refined by this project will then be used for the national strategy for chiller replacements.

The concept of a revolving fund has been analyzed, but is not included in this proposal. Results of the cash flow analysis of a revolving fund are presented as annex 4 to this document.

An opportunity cost model will be applied in each counterpart and this will take into account local factors such as energy costs, cost of debt finance, and operator's access to finance and other and average life cycles of plant. It will also be important to take account of technical and economic know how of operators when considering how to validate the models to owners, operators and investors.

The incentive for chiller replacement will be demonstrated based on the rate of return of investments in the range of 30% through an innovative financial mechanism consisting of a national component through green loans, funds from the MF, in kind contribution and provider guaranteed energy efficiency.

4.2. Outputs

The outputs of the demonstration project will include the technical selection of the most suitable replacement options, the development of appropriate monitoring and evaluation protocols and the development of appropriate financial mechanisms for co-funding future projects throughout the region.

Output	Activities	Measures
Demonstration: More chillers are converted to ODS free technology in the region.	• Selection of four chiller replacements according to selection criteria with the best demonstrative value • Detailed energy and performance monitoring • International tender on conversion technology for these four sites • Contracting the conversion and monitoring its progress • Publishing the results from the conversions	chillers converted monitoring output and analysis
Awareness: Governments, end users and manufacturers are aware of the economic and technical incentives from chiller replacement.	• Dissemination of results from the demonstration projects in Local language • National workshops with institutions, manufacturers and end users • Regional conference for all Local countries on the results of the demonstration projects • Publication of proceedings from the conference • Promotion of chiller replacement through media	regional conference user survey more suppliers enquiries
Environmental Impact:	• Provision with R&R equipment (R&R	8,400 kg

R11 and R12 is recovered and reused. Energy Savings leading to reduced CO_2 emissions	unit for R12, liquid pump for R11 and necessary storage devices)or including mandatory recovery of refrigerant in the contracts for the demonstration sites • Arranging for gas distributors or equipment supplier to buy the recovered refrigerant Monitor progress of reuse of refrigerant	CFC refrigerant recovered and available to service sector

5. Site Selection Criteria

The demonstration project will be based on installation of high efficiency non-CFC chillers with an average rated energy consumption of 0.60 kW per capacity of refrigerated ton.

The technology selected must environmentally sound, economically viable and be technically feasible for the application.

The basic estimates factors used to develop the details of the proposal are as follows:

- Average chiller capacity and efficiency
- Baseline electricity consumption
- Electricity consumption with new chillers
- Cost of electricity
- Estimated running time
- Baseline water consumption
- Cost of water
- Water consumption with new chillers
- Refrigeration demand over time
- Refrigerant leakage
- Technical condition
- Solvency of company
- Hold legal status of the buildings
- Availability of qualified technicians
- Average remaining life
- Owners prepared to co fund

The following matrix will provide the transparent criteria on the technical and economic feasibility of replacements can be based.

Criteria	Value	Bahrain	Syria
Refrigerant charge	Min. 400 kg	Given in selected location	Given in selected location
Type of chiller	centrifugal	Given in selected location	Given in selected location
ODS consumption of chiller sector	more than 7.5% of total in ref. servicing sector	Yes	Yes
Full inventory of chiller sub sector provided		Yes	Yes
Energy saving	28-45%	Kwh 0,04 US$	Kwh 0,05 US$
Rate of return of investment	4-6 years	6 years	6 years
Retrofit costs competitive	must be higher than usual maintenance costs	Costs are higher	Costs are higher
Condition of chiller	Remaining life at least 10 years	Selected site < 10 years	Selected site < 10 years

Criteria	**Value**	**Bahrain**	**Syria**
Public or private ownership	Private sector more likely to provide funding	Hospital public ownership	Hotel Gov. ownership
Recovery of refrigerant	has to be mandatory and equipment must be available	11,016 kg	6,116 kg

6. Assessment and Description of Selected Sites

The following sites were selected in consultation with the national ozone offices taking into account the criteria indicated above:

6.1. Syria

Two sites have been selected in Syria; Le Méridien Lattakia which operates 3 old centrifugal chillers which are nearing the end of their operating life, and Al Basel hospital Tartous which operates 4 air cooled condenser chillers.

Site	Make	Qty	Type of refrigerant	Ref. charge each kg	Ref charge total kg	Leakage rate each/total kg / year	Capacity TR each	Capacity TR total
Le Méridien Lattakia	Trane F	3	CFC-12	600	1800	750	320	960
Al Basel hospital Tartous	Trane F	4	CFC-12	681	2724	600	300	1200

It is necessary to prepare a detailed presentation of recommended solutions to the management and the engineering team of these sites. This presentation will stress on CFC emissions phase out, energy saving and a better operation of AC systems.

6.2. Bahrain

In Bahrain the selected site is the Salmaniya Hospital which operates 10 Carrier chillers connected to two water-cooling towers. The Inventory of chillers is as follows:

4 x CFC-12 chillers capacity of 500 TR, installed 1977.
2 x CFC-500 chillers, capacity 770 and 500 TR installed 1996.
2 x HCFC-22 based chillers, capacity each 375 TR installed 1996
2 x HFC-134a based chillers, capacity 770 TR installed 1996.

The project will replace for the four 1977 CFC-12 chillers.

Brand Name	Type of refrigerant	Refrigerant charge each kg	Refrigerant charge total kg	Leakage Rate each/total kg / year	Capacity TR each	Capacity TR total
CARRIER	R12	1040	4160	650/2600	500	2000

7. Comparison of Available Replacement Technologies

7.1. Available Technologies

The components of a chilled-water system include a chiller, air-handling units with chilled-water coils, chilled-water loop(s) with chilled-water pump(s), a condenser water loop, condenser water pump(s), and a cooling tower. Optimizing chilled-water systems requires careful integration of these components. The main components of a water chiller are compressor, evaporator and condenser (water-to-refrigerant heat exchangers). The chiller is the heart of the system and generally the single largest energy user in non-industrial buildings.

Replacement options depend on the size of cooling capacity range, energy efficiency, environmental data, safety, flammability etc.

A - Chiller technologies alternatives

Compressor	Typical Capacity Range	Refrigerant Alternative
Centrifugal	> 700 kW (200 ton)	HCFC-123, HFC-134a, HCFC-22
Screw	200-1500kW (50-400 ton)	HFC-134a, HCFC-22, HFC-407C HFC-410A , R-717
Scroll	75-300kW (20-80 ton)	HFC-134a, HCFC-22 HFC-407C, HFC-410A
Reciprocating	75-500 kW (20-150 ton)	HCFC-22, HFC-407C, HFC-410A, R-717

B - Absorption technologies

	LiBr-H20	NH3-H2O
ODP	0.0	0.0
GWP	0.0	<1
COP	≈1.0	≈1.0
Cooling capacity	> 10 kW	> 0.1 kW

Modern chillers use about 35% less electricity than average chillers produced just two decades ago and the best chiller today uses half the electricity of the average 1976 chiller.

The performance of a chiller can be specified using full-load or part-load efficiency (kW/ton) depending upon the application. Part-load efficiency (IPLV) is preferred for more variable loads accompanying variable ambient temperature and humidity that is more common situation.

Full-load is appropriate where chiller load is high and ambient temperature and humidity are relatively constant (e.g., for baseline chillers). In the following table recommended and best available chiller efficiencies are given published in 2004 by US Department of Energy - Federal Energy Management Program.

Compressor Type and Capacity	Part Load Efficiency IPLV (kW/TR)	
	Recommended	**Best Available**
Centrifugal 150 – 299 tons	0.52 or less	0.47
Centrifugal 300 – 2,000 tons	0.45 or less	0.38

Rotary Screw ≥150 tons	0.49 or less	0.46
Compressor Type and Capacity	**Full Load Efficiency (kW/TR)**	
	Recommended	**Best Available**
Centrifugal 150 – 299 tons	0.59 or less	0.50
Centrifugal 300 – 2,000 tons	0.56 or less	0.47
Rotary Screw ≥150 tons	0.64 or less	0.58

US Department of Energy - Federal Energy Management Program, 2004 (1 ton (refrigeration) = 3.517 kW)

The higher efficiency of today's chillers is a result mostly of the improved new control of chiller unit and optimisation of the cooling system including pumps, fans and cooling tower. It is common for modern chillers to incorporate Variable Speed Drive (VSD) systems, which allows the capacity to be varied by varying compressor speed and, in the case of centrifugal compressors, fine tuning of inlet vanes to maintain the optimum compressor efficiency at all loads.

The VSD control is recommended for chilled water and condenser water pumps, as well as cooling fans. The payback of investment in VSD control varies from 1 to 5 years.

7.2. Alternative Refrigerants for Chillers

A –Basic Parameters of Available Refrigerants

	CFC-11	**CFC-12**	**HCFC 22**	**HCFC 123**	**HFC 134a**	**HFC 407C**	**HFC 410A**	**R717 Ammonia**
ODP	1.00	1.00	0.055	0.02	0.0	0	0	0
GWP	4,600	10,600	1,700	120	1,300	1,700	2,000	<1
Atmospheric life (years)	45	100	11.9	1.4	13.8			
Safety group	A1	A1	A1	B1	A1	A1	A1	B2
Flammability LFL	none	None	none	None	None	none	None	15
COP (*)			6.35	6.78	6.27		5.95	6.66
Compressor type (**)	4	1, 2, 3, 4	1, 2, 3, 4	4	1, 2, 3, 4	1, 2, 3	1, 2, 3	1, 2, 3

* *Ideal cycle at condensing temperature of 40.6°C and evaporating temperature of 4.4°C*
** *Compressor types: 1-reciprocating, 2-scroll, 3-screw, 4-centrifugal*

B - Basic Performance Parameters of Alternative Plants:

This includes the comparison of the existing and possibly the new refrigeration plant. The comparison is made under identical performance requirements and plant conditions.

Comparison of performance figures:

Description	**unit**	**CFC**	**134a**	**Ammonia**	**Ammonia / SIS**
Performance rating	TR	560	560	560	310
Energy Consumption	kW	465	392	369	321
Connected Load	kW	500	550	500	367
COP (Compressor)		4,21	4,21	5,27	5,27
Condenser rating	kW	2,475	2,475	2,475	0
Chiller water volume	m^3/h	304	304	247	247
Ventilator rating	kW	13	13	13,3	13,3

Connected load	kW	15	15	14,7	14,7
Peripherals and pumps	kW	58	58	60	60
Connected load	kW	74	74	77	77
total connected load	kW	589	639	458	458
consumption	kW	546	475	395	395
main system COP		3,66	3,66	5,07	5,07
daily average refrigeration load	kWh	18894	18894	18894	18894
daily el. consumption	kWh	4849	4491	4234	3726
Water requirements	m^3/h	12.0	12.0	12	10,1
annual electricity costs	US$	106193	98353	92725	81599
annual water costs	US$	27740	27740	27740	23024
leakage rate	%/a	15-30	4	0	0

The newest chiller systems can provide up to 38% savings in electricity and 28% in water consumption.

The project will clearly demonstrate that economic incentives combined with promotional efforts will speed up and enhance the terminal phase out of CFC for chillers very quickly. Without such efforts, the sector will be at critical stake for many following years. One important indicator for decision making will be the price for CFCs. In the midterm only a drastically reduced demand and market for CFCs will make it financially nonviable.

8. Selection of the technology

8.1. Direct project impacts

The actual amount of CFC eliminated will depend on the number of chillers replaced, the size of chillers, leakage rate, age, etc. The project impact is calculated as the sum of the volume of the refrigerant leakage for the chillers being replaced.

8.2. Indirect impacts

The replacement of the existing chillers with energy efficient chillers will result in significant savings in energy consumption. This energy efficiency would lead to a savings in emissions of carbon dioxide released during the generation of electricity.

In section 6 above, the quantity and leakage of CFCs and CO2 emissions from the old CFC centrifugal chillers are presented. By replacing the CFC chillers with new non-CFC chillers, 30 ODP tons will be eliminated. If the new chillers are 40% more efficient, the CO2 emissions associated with energy consumption of chillers (indirect emission) can be reduced by the same amount as well as the CO2-equivalent emission of CFC leakage (direct emission) and from the refrigerant itself.

The average energy efficiency benefits of the replacement of one chiller are demonstrated below.

CO2 abatement benefit from energy saving

	Existing chiller	New chiller
Cooling Capacity, TR (kW)	300 (1055)	300 (1055)
Energy Consumption (kW/TR)	1.0	0.60
Operating Hours (hrs/year)	2,000	2,000
Energy Consumption (kWh/year)	600,000	360,000
Energy Saving (kWh/year)	-	240,000
CO2 intensity of power sector (kgCO2/kWh)	0.8	0.8
CO2 Emission (tCO2/year)	480	288

Reduction of CO2 emission per year		192

Climate change benefit from refrigerant substitution (Chiller 300 TR)

	Existing chiller	Existing chiller	New chiller
Refrigerant	R11	R12	R134a
Leakage average at old chiller (kg/year)	250	150	8
GWP	4,600	10,600	1,300
CO2-eq emission (tCO2/year)	1,150	1,590	10
CO2-eq reduction (tCO2/year)	1,140	1,580	-

The total annual CO2 reduction for a 300 TR R11 chiller is 1,140 tCO2/year; while that for a R12 chiller: 1,580 tCO2/year. 12 chillers are being replaced through the demonstration project is approximately 17,680 tCO2/year.

Salmaniya Hospitalm Bahrain has selected HFC-134a as substitute refrigerants for CFC-11.
The two sites in Syria on the other hand opted to use HCFC123.

Wealth Analysis of the different solutions R22, R134a, R717.

	R22	1	2	3	4	5	**R134a**	1	2	3	4	5	**R717**	1	2	3	4	5
1. ODP	0.05	Bad X				good	0.0	bad				good X	0	bad				good X
2. GWP	1700	X					1300		X				0					X
3. COP	0.7			X			0.7			X			0.9					X
4. COSTS Initial: Refrigeration system	Screw/ Turbo reference					X	Screw/ Turbo 18%	X					Screw/ Piston 10 %				X	
Handling: Refrigerant	3.0 $/kg.				X		16 (8) $/kg.		X				0.7 $					X
Lubricants	20.0$/5 L					X	60.0 $ / 5L	X					45.0$/5L		X			
Spare parts (for 15 years).	8000$		X				10 000 $	X					3000.0$				X	
5. REFRIGERANT DEPENDENCY	imported	X					imported	X					imported.					X
6. HANDLING	Reference					X	20%	X					< 20%		X			
7. SECURITY: Alarm system					X					X						X		
Forced ventilation						X						X		X				
Leakage detector	500.0$		X				500.0$		X				0.0 $					X
Other						X						X	250.0$	X				
8. TRAINING						X	5 days		X				6 days	X				
9. LIFETIME OF EQUIPMENT	30 years turbo 20 years screw			X		X	30 years turbo 20 years screw			X		x	30 years					X

Table 1: R22, R134a, R717

Wealth Analysis of the different solutions R407c and R123.

	R407c	1	2	3	4	5	**R123**	1	2	3	4	5
1. ODP		bad				good X	0.02	bad	X			Goo d
2. GWP	1610	X					1300		X			
3. COP	0.7			X			0.6					X
4. COSTS Initial: Refrigeration system	Screw 12 %			X			Screw/ Turbo 20 %	X				
Handling: Refrigerant Lubricants Spare parts (for 15 years).	24$/kg 60$/5L 10 000$	X X X					10 $/kg. 60 $/5L 10 000 $	 X X	X			
5. REFRIGERANT DEPENDENCY	imported	X					imported	X				
6. HANDLING	20%	X					0 %					X
7. SECURITY: Alarm system Forced ventilation Leakage detector Other	 500.0 $		 X	X		 X X	 500 $		 X X	X		 X
8. TRAINING	6 days	X					2 days				X	
9. LIFETIME OF EQUIPMENT	20 years			X			30 years turbo 20 years screw			 X		X

Table 2: R407c, R123

9. Calculation of Costs

9.1. Replacement at Le Meridien Hotel, Lattakia – Syria

The Hotel is a state owned one, which operates 3 CFC based chillers that require replacement.

Calculated (estimated) costs for replacement of a chiller with cooling capacity 300 TR (1,036 kW) to 500 TR

Investrnent costs (per chiller)	US$
Chiller	150,000
Installation and site preparation	30,000
Maintenance contract	15,000
Procurement / shipping / insurance	5,000
Total	200,000

For the same cooling capacity the suppliers offer a chiller with different size of evaporator and condenser and many accessories which influence the price. In principle, bigger sizes of evaporator and condenser give more efficient chiller. An improved control increases energy efficiency, especially part load efficiency up to 0.35 kW/TR if a VSD is built in (at additional cost of about 25,000 US$). This contributes to a more reliable chiller operation and long life as well.

9.2. Retrofit at the Al Basel Hospital, Tartous - Syria

The hospital has selected retrofit as the preferred technology solution, and would like to convert the existing CFC-12 chillers for operation with HCFC-123. This process requires no replacement of the compressor. The average cost of a conversion would be approximately US$ 52,900. The advantages of this approach for the hospital are:

- Few modifications would be required to the chilled water, condenser water and electrical systems.
- The cost of conversion from CFC-12 to HCFC-123 is much less than replacing the chillers.
- Reduction in emissions.
- The service and operating personnel are familiar with the chillers and the maintenance and operating procedures of the converted systems will be identical to the existing equipment.
- The skills required to carry out a conversion can be learned quite easily by the maintenance staff and other technicians, simply by assisting and observing the conversion of one machine.
- All future conversions can be carried out by the maintenance staff without/with assistance from outside sources.

Investment Costs for one chiller conversion demonstration

Compressor and motor assembly modification for seals, o-ring's etc.	$ 20,000
700 kg HCFC-123	$ 8,400
Oil-change according manufacturers instructions	3,500
1 week On-site installation and training:	$ 21,000
Total	**$ 52,900**

9.3. Salmaniya Hospital Bahrain

The Salmaniya Hospitalm Bahrain has selected to replace the existing water colled chiller with new air cooled chillers. The following table shows a comparison of the existing chillers installation and the newest available technology.

Replacement of 4 centrifugal CFC- 12chillers

	Existing water-cooled centrifugal Chiller unit	water-cooled centrifugal chiller with VSD	Air-cooled screw chiller
Refrigerant	CFC-R12	HFC-R134a	HFC-R134a
Cooling capacity TR / each	500	498	395,2
Number of chillers	4	4	5
Total cooling capacity TR	2000	1992	1976
Initial refrigerant charge / kg Each / total	1040 / 4160	726 / 2904	512 / 2560
Electricity input / kW each	706	330	643
Electricity input / kW total	2824	1320	3215
Specific consumption kW/TR	1,412	0,66	1,63
Operating hrs/a	3701	3701	3701

Estimated investment costs including installation and commissioning

	air-cooled radiator type Chiller US$
Chiller each unit	*200,000*
Chiller total	800,000
Chilled liquid piping	160,000
Insulation	80,000
Electrical panel/inst.	60,000
Pumping system/modification	60,000
Miscellaneous	20,000
Total invest	**1,180,000**

Annual Operating costs US$:

	Existing water-cooled centrifugal Chiller unit	**air-cooled Radiator type Chiller**
Electricity total cost at 0.043 US$/kW	449,420	511,645
Total water costs US$	107.944	
Waste water costs	41,230	53,440
Maintenance costs US$		
Annual costs	**598,594**	**565,085**

The detailed project costs per country are presented in Annex III to this document

9.4. Feasibility studies

The project includes a budget for preparing a feasibility study for each chiller owner with the purpose of preparing an analysis to see how much revenue would be necessary to meet the operating expenses. The feasibility study will look at three major areas: market issues, organizational/technical issues and financial issues.

The resulting Feasibility Study Report will detail the background, method, technical baselines, findings and results, proposed replacement processes, procedures and potential costs. The Report enables discussion and decision making by the decision makers and the chiller owners. The Report will also have relevance as a guidance document for others planning a chiller replacement.

10. Financial mechanism

1. Counterpart investment, 15%
2. Contracting (national or international), 10%

In West Asia, the culture is not very much loan oriented and the owners prefer to contribute in cash to the project. It was discussed with the national ozone offices that the respective ministries (Ministry of Health and Ministry of Tourism) would include in their business plan for 2006-2007 the budget required for co-financing the replacement / retrofitting of the chillers.

Manufactures of centrifugal chillers can play a vital role in this project. Usually they are well aware of the situation of the possible client for a chiller replacement. In a Memorandum of Understanding the UNIDO will formulate the cooperation with the large chiller manufacturers like York, Grasso, Carrier, and Trane.

Representatives of the suppliers in the Bahrain, Dubai as well as the international offices of the suppliers were contacted. They all showed interest to participate in the chiller demonstration projects offering average discounts of 10% or offering technical services free of charge. Energy Based Performance Contracting is also not a viable option in West Asia because of the highly subsidized electricity and energy rates.

11. PROJECT COSTS

The total project cost is estimated at US$ 2,083,070.

The Incremental Capital Costs of US$ 1,893,700 include capital investments required.

A contingency of US$ 189,370 equal to 10% of the capital equipment cost is included to cover unforeseen expenditure.

Implementing agency support costs of US$ 156,230 are 7.5% of the total grant request.

12. IMPLEMENTATION

The project will be implemented according to the rules and procedures of UNIDO, under the management of the backstopping officer of UNIDO, in close cooperation with the counterpart company. The Ozone Unit of the Ministry of the Environment in each country will do all necessary local coordination and control.

Suitably qualified and experienced consultants will be appointed and fielded by UNIDO, to substantively assist and supervise the technical aspects of the conversion process, to perform troubleshooting and to provide assistance in specialized product redesign work. The respective job description(s) will be prepared on approval of the project.

The detailed Terms of Reference for the supplies and services to be provided under the project will be elaborated after project approval and sent to the company for his review. After competitive bidding, performed by UNIDO in accordance with UNIDO's financial rules and procedures, a General Contractor will be appointed by UNIDO for the supply of the project equipment (production equipment, etc.). Training and production expertise is likely to be provided by individuals who will be separately contracted by UNIDO.

The final equipment specification and work plan can only be elaborated after approval of the basic approach for project implementation by the MFMP.

Permission from local authorities for the introduction of the new technologies under this project will be obtained by the counterpart, who will also be responsible for the compliance of the new technologies with the established national standards.

Having accepted the conversion of its plants to the application of non-ODS technologies under this project, the counterpart, shall be committed to provide the following inputs:

- All activities and costs related to the construction work needed (including the provision of technical infrastructure) to accommodate the new technologies introduced under this project;
- Technical staff, local labor as required by the General Contractor;
- Provision of tools, transportation and lifting equipment as required;
- Provision of materials, utilities, services, manpower, etc. related to commissioning, start-up, trial runs, prototyping and testing;
- Local transport, communication and secretarial facilities for the General Contractor's and UNIDO's staff involved in the project's implementation;
- All other expenses not included in this Project Document and not covered by the budget approved by the Multilateral Fund for the Implementation of the Montreal Protocol.

The General Contractor will elaborate the specification of these works after project approval and the necessary site inspection. Thus, the costs of construction work can be specified only after appointment of the General Contractor and finalization of the equipment list. The relevant construction work shall be arranged by the counterpart under the supervision of the General Contractor and in line with the established milestones for this project

UNIDO as Implementing Agency has the necessary experience and capabilities for the successful implementation of projects at enterprise level. Upon approval of the project by the MFMP the whole budget will be transferred to UNIDO. Any substantive or financial deviation from the approved project is subject to approval by the MFMP and UNIDO.

13. PROJECT MONITORING MILESTONES

Milestone	Month, after approval	Results			Remarks
		Achieved	Not achieved	Delay	
Implementation Agreement submitted to beneficiary	2				
Implementation Agreement signed	2				
TOR for equipment (Refrigerant equipment and foaming machines)	2				
TOR for equipment cleared by beneficiary	2				
Bids requested	2				
Bids received, evaluated	4				
Contract for equipment supply signed	4				
Equipment delivered	8				
Commissioning and trial runs	8				
Decommissioning and destruction of replaced equipment	2				
Submission of project	36				

Annex 1
Survey of chiller installations for the State of Bahrain

Chillers are widely used in hospitals, business buildings, universities, industrial factories and hotels. The majority of installations of air-conditioning of the institutional sector comprised air-cooled groups with reciprocating or rotary compressors functioning mainly with refrigerant HCFC R22 but in total the refrigerant charge is less than the total charge of CHC based R12 or R500 centrifugal chillers.

The minority of CFC R12 and R500 bases centrifugal chillers installations are water-cooled. For this kind of technology it is a fact, that water-cooled chiller systems are more energy efficient as air-cooled systems at high ambient temperature. The purchase price of a water-cooled system is less than an air-cooled system.

Reasons:

- The heat transmission out of these chiller systems to the ambient air is more efficient as by air transmission.
- The space required of cooling towers is less than the space required for air cooled condenser or heat-exchanger.

For the State of Bahrain the number of water-cooled systems will be reduced in the future case by case due to the replacement of old and obsolete installations, because there is a shortage of water in the country.

- The total amount of chillers in the field is 155.
- 35 CFC-chillers were counted so far and there is a will to benefit from this opportunity either at the environmental affairs level or at the owner's level.
- There are no CFC R11 based chillers in the country.
- The survey identifies mainly 104 HCFC R22 based and 15 HFC based chiller.
- One chiller system is operated with the natural refrigerant Ammonia NH3 (R717)

Lacking further advice and assistance, the State of Bahrain as all other A5Cs, will probably continue using these systems up to the maximum lifetime – the next thirty years.

Full inventory of centrifugal chillers in Bahrain: 1TR = 3,513kW

Type of Refrigerant	Number of chillers	Initial Charge Kg	Annual Leakage rate / kg	Annual Leakage rate / a	Total Capacity TR
CFC – R11	-/-	-/-	-/-	-/-	-/-
CFC – R12	33	25.214,00	5.530,00	21,93%	13.642,00
CFC – R500	2	2.386,00	5,00	0,21%	1270,00
HCFC – R22	104	19.447,00	6.210,00	31,93%	17.476,50
HCFC – R123	-/-	-/-	-/-	-/-	-/-
HFC – R407C	2	80,00	20,00	25,00%	170,00
HFC – R134a	13	7.880,00	2.283,00	28,97%	5.542,00
NH3 – R717	1	2.700,00	200,00	7,41%	512,00
Total No. Chillers	**155**				
Total amount / consumption of CFC = **27.600,00 kg / 5.535,00 kg**					
Installed refrigeration capacity (TR) State of Bahrain					**38.612,50**

Annex 2
Survey of chiller installations for the State of Syria

Existing centrifugal chillers in Syria

Chart 1 below gives the list of existing and foreseen centrifugal chillers installations.

Name of site	Type of buildg	Trade mark	Qy chil	Unit TR	Total TR	Type of cooling	CFC used	Commis-sionning	Obser-vations
Damascus									
Tishrin President Palace	exist	Trane F	3	350	1 050	water	R 12	1982	Centrifugal
Public President Palace	exist	Trane US	4	500	2 000	water	R 11	1982	Centrifugal
	exist	Trane US	3	200	600	water	R 113	1982	Centrifugal
Hotel Le Méridien	exist	Trane F	2	420	840	water	R 12	1976	Centrifugal
	exist	Trane F	2	210	420	Air		1995	Reciprocating
Cham hotel	exist	Trane F	3	300	900	water	R12	1986	Centrifugal
	exist	York	4	220	880			1994/1996	Reciprocating
Ebla Cham hotel	exist	Carrier	4	500	2 000	water	R 11	1989	Centrifugal
	exist	York	3	210	630	Air	R 22	1995	Reciprocating
Scientific stud. research c.	exist	Trane US	3	300	900	Air	R 12	1983	Centrifugal
	exist	Trane US	2	210	420	Air	R 12	1983	Centrifugal
Tishrin Hospital	exist	McQuay	3	400	1 200		R 134a	1999 ?	Centrifugal
Airport	exist	Trane F	5	300	1 500	Air	R 134a	1998	Centrifugal
Latakia									
Hotel Le Meridien	exist	Trane F	3	320	960	Air	R12	1976	Centrifugal
Tishrin Hospital	to build		3	300	900	Air	R 134a	2000 ?	Centrifugal
Tartus									
Hospital	exist	Trane F	4	300	1 200	Air	R12	1997(*)	Centrifugal
Alepo									
Airport	to build		3	270	810	Air	R 134a	2000 ?	Centrifugal
Jabla									
Textile project (China)	to build		8	1000	8 000	?	R 134a	2001 ?	Centrifugal
Others									
Textile project	to build		8	1000	8 000				Centrifugal
Refrigeration tonnage	**Total**		70		**33210**				

(*) Ordered in 1991, installed in 1995 and commissioned in 1997

This chart shows that:

- 70 centrifugal chillers will be in operation in the next future,
- Almost all the new chillers are 134a, that means that Syria is already on the way of elimination of CFC.
- The total cooling capacity of installed and new projected chillers is 33 210 TR.

Centrifugal chillers in Syria using CFC refrigerants CFC-11, 2 and 113

Name of site	Trade mark	No.	Unit TR	Total TR	Coo-ling	CFC used	Start up	Age * RT	CFC loss pa	CFC per unit	CFC total
Damascus											
Tishrin President Palace	Trane F	3	350	1050	water	R 12	1982	17850	375	350	1050
Public President Palace	Trane US	4	500	2000	water	R 11	1982	34000	720	500	2000
	Trane US	3	200	600	water	R 113	1982	10200	385	200	600
Hotel Le Meridien	Trane F	2	420	840	water	R 12	1976	13800	320	350	700
As Cham hotel	Trane F	3	326	978	water	R12	1986	12714	295	350	1050
Ebla Cham hotel	Carrier	4	500	2000	water	R11	1988	22000	840	848	3392
Scientific research centr	Trane US	3	300	900	air	R 12	1983	14400	315	300	900
	Trane US	3	210	630	air	R 12	1983	10080	225	210	630
Latakia											
Hotel Le Meridien	Trane F	3	320	960	air	R12	1981	17280	235	500	1500
Tartus											
Hospital	Trane F	4	317	1268	air	R12	1997(*)	2536	90	500	2000
TOTAL		**32**		**11 226**			**mean age**	**14,72**	**3800**		**13 822**

(*) Ordered in 1991, installed in 1995 and commissioned in 1997

The above chart shows that:

These sites have all together 32 centrifugal chillers.

1. 8 sites use centrifugal chillers with CFC R11,
2. 21 sites use centrifugal chillers with CFC R12
3. 3 sites use centrifugal chillers with R113.
4. The capacity of these chillers are between 200 and 500 RT, that is between 700 to 1750 kWh (1TR = 3,513 kW).
5. All concerned sites are owned by Syrian Authorities. But in the case of hotels, the managing company has generally to cover the cost of replacement of mechanical equipment.
6. The 32 above mentioned chillers contain more than 13 tons of CFC and their CFC emissions can be estimated to 3,8 tons per year.
7. Most of centrifugal chillers have been supplied by Trane France.
8. Among the 32 centrifugal chillers concerned, 25 have been installed during period 1976 – 1986.
9. Existing centrifugal chillers have on average been operating for more than 14 years.

Following aspect has to be taken in consideration:
The normal life cycle of centrifugal chillers is ~ 25 years, which is much more than window or split type AC units or refrigerators, which will be easier naturally replaced by non ODS equipment due to their shorter life cycle. In addition, due to operation of AC systems only during 5 to 6 months per year with partial load most of the time, the real life time of chillers can be much more than 25 years, in Syrian conditions. So existing CFC chillers can still be used during many years if incentives are not proposed by Montreal Protocol to users.

Annex 3 - Project costs

Bahrain	**Total Cost**	**Cost to MLF**	**Co-Financing**
Cost of replacing 4 chillers	1,180,000	885,000	295,000
Technical Assistance	50,000	50,000	0
Preparation of local initiatives to replace chillers	50,000	50,000	0
Preparation of feasibility studies for chiller replacement	50,000	50,000	0
Regional Workshop for Information Dissemination on results of the Demonstration Project	35,000	35,000	0
Sub-Total	**1,295,000**	**1,070,000**	**295,000**
Syria	**Total Cost**	**Cost to MLF**	**Co-Financing**
Cost of replacement of 3 chillers	600,000	480,000	120,000
Cost of retrofitting 4 chillers	211,600	158,700	52,900
Technical Assistance	50,000	50,000	0
Preparation of local initiatives to replace chillers	50,000	50,000	0
Preparation of feasibility studies for chiller replacement	50,000	50,000	0
Regional Workshop for Information Dissemination on results of the Demonstration Project	35,000	35,000	0
Sub-total	**996,600**	**823,700**	**172,900**
Sub - Total	**2,291,600**	**1,893,700**	**467,900**
Contingency (10%)	**229,160**	**189,370**	**46,790**
Total	**2,520,760**	**2,083,070**	**514,690**

Annex 4 – Analysis of a Revolving Fund

Cash flow Analysis Revolving Fund

year	Payback period	Balance owed	Payback	Repayments	Admin cost	Unit repl.	Funds available	Net repayments	Year 1	2	3	4	5	6	7	8	9	10	11	Year 12
1						11	2.200.000	2.365.000	788.333	788.333	788.333									
2	1	3.758.700	-1557490	-592.410	15.661	21	3.938.962	4.234.384		1.411.461	1.411.461	1.411.461								
3	2	3.602.951	-1744380	-592.410	15.661	8	1.591.724	1.711.103			570.368	570.368	570.368							
4	3	3.428.513	-1953710	-592.410	15.661	12	2.162.091	2.324.248				774.749	774.749	774.749						
5	4	3.233.142	-2188150	-592.410	15.661	11	2.148.507	2.309.646					769.882	769.882	769.882					
6	5	3.014.327	-2450730	-592.410	15.661	9	1.506.928	1.619.947						539.982	539.982	539.982				
7	6	2.769.253	-2744820	-592.410	15.661	8	1.476.543	1.587.283							529.094	529.094	529.094			
8	7	2.494.771	-3074200	-592.410	15.661	6	1.230.888	1.323.204								441.068	441.068	441.068		
9	8	2.187.351	-3443100	-592.410	15.661	5	902.074	969.730									323.243	323.243	323.243	
10	9	1.843.041	-3856280	-592.410	15.661	4	685.335	736.735										245.578	245.578	245.578
11	10	1.457.413	-4319030	-592.410	15.661		401.818	0												
12	11	1.025.510	-4837310	-592.410	15.661		362.569	0												
13	12	541.779	-5417790	-592.410	15.661		76	0												
	Totals				187.935		18.607.515	19.181.281	180.262	1.591.724	2.162.091	2.148.507	1.506.928	1.476.543	1.230.888	902.074	685.335	401.818	-39.250	-362.493

Payback rate/a	**-592.410**		
Years	**12**	**Net repayment**	**16.981.281**
Inflation	**1,065**		
SubsInt.	**1,075**		
Intern.Cred.	**12%**		
Units replaced	**95**		

PROJECT COVER SHEET

COUNTRY: Global	**IMPLEMENTING AGENCY:** The World Bank
PROJECT TITLE:	Global Chiller Replacement Project
PROJECT IN CURRENT BUSINESS PLAN:	Yes
SECTOR/SUB-SECTOR	Refrigeration/Chillers
TOTAL ODS USE:	2001: 2,000 ODP tons (Annex A, Group I)
PROJECT IMPACT:	Annex A, Group I: 2,000 ODP tons
PROJECT DURATION:	8 Years
PROJECT COSTS:	
Investment Activities:	
Equipment Cost:	US$ 663,000,000
Contingency (10%):	Included above
Incremental Operating Cost:	Not included
Sub-total:	US$ 663,000,000
Non-investment Activities:	US$ 20,000,000
Total Project Cost	**US$ 683,000,000**
LOCAL OWNERSHIP:	n.a.
EXPORT COMPONENT:	0%
TOTAL REQUESTED MLF GRANT:	US$ 15,000,000
Investment:	US$ 15,000,000
Non-investment:	US$ 0
IMPLEMENTING AGENCY SUPPORT COST:	US$ 1,125,000
TOTAL COST OF PROJECT TO MLF:	US$ 16,125,000
OVERALL COST-EFFECTIVENESS:	n.a.
STATUS OF COUNTERPART FUNDING:	Private Sector: US$ 516,000,000 (commercial loans) GEF: US$ 70,000,000 (planned) Carbon Finance: US$ 82,000,000 (planned)
PROJECT MONITORING/MILESTONES:	Included
NATIONAL COORDINATING AGENCY:	Multiple countries

PROJECT SUMMARY

The Global Chiller Replacement Plan will support early replacement of CFC-based chillers on a global basis. The project will be orchestrated on a global basis, but implemented locally. The Governments of Argentina, China, India, Indonesia, Jordan, Philippines, Mexico, Malaysia, Tunisia, Turkey and Venezuela have expressed interest in participating. The design of the project will provide for later inclusion of any other Article 5 countries on demand, and subject to funding availability, which will be allocated on a first-come, first-serve basis. By accelerating the replacement of energy-inefficient CFC-based chillers, the outcome of the project will not only be to phase out annual consumption of 2,000 ODP tons of Annex A, Group I chemical, in the chiller sub-sector, it will also reduce carbon emissions by 5.3 million tCO2/year, and reduce power demand by 416 MW. The project therefore will be co-financed by GEF grant, and Carbon Finance credits. Total grant assistance will amount to an estimated 22% of total project cost. To achieve the desired project outcomes, a series of investment, non-investment, technical assistance, and capacity building activities will be carried out in participating countries. The total cost of this plan is US$683 million. The MLF grant of US$15 million, representing 2% of the total project cost, will be combined with GEF financing of US$70 million, Carbon Finance credits of US$82 million, and private financing arranged by the affected chiller owners of the balance of US$516 million.

The requested funding of US$15,000,000 from the Multilateral Fund will be used in form of grant funds to cover part of the cost of early replacement of CFC chillers and non-investment activities on a global basis. Currently, there are 11 countries

that have already committed to participate in this project. The project would, however, open for additional countries. A small window will be established to provide assistance to countries with smaller CFC centrifugal chiller population.

IMPACT OF PROJECT ON COUNTRY'S MONTREAL PROTOCOL OBLIGATIONS

The project will help Article 5 countries to meet its Montreal Protocol obligations pertaining to Annex A chemicals, and in particular prevent the emergence of illegal markets for CFC post-2010.

Prepared by: The World Bank Date: 10.7.2005

Background

The ExCom decided at the 46th Meeting to request implementing agencies and Article 5 countries to submit chiller replacement project proposals in the chiller sub-sector that could be replicated in other countries to demonstrate the feasibility and modalities for replacing centrifugal chillers in the future through the use of resources external to the Multilateral Fund -- to the extent that funds from the Multilateral Fund would be able to initiate an activity that leverages other sources of long-term sustainable financing. The project proposal should include a general strategy for managing the entire CFC chiller sub-sector including the cost-effective use and/or disposal of CFCs recovered from chillers in the countries concerned. The ExCom also decided to consider only proposals from countries that have already enacted and enforced legislation to phase out ODS. The present project proposal is responsive to this decision of the ExCom.

Project Objectives

In the short to medium term, the objective of the Global CFC Chiller Replacement Project ("the Project") is to support the completion of the phaseout of ozone depleting substances required under the Montreal Protocol and to stimulate the accelerated conversion of building chillers to new and more energy efficient technology by bringing down the well-documented techno-economic barriers. The sustainability of this endeavor would be further enhanced through the capture of carbon finance revenues and provide the sustainability for a programmatic approach that would lead to a permanent transformation of the chiller market towards an accelerated replacement of old systems and a culture of early adoption of new technologies as the energy efficiency of future systems will continue to improve.

In the longer term, this initiative could provide a framework for extending energy efficiency interventions beyond chillers and deal with a full menu of opportunities for increasing the energy efficiency of large building/facilities, including more energy efficient lighting, heating and ventilation, among others.

Conceptual Justification

The proposed project has been preceded by three demonstration projects respectively in Mexico, Thailand, and Turkey, a sector strategy study carried out in India, and considerable project preparation work carried out in China, Malaysia, Philippines, and Indonesia. Most recently, on September 27, 2005, an international conference hosted by the Bank, was held to consider design issues pertaining to a global chiller sector project. All of this work has been predicated on the following paradox: On the one hand, there is clear private benefit to chiller owners of early replacement of CFC-based chillers with non-CFC ones, which offer energy savings generally sufficient to pay back the initial cost of the new equipment purchase within 3-5 years. Yet, on the other hand, despite this clear internal incentive to early replacement, it has been found in country after country that early replacement does not take place at a pace that might be expected. Based on the cross-country experience that has now accumulated, the consensus which emerged at the recent international design conference is that the paradox may be explained in the following relatively simple terms: chiller replacement decisions are not driven simply by calculations of internal rate of return or financial payback considered in an unconstrained, abstract sense. Rather, as a common sense matter, managers take up projects for consideration in an environment of hard resource constraints, where mission-critical projects must obviously be given priority over mission-marginal projects. As a simple example with which we are all familiar, there are few households, even those belonging to energy experts, where all the old incandescent light bulbs have been replaced by the energy-efficient variety, despite high internal rate of return and quick payback. The mission-marginality of the investment, coupled with the higher first cost, together constitute a formidable barrier to more widespread adoption of the energy-efficient alternative. As another example, a hotel manager may give greater priority to a project to improve the look of the hotel lobby, rather than to improving the energy efficiency of the chiller plant; the former may be seen as critical to business success, even if the internal rate of return of the chiller replacement project may, in the narrow sense in which these calculations are made, be considered higher. In the case of the India study, based on a full life-cycle cost analysis carried out for a large sample of chillers, with effects then considered in the aggregate, it was possible to draw the conclusion that Indian chiller owners, in effect, apply a discount rate of about 30% to chiller replacement projects. At such a high discount rate, it begins to make sense why chiller replacement projects are not taken up at a rate that would render moot the problem of the CFC chiller sector, in so far as it could be a source of continuing CFC demand post-2010.

Instead, the country experience suggests that if no action were taken in the chiller sector, there would be continuing demand for CFCs past the phaseout deadline date. In India, it is estimated that unconstrained phase-out would not be complete until 2025, while in China the corresponding estimated unconstrained phase-out date is 2028. It is fully expected that the picture is similar for other Article 5 countries.

Doing nothing is clearly not a desirable option, as a large stock of CFC chillers with continuing demand for CFCs to make up leakage and servicing losses, could encourage illegal manufacture and trade of these substances, in direct opposition to the goals of the Protocol.

Another option is to recover the refrigerant charge of decommissioned chillers, process the recovered gas as necessary to make it near-virgin quality, and to use such recovered gases to meet the post-2010 recharge demand of the stock of CFC chillers that would remain. Such recovered and reused gas would of course not count toward consumption in the sense of the Protocol. In India, such a strategy would have to be supplemented with a stockpile of virgin CFC put in place prior to 2010 of about 250 MT, and in the case of China, of about 95 MT (assuming 3R measures), or about 840 MT (without 3R measures).

Based on the global inventory of CFC centrifugal chillers to be discussed in later sections of this report, there are at least 15,000 CFC centrifugal chillers that are still in operations in Article 5 countries. The total quantity of refrigerant installed in these chillers is estimated to be at least 6,000 MT. With the average age of CFC chillers of 15 – 17 years, these CFC chillers could remain in operations for another 15 – 20 years.

Without any intervention, the only factor that could reduce the demand of CFC refrigerants for servicing these existing chillers is the attrition of these units over the next 15 – 20 years.

Assuming that full charge of refrigerant could be recovered from retiring chillers, which is unlikely, there will be residual demand of CFC refrigerant, assuming that leakage rate of these chillers is about 10% per annum, for at least 2,000 MT after 2010. The leakage rate used in this analysis is significantly lower than the level suggested by other studies. Therefore, better containment or 3R approaches would not be sufficient to meet the demand of CFCs after 2010.

If so supplemented, such a strategy is in principle a viable one in terms of strict Protocol compliance. It would however be a risky strategy: if stockpiling is on a decentralized basis, it would weaken the control regime sought to be put in place to prevent illegal new production or trade in CFCs; and if stockpiling is on a centralized basis, there would be associated challenges of managing the stockpile, and in addition the pure physical risk of fire or other calamity. The experience in Malaysia suggests that this is not a practical option.

A third option is the proactive one of providing an incentive to early replacement, justified by the clear economic and environmental externalities involved. It is precisely to address such environmental externalities that the GEF was created, and Carbon Finance arrangements put in place. The Montreal Protocol likewise addresses the negative environmental externality associated with the depletion of the ozone layer, with grant assistance to affected enterprises considered a necessity in the effort to phase out ODS. By the same token, from the standpoint of country governments, facing severe pressure in respect of their ability to meet growing demand for power, the evident gap between private behavior and desirable social behavior in terms of energy efficiency investments, there is a strong economic externality consideration to subsidizing the early replacement of aging energy-inefficient chillers. In this regard, it should be noted that China is considering a policy that requires the mandatory retirement of old (over 30 years), or energy-intensive (over 0.95 kW/TR) chillers, or leaky (over 25% refrigerant leakage rate) chillers.

It is this third option that is proposed to be adopted. An average incentive of 20% is proposed, with a minimum of 10% and a maximum of 40%, with precise amounts varying depending upon chiller age, according to a transparent sliding scale. At this level of incentive, based on the analysis of the India study, private behavior would approximate a 15% discount rate, instead of the 30% observed, and an acceleration of eight to 10 years could be expected in the overall phaseout profile for CFC chillers.

This carrot, together with the implicit stick of uncertain CFC supply availability and prices post-2010, will induce a sufficient desired change in market behavior, namely (i) assure fulfillment of Protocol-mandated phaseout of CFC consumption and assure that the absence of incentive for the post-2010 emergence of illegal production and trade of CFCs to satisfy the demand of the few CFC-based chillers that would remain – the CFC refrigerant demand of these remaining chillers should easily be met from the capture and re-use of the refrigerant charge of de-commissioned CFC chillers; (ii) free up power capacity of 416 MW; and (iii) reduce carbon emissions by 5.3 million MT of carbon dioxide equivalent per year. It should be noted that from the energy externality angle, individual country Governments may also want to follow the policy approach being considered by China of forcing the retirement of energy-inefficient chillers.

It should be noted that this justification from externality does not imply the necessity of a revolving fund as a delivery mechanism. Equally, there is no suggestion that a revolving fund financing mechanism would be a sufficient condition of achieving the outcomes sought. The key conditions of success are rather the "carrot" of incentive, and the "stick" of the post-2010 squeeze in CFC supply. With these conditions in place as proposed under the global arrangements for the project, the delivery mechanisms can vary from country to country. Bearing in mind that the average incentive amount required in terms of grant-equivalent is 20% of the new chiller cost, it follows that 80% of project financing will be on commercial terms. In view of the strong payback characteristics associated with chiller replacement projects, raising loan finance on commercial terms (supply) is not where the problem lies, rather it is on the demand side for reasons (high effective discount rate – 30% in India) already discussed. Therefore, first, it is not considered necessary to establish revolving funds for chiller replacement; and second, it is proposed to allow chiller owners the freedom to select whatever lending institution (LI) they may desire, for purposes of the loan portion of the required finance.

It may be suggested that a revolving fund mechanism may be desirable as a means of reducing the financing burden placed on the MLF. This needs careful consideration. Assuming a 3-year repayment cycle and only six years between 2008 and 2014, to build up enough stockpiles of recycled CFCs, such a revolving fund can at most deliver two funding cycles. Assuming a chiller stock for replacement of 5,000 chillers, the revolving fund would have to be large enough to do 2,500 chillers on the first funding cycle. At a cost of US$180,000 per chiller, the funding required would be US$450 million, which would seem outside of the comfortable range to mobilize, even if all the funds were to be returned in the end. In any case, the support in form of a revolving fund may not address the actual barriers that prevent replacement of chillers. Based on the life-cycle analysis for the chiller sector in India, to remove barriers a grant incentive is required to achieve the outcome sought, and indeed must be supplemented by the "stick" already alluded to. As mentioned earlier that chiller replacement decisions are often delayed by the investors due to the loss of income that could be generated from other investment activities. Hence, if an incentive component of funding is provided, the remaining loan portion can be provided on purely commercial terms, and there is no shortage of such funds in most Article 5 countries.

For the grant portions sourced respectively through the MLF, and the GEF however, it is proposed to establish in each participating country an apex financial institution (AFI) which would administer the grant flow-through, both as to financial mechanics and as to ensuring necessary grant conditionalities, essential to fulfilling their purpose, are met. They would also administer the flow through of carbon credits, where again it will be necessary to measure, certify, and verify carbon reductions as a condition of funds release. While grant incentives and carbon credits will belong to chiller owners, it is proposed to require such rights to be assigned to the LIs, as a way to strengthen the quality of the loans they are asked to make. Specifically, upfront grants from the MLF and the GEF will be applied towards the down payment on the new chiller purchase; and earned carbon credits will be applied over the term of the loan toward servicing.

In addition to the local apex financial institutions, it is proposed to have one or more global apex financial institutions (GAFI). The GAFI will function as an AFI to chiller owners in countries where no local AFI has been designated. This is considered necessary for the many small countries with few chillers, where the global externality argument applies just as forcefully as it does for the larger Article 5 countries such as India and China, hence fairness dictates that they too enjoy the opportunity to participate in this global chiller project. This arrangement is considered feasible because there are but few global manufacturers of chillers, who collectively have within their databases knowledge of the entire target population of CFC chillers, which would have been sold and installed worldwide prior to the mid-1990s. Therefore, we expect that the sales forces of these global manufacturers (GM) – Carrier, McQuay, Trane, York from the U.S., and Hitachi, Mitsubishi, and Ebara from Japan – to play a critical role both in the market outreach effort, and the financial intermediation effort. Specifically, the GMs may choose to extend supplier's credits to buyers under back-to-back refinance arrangements with a GAFI. Under this sort of scenario it is evident that Exim USA and Exim Japan are likely candidates for a GAFI role. It should be emphasized that even in countries without an AFI, chiller owners may in general be free to take their business to whatever financial institution, local or foreign, they may desire, and market considerations permit.

Sector Background

Manufacturers. The global market for large centrifugal chillers is and has been dominated by a few large players, namely Carrier, McQuay, Trane and York of the U.S., and Ebara, Hitachi, and Mitsubishi of Japan. India's domestic manufacturers – Bluestar, Kirloskar Pneumatic, Utility Engineer, and Voltas -- were all under technology license from the global majors. China created its own domestic manufacturing capability in the 1960s, and the Shanghai No. 2 Refrigeration Plant, and the Chongqing General Refrigeration Plant (later CGIG) emerged as the dominant manufacturers within China. With the liberalization of the Indian and Chinese economies in the 1990s, the global manufacturers formed local manufacturing joint ventures within China, and in India set up import shops competing directly with the domestic manufacturers. What is true for China and India is true worldwide, namely that relatively few American and Japanese companies dominate the market for centrifugal chillers, but with local niche players themselves partnered with the global majors. Collectively, these relatively few manufacturers have within their sales databases the entire CFC chiller population being targeted for early replacement under the proposed Project. This is a useful circumstance, as it means that it is in the self-interest of the dominant players, to provide the market outreach that would be needed.

Table 1: CFC Chiller Population Counts for selected Article 5 Countries

Country	Total CFC Chiller Stock	Total CFC Use (tons)	Total Charge (tons)	Annual Losses (percent)
Argentina	300	60	120	50%
Botswana	80	12	32	12%
Chile	170	25	68	36.76%
China	1,750	460	1,225	37.55%
Columbia	450	68	180	37.78%
Croatia	54	3	14	21.43%
Egypt	670	100	268	37.31%
Fiji	5	3	2	150.0%
Guatemala	100	15	40	37.50%

India	1,100	171	596	28.69%
Indonesia	1,300	195	520	37.50%
Malaysia	1,500	225	600	37.50%
Mexico	1,500	225	600	37.50%
Philippines	800	120	320	37.50%
South Africa	250	14	38	36.84%
Syria	32	13	13	100.0%
Thailand	1,500	225	600	37.50%
Turkey	2,500	188	500	37.60%
Venezuela	500	100	200	50.0%
Total	**14,561**	**2,222**	**5,935**	**37.38%**

Source: ICF Consultants, 2005. International Chiller Study, for the World Bank. Compiled from various sources, primarily UNEP.

Population count. It is estimated that as of 2004, there are about 15,000 CFC-based centrifugal chillers in use in Article 5 countries. Table 1 is a compilation from various sources of chiller population estimates by country. For the countries shown in Table 1, the total population count is some 14,561. It is not expected that the long list of countries with small chiller populations would add more than another 10% to the count, which would bring the total count to 16,279. For the purposes of this project, we assert a round count of 16,000 CFC-based chillers -- the target population of the project -- with an error range of plus/minus 2,000. Table 1 suggests a total refrigerant charge in use by these chillers of about 6,000 MT CFC, and an annual demand of about 2,200 MT to make up leakage and other losses of about 37% per year.

Size Distribution. CFC-based centrifugal chillers range in size from about 100 tons refrigeration (TR) to over 2,000 TR in some cases. Based on the survey results from China, India, Indonesia, Malaysia, and Philippines, the average cooling capacity of CFC centrifugal chillers in these countries could be summarized below. Profiles of CFC centrifugal chillers in these five sample countries are included in Annexes 2 – 6.

Table 2 Average Cooling Capacity of CFC Centrifugal Chillers

	China	India	Indonesia	Malaysia	Philippines	Weighted Average (RT)
Average Cooling Capacity (RT)	350	460	490	512	430	435
Number of Chillers	1,404	1,100	714	683	193	4,094

Age distribution. By and large, there were no new CFC-based chillers sold anywhere after 1998. Therefore, as of 2005, the youngest CFC chillers are now 7-8 years old. At the other extreme, the India study revealed some CFC chillers as old as 40 years still in use. The age distribution of CFC centrifugals is available for the five sample countries and shown in Table 3. As may be seen most chillers are 16 - 19 years old, with an average age of 17 years. Since chillers could normally be kept running 30 years or more, it is not surprising that unconstrained replacement plans would see China and India respectively having final capacity phase-out dates of 2028 and 2025. As becomes clear in a life-cycle analysis such as was carried out in the India study, it is the age of the chiller that drives the real and perceived cost of early replacement: the younger the chiller the greater the required incentive cost of early replacement.

Table 3: CFC Chiller Age Distribution as of 2005

Age Bracket (years)	% Distribution in Age Bracket					
	China	India	Indonesia	Malaysia	Philippines	Weighted Average
0 - 5	0	0		0	1	0
6 - 10	6.4	15		3	3	7
11 - 15	44.2	32	49	30	30	39
16 -20	36	26	26	39	23	31
21 - 25	13.3	20	19	20	26	18
26 - 30	0	7	6	8	12	5
>30	0.1	0			5	0
Total	100	100	100	100	100	100
Number of Chillers	1,404	1,100	714	683	193	4,094
Average Age (Years)	15.83	16.6	17.1	18	19.3	16.78

Power consumption. As developed in the India study based on a survey of chiller owners which collected the necessary raw data, specific power consumption of CFC centrifugal chillers at rated capacity could be determined from the following fitted formula:

$$P = 0.28 * \text{Ln}(A + 5)$$

where

P = Power consumption (kW/TR);
Ln = Natural logarithmic function; and
A = Age of the chiller in years.

Table 4 Specific Energy Consumption by Age of Chillers

Age of Chillers	Energy Consumption (kW/TR)
5	0.64
10	0.76
15	0.84
20	0.90
25	0.95
30	1.00

This fitted formula is based on a study of cross-sectional rather than longitudinal time data, therefore the effects of age and vintage are completely confounded in the foregoing formula. In practice, the distinction does not matter for most purposes. In particular, as an engineering matter, the new energy-efficient non-CFC chillers will age-for-age remain more energy-efficient than the CFC chillers they would replace. The multipliers developed in the India study were respectively 0.98 for HFC-134a and 0.90 for HCFC-123 chillers respectively. More recent developments suggest that HFC-134a may have achieved parity with HCFC-123 in terms of energy efficiency achieved, and moreover that the multiplier for new technologies relative to CFC may now be closer to 0.80. Thus, depending upon the age of the old chiller, the immediate energy efficiency gain may be 50% or more. It should be noted also that the fitted formula is not immutable, since it is based on a statistical association across many chillers; rather, depending upon how well chillers are maintained, they may retain first-year power efficiency performance for a long time.

Other life-cycle costs. While power consumption reduction is the main benefit from early replacement, a full analysis of the replacement option calls for a life-cycle analysis of costs, which was fully developed in the India study. To implement a full life-cycle model, formulae were fitted also for increase of other running costs with chiller age, namely maintenance costs, refrigerant recharge costs, and downtime costs due to chiller breakdown or maintenance. On the assumption that new non-CFC chillers would exhibit similar life-cycle behavior, except for appropriate multiplication factors as just discussed for power consumption rates, it is possible to estimate the net present value of owning and operating costs over any given life-cycle, and it is further possible to estimate the optimal replacement policy – that is the number of years to keep the new chiller before it should be replaced – for the new chiller. More to the point, such an analysis would reveal the net present value (NPV) of the cost of maintaining a chiller facility if the new chiller were purchased, and an optimal replacement policy followed thereafter.[1]

Replacement alternatives. In general through this chiller replacement plan, CFC chillers will be replaced with high-efficiency HCFC-123 or HFC-134a chillers. Both HCFC-123 and HFC-134a chillers are widely available around the world, and since 1993 these types of chillers have been introduced in India.

Both are effective replacements in terms of refrigerant properties, but both have environmental considerations associated with their use. HCFC-123, while being much preferred to CFC-11 in terms of ozone-depletion potential (ODP), still has a very small ODP of 0.02. It is therefore also controlled under the Montreal Protocol and will ultimately be subject to a phase-out as well. HFC-134a has no ODP, but it does have a global warming potential of approximately 1,300 or more than 10 times higher than HCFC-123. However, the global warming potential of HFC-134a is still substantially lower than that of CFC-12 (GWP = 10,600), which it is replacing.

As a result, both HCFC-123 and HFC-134a have become the refrigerant of choice in many chiller conversions. Their effectiveness is well proven in developed and developing countries around the world.

1 On the basis of this sort of analysis, it may be shown that the initial purchase cost of a new chiller would represent in present-value terms only about 20% of the life-cycle costs of owning and operating, assuming a 15% discount rate. At a higher discount rate, the initial capital cost assumes greater importance: around 40% of life-cycle cost for a 30% discount rate.

Analysis of replacement decision and incentive. Armed with the NPV cost assuming an optimal replacement policy is followed, the early replacement decision may then be considered as follows (using illustrative data from Case 58 of the India study – Annex 1 shows owning and operating cost assumptions):

Assume discount rate	: 30%
NPV of replacement policy cost for new HFC134a chiller	: US$589,000
Age of old chiller in 2005	: 12 years
Year 13 running cost of old chiller	: US$130,000
NPV cost to replace now	: US$589,000
NPV cost to replace next year: US$(130+589)K×(1/1.30)	: US$551,000

From this analysis, we see immediately that on the given assumptions, it would be better to defer replacement. A similar analysis could be done to see whether to replace next year, or the year after, and so on. If the analysis is repeated, it would be found that in year 2007 the decision should be to replace immediately rather than to incur age 15 running cost of US$141,000 in year 2008, and only then to replace. The discount rate switching point for immediate replacement is 22% or less, and the running cost switching point for immediate replacement is US$176,000 or more. Finally, the analysis suggests that for a chiller owner discounting future cash flows at 30% p.a. the incentive amount required to induce immediate replacement is US$589,000 - US$551,000= US$38,000, which represents 15% of the purchase cost (US$252,000) of a non-CFC HFC-134a replacement chiller.

Discount rate assumption. The use of a 30% discount rate in the foregoing example is intentional. When the foregoing replacement analysis is carried out for every chiller in the owners' survey sample, for which adequate data were available to permit it, it is possible to generate, for different discount rates, the unconstrained phaseout profile consistent with each assumed discount rate. Assuming as we must that the sample is representative of the whole, we have a basis on which to plot a family of phaseout profiles for the chiller population as a whole, each corresponding to an assumed discount rate. These phaseout profiles in turn can be compared with the phaseout profile that would be generated if we took chiller owners at their word regarding when in each case they intend to retire their existing CFC chillers (**Figure 1**). When this analysis is done, it becomes apparent that the unconstrained phaseout profile intended to be followed by chiller owners is consistent with an implicit effective discount rate being assumed by them of 30%. This discount rate at first seems high, until it is realized that it is consistent also with the known fact that chiller owner behavior in respect of the adoption of new energy-efficient technologies does indeed appear to reflect what are assumed to be “barriers” to such adoption. In other words, the high implicit discount rate is a way of capturing the financial implications of the barriers at play, whether lack of awareness, uncertainty, lack of access to required funds, or any of a number of other barriers that have been suggested. While these are all explanatory factors, to varying degrees, it is also possible to have much the same result even after all these barriers have been removed, when it is considered that management decision-making is a form of constrained optimization, with management time being one of the scarce resources that determine what projects are put on the priority list. From this angle, it is not sufficient that a project have a high rate of return, or fast payback, the project must also be important to the business. For example, if two projects, one for a $100,000, and the other for

$1,000,000, would consume the same amount of management time and attention, the return per hour of management time would be higher for the latter project, even if the internal rate of return of the latter were half that of the former. If in addition, the latter project is critical to the long-term competitive positioning of the enterprise, it is clear that the latter project would take priority. Chiller replacement projects tend to be of the former sort, and therefore tend to find little space on management's crowded agenda. There are of course exceptions, namely in enterprises where energy efficiency is critical to long-term success, e.g. in some process industries, or where chiller reliability is critical to business success, e.g. five-star hotels. Where neither energy costs, nor chiller reliability are considered key success factors for the business, one would expect chiller replacement projects to continue to be heavily discounted. It is on this mode of argumentation that the result of the India study was accepted, that a discount rate of 30% was needed for the financial analysis of chiller replacement projects. The available evidence emerging out of other countries suggests that the same conclusion may be applied to other countries as well.

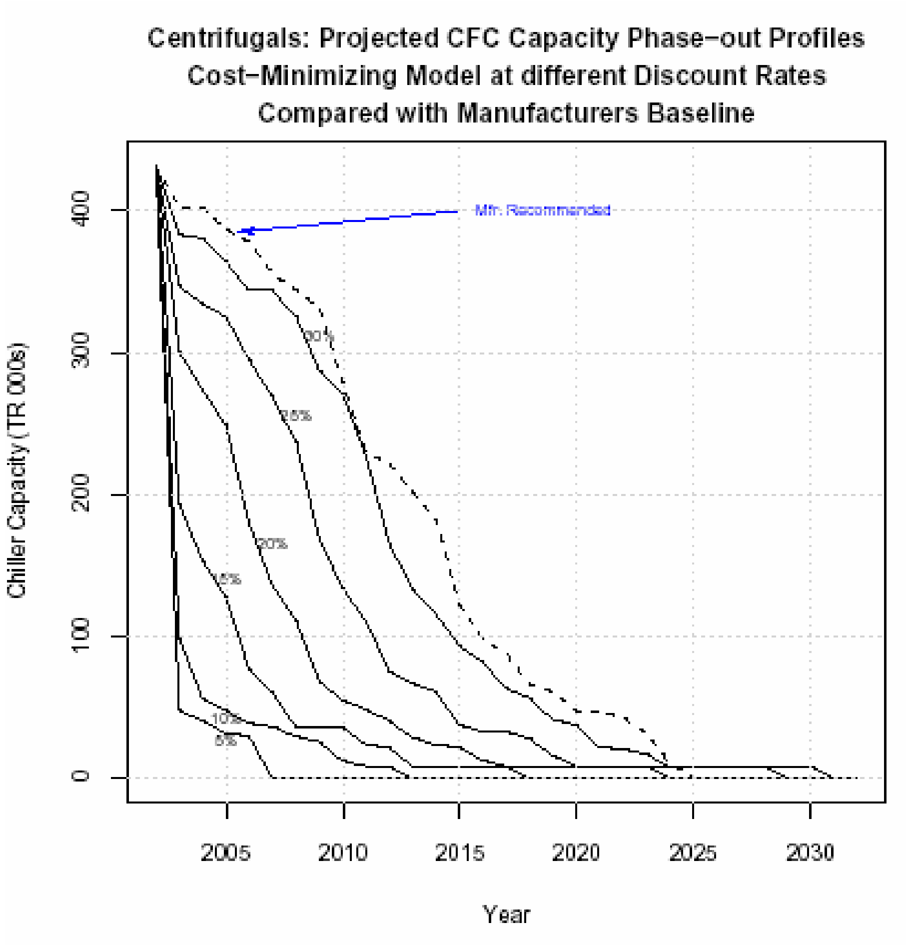


Figure 1: Phaseout Profiles for Different Discount Rates

Implications in aggregate. The immediate implication of the foregoing conclusion emerges forcefully in the present context where it is sought to phase out CFC refrigerant for environmental reasons, and it would appear that notwithstanding the assumed and demonstrable internal private incentive for early phaseout, such phaseout is not happening at a rate that would take care of itself. Instead, the problem does not appear to want to disappear of its own accord, imposing therefore a burden on the MLF and on Parties seeking to fulfill their phaseout obligations. The present analysis supports the strong conclusion that moving the unconstrained phaseout profile into a more acceptable position in terms of accelerated replacement will require the provision of grants or the equivalent, sufficient to the task. A strong externality argument with the same conclusion could be made from the power consumption and carbon emission (global warming) angles, where the huge variance between a 30% private discount rate, and a reasonable social discount rate of no more than 10%, would suggest either a need for subsidies to bring private behavior closer in line with what would be desirable social behavior, or to undertake policy and regulatory reform with the same objective in mind, or some combination of the two.

Project Description

The project will broadly:

1) deliver incentives to CFC chiller owners sufficient to overcome the well-documented techno-economic barriers, and achieve the desired outcome of accelerated chiller replacement at least sufficient to squelch post-2010 CFC refrigerant demand in participating countries to within limits that would not require new virgin production but could be met out of modest pre-2010 stockpiles, combined with recycled CFC recovered from de-commissioned CFC chillers;

2) stimulate the adoption by participating countries of policy and regulatory measures aimed at:

   a) fulfillment of CFC phaseout obligations under the Montreal Protocol

   b) bringing private behavior in respect of energy conservation more in line with desirable social behavior, and

   c) reducing or eliminating avoidable greenhouse gas emissions by encouraging the adoption of carbon-friendly energy technologies.

More specifically, the project should cause the early replacement within Article 5 countries of about 5,000 existing CFC-based centrifugal chillers, representing chiller capacity of about 2,175,000 TR, and annual CFC recharge demand of about 800 MT. Early replacement of 5,000 CFC centrifugal chillers will result in availability of recycled CFC of approximately 2,000 MT to meet the need for servicing of remaining CFC chillers until the end of their useful life. This estimate is based on the assumption that full charge of refrigerant could be collected from those units that reach their end of useful life under unconstrained scenario.

Of approximately 16,000 CFC chillers in total constituting the target group, it is estimated that about one-third will not qualify for assistance because they exceed the age limit (end of useful life) over which no incentive is considered necessary. Of the balance, funding is provided only for about half, or another one-third of the total. The remaining one-third of owners are expected to decline or be declined for any number of reasons, ranging from lack of credit-worthiness to lack of interest in the product on offer. It is expected that some in the latter category may include newer chillers where the energy efficiency is already fairly high and comparable with newer chillers, therefore the replacement incentive would have to be too high. In such cases, the appropriate least-cost option for the owners would be to acquire and maintain a stockpile of CFC for their own use post-2010, and adopt containment measures to minimize losses in operation (from 20% or 30% per year down to 10% per year) due to leakage and losses while servicing the chiller. Demand of CFC refrigerant from this group of chillers will be supplemented by the expected recycled refrigerant of approximately 2,000 MT to be recovered from the retired units as mentioned above.

As a condition of participation in the project, countries will be required to adopt or have adopted policies and regulations reasonably calculated:

1) to force ODS phaseout compliance;

2) encourage the adoption of energy conservation measures by heavy consumers of energy such as chillers; and

3) discourage greenhouse gas emissions[2].

It will be a requirement for inclusion that CFC centrifugal chillers should be replaced by new non-CFC chillers with energy consumption at the rated capacity of not more than 0.63 kW/TR. This requirement should be easily met by either new HFC-134a, or HCFC-123 based centrifugal chillers. In case existing facilities have waste heat from other processes, absorption chillers could be considered as a candidate for replacing existing CFC centrifugal chillers.

When replacing chillers, chiller owners will be encouraged to take this opportunity to assess the performance of the whole chiller plant in order to optimize the performance of the new system. Proper sizing of the new chillers as well as cooling towers, air handling units, energy-minimizing instrumentation and control systems for building management, and other components, should be included in the broader subproject design. Incentive financial support from this project would, however, be limited to the case-to-case chiller replacement. Costs of replacement of other components would have to be borne in full by chiller owners, with appropriate loan or other financing on commercial terms. However, the comprehensive system change would render more energy savings to chiller owners.

When dismantling existing CFC centrifugal chillers, chiller suppliers or their contractors must ensure that CFCs in the existing units be recovered properly. Chiller suppliers and their contractors must follow relevant ASHRAE guidelines regarding installation and dismantling of

[2] It should be noted that, while energy conservation as a practical matter also tends to have the effect of reducing greenhouse gas emission, due to the linkage with carbon dioxide emission from thermal power generating plant, the two concerns are distinct. Power can be generated from means (hydro, wind, solar, for example) that impose no greenhouse gas burden, but energy conservation would still be a concern because of the huge social investments required to fund power consumption. Also, greenhouse gas emissions may come from sources that have nothing to do with power generation, for example refrigerants also have varying degrees of global warming potential.

CFC equipment. Chiller owners will be allowed to retain the recovered CFC for maintenance the remaining CFC centrifugal chillers in their premises or to transfer recovered CFCs to chiller suppliers so CFCs could be used for maintenance CFC chillers in other facilities.

It is expected that all necessary financing arrangements from the MLF and co-financiers will be put in place by mid-2007. Given time for subproject proposals to be developed and equipment orders to be placed, it is expected that the first subprojects should come online in CY 2008. It is expected that the delivery of new systems will be supply-constrained to an incremental 1,000 units per year from a normal supply position of about 7,000 units per year worldwide. On that basis, it is anticipated that the project will require seven years in implementation, with replacement chiller deliveries roughly as shown in Table 5. The delivery profile shows a quick ramp-up to peak deliveries in 2009 and 2010, with 62% of replacements projected to occur by 2010, then a gradual drop-off until 2014 when the program will be closed.

Table 5: Projected Chiller Replacements By Year of Implementation

	2007	2008	2009	2010	2011	2012	2013	Total
No. of Chiller Replaced	-	750	1,063	994	610	742	904	5,063
Cumulative Number of Chillers	-	750	1,813	2,807	3,417	4,159	5,063	

Project Implementation Arrangements

The overall project implementation framework is presented in **Figure 2**[3] using India as an example of a country component. The implementation framework is detailed below in three broad sections: Financial Framework; Operational and Project Management Framework; and Technical Implementation Framework.

Financial Framework

The financial structure of the Project is based on four sources of financing, as illustrated in **Figure 3.** Three of these sources are from international financial instruments (20%) while the fourth, and most important from a financing perspective, is commercial finance (80%). Funds are to be mobilized from the Multilateral Fund (MLF) and the Global Environment Facility (GEF) through an umbrella trust fund (UTF) from which will be made country-specific allocations to country apex financial institutions (CAFIs) selected for this purpose in pre-listed participating countries with large CFC chiller populations, and a pooled allocation to one or two global apex financial institutions (GAFIs) through which the demand of smaller, unlisted countries will be met. The Bank as Implementing Agency will enter into agreements at the CAFI or GAFI level, as the case may be. In the case of CAFI level agreements, there will also be the need to enter into parallel agreements with the country governments concerned, which would be the notional sovereign recipients of the grant funds, pursuant to the relevant treaties and protocols, and back-to-back grantors to the ultimate recipients, the chiller owners, through the financial intermediation of the CAFI in each case. The country and/or CAFI will, in addition, enter into a purchase agreement with a carbon finance fund.

[3] The figure uses the term "Bundling Agent" where in the text the term AFI – apex financial institution is used.

Figure 2: Global Chiller Energy Efficiency Project – India Component

Implementation Arrangements

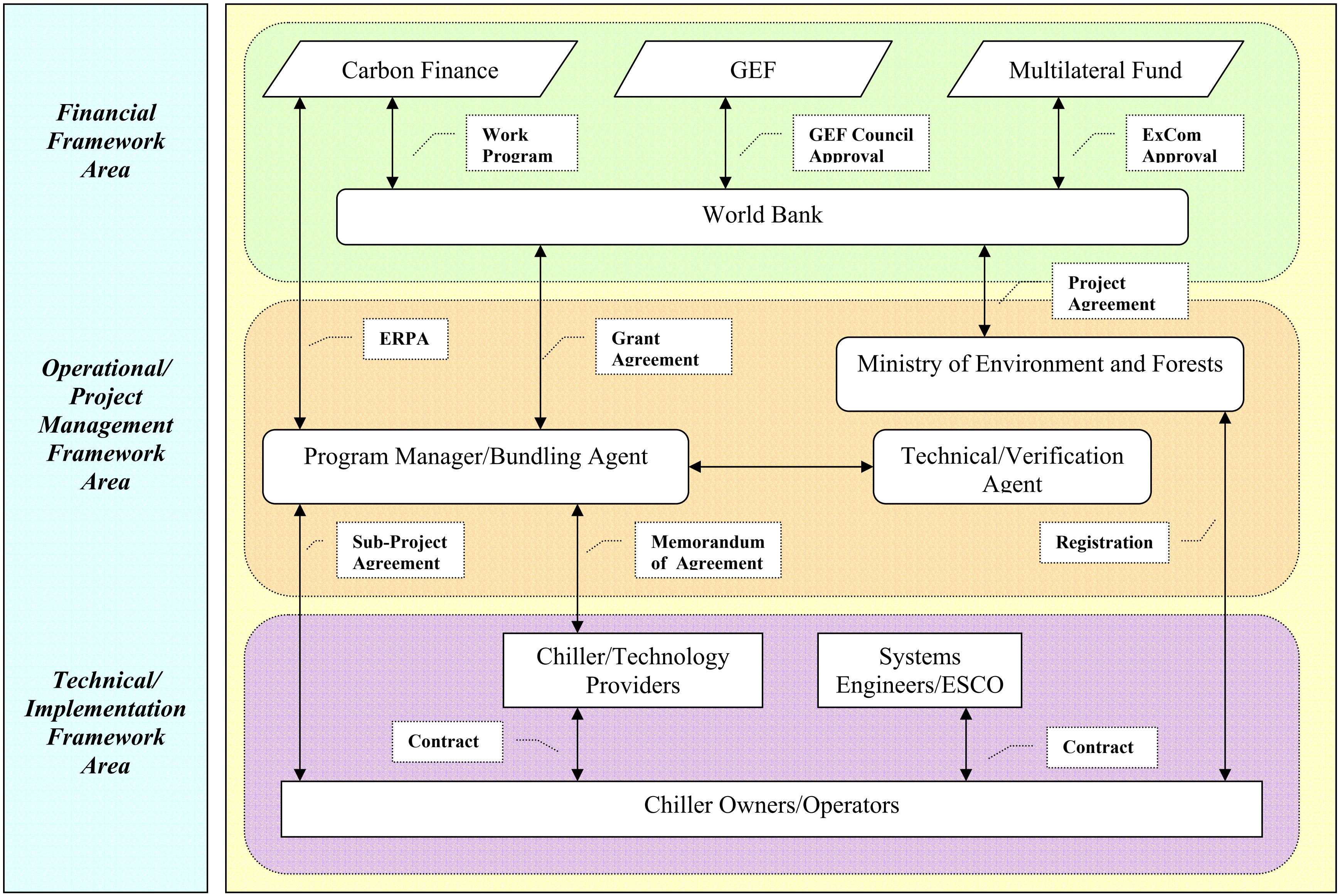
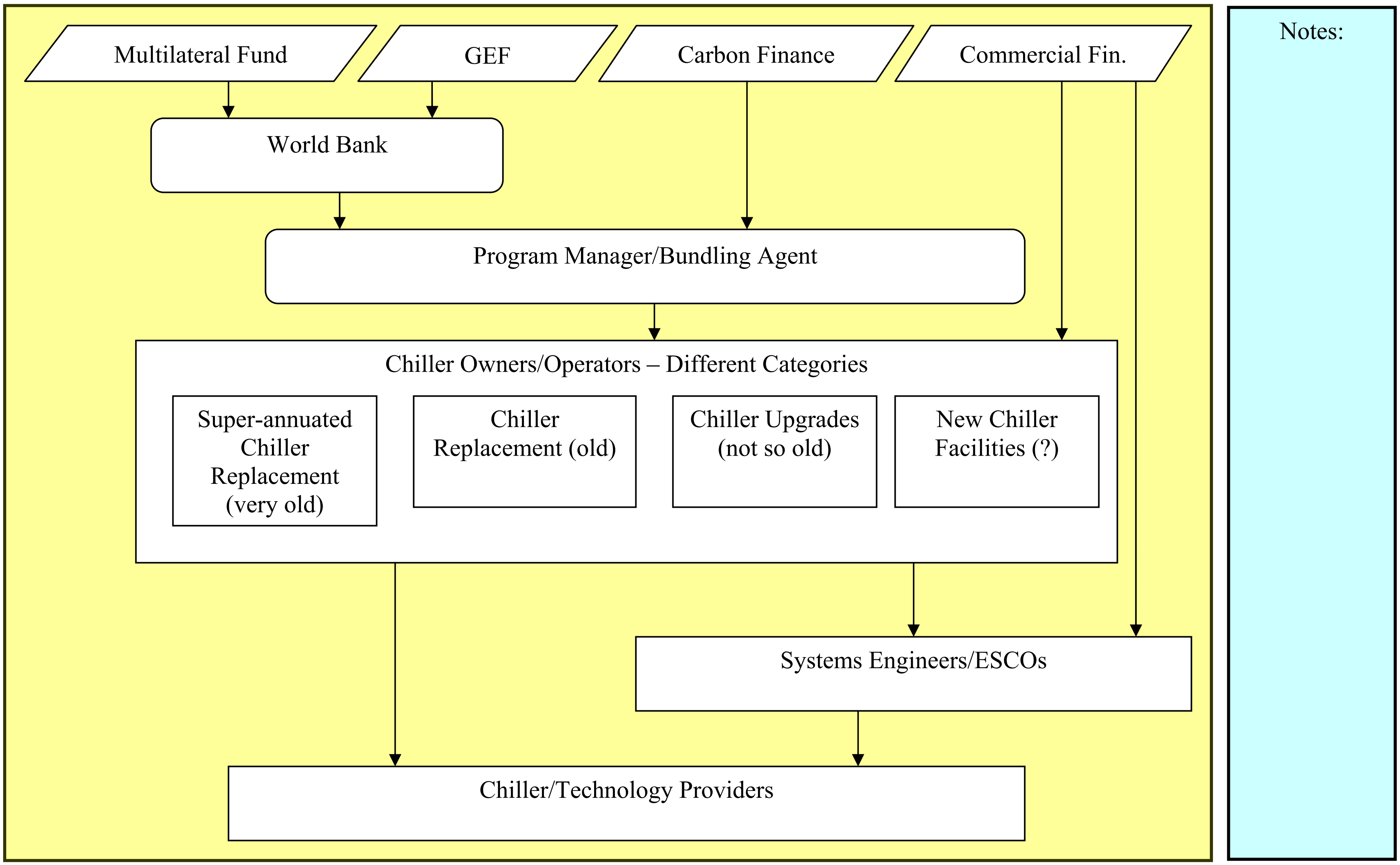


Figure 3: Global Chiller Energy Efficiency Project – India Component

Sources and Flow of Funds



This fund will purchase emissions reductions generated by the chiller replacements. Grants from the MLF and GEF, plus revenues for carbon finance, will be utilized to fund the incentive product which will be offered plus the administrative costs of program administration. For pre-listed countries, the country government and/or CAFI will enter into project agreements with chiller owners, while for unlisted country participants, the relevant GAFI will enter into project agreements with chiller owners.

Disbursement conditions. Grant disbursements from the MLF and GEF will in principle be conditioned on completion of the replacement project, and the certification of the relevant characteristics (age, cooling capacity, refrigerant, baseline power consumption) of the replaced chiller, as well as of the replacing chiller, and of the destruction of the old chiller. The disbursement of earned carbon credits will in principle be conditioned on actual power consumption performance of the new chiller relative to the pre-established old-chiller baseline. While these grants and carbon credit revenues are to the benefit of the chiller owner, and to which the chiller owners may be considered to have a right, it will be a requirement that these rights be applied toward the purchase of the replacement chiller in the first instance, and toward the servicing of any commercial loan used to complete the purchase of the new chiller. Specifically, the MLF and GEF grant rights will be applied toward the down payment on the new chiller purchase, and the carbon credits toward commercial loan servicing. For this purpose, the commercial lending institution (LI) of the chiller owner's choice may have the carbon credit rights of the owner assigned over to it, and the AFI (CAFI or GAFI) involved in the transaction will be made to require the MLF and GEF grants be applied directly toward the purchase of the new chiller. Chiller owners will have the right and responsibility to mobilize needed loan finance from the LI of their choice to complete the financing package necessary to implement the conversion. AFIs also suppliers will be permitted to also be the LI for any given transaction, at the choice of the owner.

Physical Framework. With respect to the physical framework of implementation, the key steps to be followed, at the level of the chiller owner, are: (i) subproject design and appraisal; (ii) inviting and evaluating proposals from suppliers; (iii) contract negotiations and signing; (iv) delivery of new chiller; (v) de-commissioning of the old chiller; and (vi) installation and commissioning of the new chiller, and of ancillary system improvements (e.g. intelligent building management control systems). Chiller owners will be encouraged to use energy service companies (ESCOs) or engineering consultants to maximize the scope for reduction of chiller facility cost. However, the financing of such services will not fall to the MLF or GEF grant sources, rather will be left to the chiller owners and the ESCO/consultants to devise among themselves; there should be ample scope for ESCO/consultants to be paid out of cost savings achieved, and – in a fungibility sense – out of carbon credits earned.

Procurement. It is proposed to allow chiller owners maximum flexibility in the procurement methods applied, i.e. local and international shopping procedures in accordance with normal prudent commercial practice will be allowed.

Fiduciary duty compliance. At the level of the AFI (CAFI or GAFI), fiduciary duties with respect to the intermediating of MLF and GEF grant funds, and of carbon finance credits will require that physical arrangements are put in place for obtaining the required certifications: (i) with respect to the old chiller, certification of age, cooling capacity, and refrigerant, and base-line power consumption; (ii) with respect to the new chiller, certification of age (must be new), cooling capacity, refrigerant (non-CFC), and rated power consumption (must be not greater than 0.63 kW/TR); and (iii) after installation and commissioning, required data logging to establish basis for earned carbon finance credits. To carry out these duties, the AFIs will need to establish a roster of qualified experts or engineering companies capable of carrying out these duties. The minimum documentation required from such experts will be a standard form of report at each stage listed above.

Audit framework. The Bank will put in place arrangements for independent audits of the foregoing process, and of the financial and physical outcomes flowing out of it. For pre-listed participating countries, the nodal authority charged with responsibility for fulfilling country obligations under the Protocol, will have oversight responsibility under the Bank's project agreement with the Government. The Bank country teams will also independently organize annual audits of a sample of the chiller replacement projects. For unlisted countries, the Bank central team will organize verification audits of a random sample of GAFI-intermediated chiller replacement projects.

Project Cost and Financing

Investment Component

To determine the level of the incentive needed for earlier replacement than would otherwise be the case, the mathematical model approved by the ExCom at its 46th Meeting is employed. The level of funding determined by this model is used as a basis for requesting grant funds from both MLF and GEF. However, additional resources are required to support non-investment activities such as development of general guidelines for establishing the baseline energy consumption, monitoring of performance, training for chiller owners on enterprise-level refrigerant management plan, and capacity to recover and recycling CFCs from retired units.

The global average of cooling capacity of CFC centrifugal chillers is 435 TR. The estimated cost of the 435 TR chiller including installation costs is approximately US$180,000. The results of survey indicate that in average chillers are running about 14 hours a day, 26 days a week. An average electricity cost of US$ 0.10/kWhr is used for the analysis. Moreover, an average carbon intensity of 0.8 kgC/kWh is used as a basis for determining the quantity of carbon emission reduction. Based on the mathematical model approved by the ExCom, the maximum financial support to be provided for chillers at different age ranges is shown below.

Table 6: Financial Support for Chiller Replacement by Chiller Age

Item	Chiller Age (years)			
	15	20	25	30
Chiller Population Fraction (%)	39%	31%	18%	5%
Maximum Funding Level	$82,817	$55,050	$31,911	$8,772

The global weighted average of the maximum funding level to be given to each CFC centrifugal chiller, based on the representative group of CFC centrifugal chillers in China, India, Indonesia, Malaysia, and the Philippines, is $59,728 or about 33% of the cost of a new chiller. In anticipation of increasing price of CFC and potential disruption of CFC supply in the near future due to the current effort of CFC manufacturing countries to close down their production facilities, the project proposes that an average upfront financial support of 22%, or $40,000 per unit, would be sufficient.

In compliance with the ExCom's condition that financial resources outside the Multilateral Fund should supplement the resources from the Multilateral Fund to support this project, and to use the funds from the Multilateral Fund to initiate an activity that leverages other sources of long-term sustainable financing, it is proposed that additional funds be requested from GEF and carbon emission reduction should be traded to generate a stream of cash-flow to provide grant-equivalent incentive to the chiller replacements.

Income from carbon trade depends on the actual energy savings from replacing chillers. Chillers at different age ranges would provide different level of savings. The expected level of annual carbon emission reduction from replacing chillers of different age ranges and the expected income from carbon trade based on the average rate of US$6 per ton of carbon dioxide equivalent is shown below. Chiller replacement would also render additional carbon emission reduction due to the lower GWP values of alternative refrigerants. CFC-11, which is the common refrigerant used in the existing CFC centrifugal chiller, has a GWP value of 4,680 while the GWP values of HCFC-123 and HFC-134a are 120 and 1,300, respectively. However, the projected revenue does not take into account this additional global benefits.

Table 7: Projected CO2 Emission Reductions and Revenue from Carbon Trade

Item	Age of chiller (years)			
	15	20	25	30
Chiller Population Fraction (%)	39%	31%	18%	5%
Annual CO2 Emission Reduction per Unit (tCO2 equiv)	1,170	1,505	1,784	2,062
Annual Revenue (US$) from Carbon Trade per Unit (based on the rate of US$6 per tCO2)	7,023	9,029	10,701	12,373

The global weighted average of the annual revenue from carbon trade per unit that could be generated by chiller replacement based on the representative group of CFC centrifugal chillers in China, India, Indonesia, Malaysia, and the Philippines, is US$8,690 per unit.

With the average level of funding per chiller of US$40,000, the total grant requirement to finance replacement of 5000 chillers is US$ 200 million. Based on the replacement schedule proposed above, the financing plan is shown as follows:

Table 8: Financing Plan

	2007	2008	2009	2010	2011	2012	2013	Total
No. of Chiller Replaced	-	750	1,063	994	610	742	904	5,063
Cumulative Number of Chillers	-	750	1,813	2,807	3,417	4,159	5,063	
Financial Resource Requirement	-	30,000,000	42,518,378	39,756,739	24,395,054	29,695,593	36,147,829	202,513,593
Inflow	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**Total**
Multilateral Fund		20,000,000	20,000,000	-				40,000,000
GEF		10,000,000	16,000,000	24,000,000	-	-		50,000,000
Carbon Finance		-	6,518,378	15,756,739	24,395,054	29,695,593	36,147,829	112,513,593
Contribution within the Year		30,000,000	42,518,378	39,756,739	24,395,054	29,695,593	36,147,829	202,513,593

To undertake replacement of approximately 5,000 chillers in a period of six years would require grant funding of US$90 million plus US$112.5 million of carbon credits. Other replacement schedules have to be considered. Assuming that the funding contribution from GEF for equipment replacement remains constant at US$50 million, the chiller replacement scenarios for different MLF contribution are shown below.

Table 9: Chiller Replacement Scenario

Scenario	Contribution (US$ million)		Carbon Credits	Total Resource	No. of Chillers
	MLF	GEF	(US$ million)	(US$ million)	Replaced
1	15	50	82	147	3,685
2	20	50	89	159	3,963
3	30	50	101	181	4,513
4	40	50	113	203	5,063

In light of Dec. 46/33, *the scenario 1 is selected.*

Non-investment Component

Technical Assistance – To ensure success of the project each chiller owner should develop his own refrigerant management plan. The refrigerant management plan should include consideration on better containment by improving the servicing standard for the existing CFC centrifugal chillers. This could be achieved through a better preventive maintenance. Moreover, consideration should be given to timing for replacement of its inefficient chillers, and measures to capture chillers from the retiring units and to set up facilities to store recovered chillers for servicing remaining CFC centrifugal chillers in their chiller plants.

The apex institution in charge of the chiller replacement program in the country will work with the National Ozone Unit in order to assist chiller owners to come up with this refrigerant management plans. Chiller owners having younger machines, which will not be replaced under the project, will therefore be in need of CFC recharge requirement post-2010, and for which provision must be made from stockpiling pre-2010, and from recovery and recycling of refrigerant charge from machines being retired. To ensure effective implementation of the refrigerant management plans, it is important that service technicians from both contractors and in-house staff should be trained on proper handling of CFCs. It is proposed to employ a decentralized refrigerant management plan approach, where it is up to individual chiller owners to establish and manage their own stockpiles. However, although the approach is decentralized, some centrally delivered technical assistance will be needed to ensure that chiller owners are made aware of the pitfalls, and are trained in refrigerant management practices more broadly. The apex institutions would rely heavily on the existing program conducted by the governments as part of their implementation of the national CFC phase-out in the refrigeration servicing sector.

The project would also provide funding to the apex institutions to augment their capacity to deliver the needed technical assistance on energy conservation, and to develop an operating protocol for documenting energy savings from the chiller replacement. The project will also use this opportunity to educate chiller owners of other energy conservation measures beyond chillers. Chiller owners will be made aware of a full menu of opportunities for increasing the energy efficiency of large building/facilities, including more energy efficient lighting, heating and ventilation, electric motors, boilers, among others. For this purpose, it is proposed to provide needed funding in the global amount of US$5 million. This level of support would deliver approximately US$1,000 per chiller or about 3 – 5 man-days of assistance or the demonstration equipment.

Project Management

The AFI is to be paid a fee of US$4,000 per chiller, which represents 25% of the total support being provided from MLF, GEF, and Carbon Finance sources. This fee should be adequate to compensate the AFIs for the fiduciary duties they are being called upon to perform, specifically with respect to certifications, earlier discussed, they will be called upon to arrange for and provide, i.e with respect to old chiller characteristics needed to establish eligibility and grant amount, new chiller characteristics needed to establish eligibility, and post-installation data logging and certifications needed to establish Carbon Finance credits earned. In addition, the AFIs will need to carry out some promotional and information dissemination work vis-a-vis LIs that will participate in chiller financing, and negotiate and enter into contracts with participating LIs and their client chiller owners.

Table 10: Project Cost Component

	US$ million				
	MLF	GEF	Carbon Credits	Commercial Sources	Total
Investment Component					
Chiller Replacement	15	50	82	516	663
Sub-Total	15	50	82	516	663
Non-Investment Component					
Technical Assistance		5			5
Project Management ($4,000/chiller)		15			15
Sub-Total		20			20
Total	15	70	82	516	683

Project Impact

The proposed project will contribute 1,480 MT of recyclable CFC refrigerant to the 2,000 MT of additional recycled CFCs required for servicing the remaining CFC centrifugal chillers under unconstrained scenario.

The total carbon dioxide emission reduction gained from energy savings over the period 2008 – 20012 is 14 million tons of carbon dioxide equivalent.

Since the proposed plan will only finance chillers with the age range from 10 – 30 years old, the weighted average of the chiller age is about 17 years. While the manufacturer's recommended life of chillers is in the average of 30 years, it is very common that these chillers would be in operation up to 40 years or more. Hence, in average the proposed plan would accelerate replacement of chillers by 20 years. Consequently, the total carbon dioxide emissions avoided by this plan as per Scenario 1 is approximately 93 million tons of carbon dioxide equivalent.

New non-CFC centrifugal chillers are using HCFC-123 and HFC-134a, which have a much lower GWP values than CFC-11.

Table 11: GWP of Common Refrigerants Used in Centrifugal Chillers

Refrigerant	GWP
CFC-11	4,680
HCFC-123	120
HFC-134a	1,300

For the purpose of determining additional carbon emission reduction from replacing refrigerant with lower GWP, it is assumed that all chillers will be replaced by HFC-134a. Hence, the total impact of refrigerant change will be rather conservative. With the weighted average of the chiller age of 17 years, replacement of CFC chillers will advance the change in refrigerant by approximately 20 - 23 years. Based on the 20% leakage rate of existing CFC chillers and 10% leakage rate for new non-CFC chillers, it is projected that additional reduction of greenhouse gas refrigerant of 23 million tons carbon dioxide equivalent would be achieved by Scenario 1. The global impact based on other scenarios could be found in Table 12.

Table 12: Global Impact from Chiller Replacement Plan

	Scenario 1 ($15m)	Scenario 2 ($20m)	Scenario 3 ($30m)	Scenario 4 ($40m)
Recyclable CFCs (MT)	1,480	1,600	1,800	2,000
Total CO2 Emission Reduction (2007-2012) (tCO2)	13,730,766	14,755,516	16,753,891	18,752,265
Total CO2 Emission Reduction Avoided from Early Retirement (from 2008 - End of Useful Life) (tCO2)	93,789,804	100,870,401	114,813,836	128,757,272
Total CO2 (equiv) Emission Reduction Avoided from Lower GWP Refrigerant (from 2008 - End of Useful Life) (tCO2)	22,701,415	24,215,242	27,790,190	31,165,138

Project Milestones

Table 12: Project Milestones

Activity	Quarters																																			
	2005				2006				2007				2008				2009				2010				2011				2012				2013			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
MLF Project Approval				x																																
GEF Approval							x																													
Carbon Finance Approval							x																													
Grant Agreement for MLF Signed						x																														
Establishment of PMU						x																														
First Disbursement to PMU						x																														
Grant Agreement for GEF Signed									x																											
Carbon Finance Agreement									x																											
Sub-project Agreements Signed									x																											
Installation of New Chillers									x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

ANNEX 1

REPLACEMENT MACHINE (Case ID 58: 1994 600.00TR Centrifugal 1357 hours/yr)
Option No. 1 (HFC-134a)
REPLACEMENT POLICY ANALYSIS - SUMMARY

Discount rate assumed:	30.0%
Make:	(generic)
Type:	Centrifugal
Size:	600.00
Refrigerant:	HFC-134a
Power rating:	0.67 kW per TR
Annual usage:	1357 hours
Electricity Tariff:	5.18 Rs/kWh
Specific Initial Capital Cost:	Rs19111.1 per TR
Initial Capital Cost:	Rs 114.7 lakhs
Initial Capital Cost:	US$ 252.0 thousand
Residual Scrap Value:	Rs 3.7 lakhs
Residual Scrap Value:	US$ 8.2 thousand
Optimal Year after which to replace:	14
Social Discount rate assumed:	5.0%
Net Present Value of Optimal Replacement Policy:	Rs 267.9 lakhs
Social Net Present Value of Optimal Replacement Policy:	Rs 1106.0 lakhs
Exchange rate assumption:	US$1=45.5

REPLACEMENT POLICY ANALYSIS - COST DETAIL
REPLACEMENT MACHINE: (Case ID 58: 1994 600.00TR Centrifugal 1357 hours/yr)
REFRIGERANT OPTION 1 (HFC-134a)
(Rs Lakhs)

Repl Pol. (yrs)	Ann. Cap. Cost	Ann. Egy Cost	Ann. Mtce Cost	Ann. Down Cost	Ann. Refr Cost	Ann. TotRun Cost	Tot. Ann. Cost	Disc. Run Cost	Disc. TotAnn Cost	Disc. Scrap Cost	NPV. Life Cost	NPV Repl Pol.
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1	114.7	24.5	0.3	2.2	0.0	27.0	141.7	27.0	138.8	2.9	138.8	601.5
2	64.8	24.7	0.4	4.4	0.1	29.6	94.4	22.8	85.4	2.2	162.3	397.4
3	48.6	25.0	0.6	6.6	0.1	32.2	80.8	19.0	65.9	1.7	181.8	333.7
4	40.7	25.2	0.7	8.7	0.1	34.8	75.5	15.8	55.2	1.3	198.0	304.7
5	36.2	25.4	0.9	10.9	0.2	37.4	73.6	13.1	48.3	1.0	211.4	289.3

6	33.4	25.6	1.1	13.1	0.2	39.9	73.3	10.8	43.4	0.8	222.4	280.5
7	31.5	25.7	1.3	15.3	0.2	42.5	74.0	8.8	39.7	0.6	231.4	275.3
8	30.2	25.9	1.5	17.5	0.3	45.1	75.3	7.2	36.9	0.5	238.7	272.1
9	29.2	26.1	1.7	19.7	0.3	47.7	76.9	5.8	34.7	0.4	244.7	270.1
10	28.5	26.2	1.9	21.8	0.3	50.3	78.8	4.7	33.0	0.3	249.5	269.0
11	28.0	26.4	2.2	24.0	0.4	52.9	81.0	3.8	31.7	0.2	253.4	268.4
12	27.6	26.5	2.4	26.2	0.4	55.6	83.2	3.1	30.6	0.2	256.5	268.1
13	27.4	26.6	2.7	28.4	0.4	58.2	85.5	2.5	29.7	0.1	259.1	267.9
14	27.2	26.7	3.0	30.6	0.5	60.8	88.0	2.0	29.1	0.1	261.1	267.9*
15	27.0	26.9	3.4	32.8	0.5	63.5	90.5	1.6	28.5	0.1	262.7	268.0
16	26.9	27.0	3.7	34.9	0.5	66.1	93.0	1.3	28.1	0.1	264.1	268.1
17	26.8	27.1	4.0	37.1	0.6	68.8	95.6	1.0	27.8	0.0	265.1	268.2
18	26.7	27.2	4.4	39.3	0.6	71.5	98.2	0.8	27.5	0.0	265.9	268.3
19	26.6	27.3	4.8	41.5	0.6	74.2	100.8	0.7	27.3	0.0	266.6	268.4
20	26.6	27.4	5.2	43.7	0.7	76.9	103.5	0.5	27.1	0.0	267.1	268.6
21	26.6	27.5	5.6	45.9	0.7	79.6	106.2	0.4	27.0	0.0	267.6	268.7
22	26.5	27.6	6.0	48.1	0.7	82.3	108.9	0.3	26.9	0.0	267.9	268.7
23	26.5	27.6	6.4	50.2	0.8	85.1	111.6	0.3	26.8	0.0	268.2	268.8
24	26.5	27.7	6.9	52.4	0.8	87.8	114.3	0.2	26.7	0.0	268.4	268.9
25	26.5	27.8	7.3	54.6	0.8	90.6	117.1	0.2	26.7	0.0	268.5	268.9
26	26.5	27.9	7.8	56.8	0.9	93.4	119.8	0.1	26.6	0.0	268.7	269.0
27	26.5	28.0	8.3	59.0	0.9	96.1	122.6	0.1	26.6	0.0	268.8	269.0
28	26.5	28.0	8.8	61.2	0.9	98.9	125.4	0.1	26.6	0.0	268.9	269.0
29	26.5	28.1	9.3	63.3	1.0	101.8	128.2	0.1	26.5	0.0	268.9	269.1
30	26.5	28.2	9.9	65.5	1.0	104.6	131.1	0.1	26.5	0.0	269.0	269.1

Optimal policy is to replace after 14 years. The minimum net present value of owning and operating cost is Rs 267.9 lakhs (US$ 588.84 thousand).

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Exchange rate: US$1=45.5; Discount rate: 30.0%

Annex 2 - CHILLER DATA FOR CHINA

Country China

Total Number of CFC Centrifugal Chillers: 1,404 chillers
(as of August 2005)

Data Collection Process

The data collection was conducted on the basis of manufacturers' survey. Chillers in China are supplied by York, Trane, Carrier, Mitsubishi Electrics, Hitachi, Shanghai No. 2 Refrigeration Plant and the Chongqing General Refrigeration Plant (i.e, the Chongqing General Industrial Group Ltd. – CGIG – as of 2005). The Shanghai Plant stopped its CFC chiller production after it formed a joint venture with Carrier in 1987.

The inventory of CFC centrifugal chillers was developed on the basis of input provided by four manufacturers – York, Trane, Carrier, and CGIG, in August 2005. Information on CFC chillers manufactured by the Shanghai Plant, the Mitsubishi Electrics, and Hitachi, is not available. Based on information provided by the four manufacturers mentioned above, there are at least 1,404 CFC centrifugal chillers currently in operations. Additional information would be collected during the implementation of the project.

Age Profile

Based on the manufacturers' survey described above, the age profile of the existing CFC centrifugal chillers could be derived as shown in the table below. The majority of existing CFC chillers was installed during 1975 and 1990.

Age of Chillers	% of Chiller Population*
1 – 5	0%
6 – 10	6.4%
11 - 15	44.2%
16 – 20	36%
21 – 25	13.3%
26 - 30	0%
> 30	0.1%

*Based on the total number of chillers of 1,404 units that are still in operation in 2005.

Average Cooling Capacity

Based on the information of the identified 1,404 CFC centrifugal chillers, 1,292 units are CFC-11 technology and 112 units are CFC-12 technology. The total cooling capacity of these 1,404 units is approximately 490,000 RT. In other words, the average cooling capacity of the identified CFC centrifugal chillers in China is about 350 RT.

Power Consumption

Specific power consumption of CFC centrifugal chillers at rated capacity for each age range could be determined from the following empirical formula.

P = 0.28 * Ln (A + 5); where

P = Power consumption (kW/TR);
Ln = Natural logarithmic function; and
A = Age of the chiller.

Age of Chillers	Energy Consumption (kW/TR)
0 – 5	0.64
6 – 10	0.76
11 - 15	0.84
16 – 20	0.90
21 – 25	0.95
26 – 30	1.00

Cost of Electricity

The cost of electricity in China varies from one region to another and also from one application to another. The electricity cost is shown below.

Electricity Prices for Different Users in Different Regions (US$/kWh)

	Factory	Mall	Hotel	Office	Hospital
North	0.0786	0.09	0.09	0.0765	0.0765
East	0.075	0.082	0.082	0.082	0.082
South	0.0785	0.099	0.099	0.0785	0.0785

ANNEX 3 - CHILLER DATA FOR INDIA

Country India

Total Number of CFC Centrifugal Chillers: 1,100 chillers
(as of end of 2001)

Data Collection Process

The data collection was conducted based on two approaches: chiller manufacturer's survey; and chiller owners' survey. Chiller manufacturers' survey was the basis for the development of a database. It was created through the development and administration of a survey questionnaire and included a web-based data collection system. It included direct administration of the survey questionnaire in separate meetings will all of the major chiller manufacturers. Chiller owners' survey was conducted through the indirect administration of a survey questionnaire via mailings and a web site developed for this purpose. It was supported by advertisements and announcements in association newsletter.

Age Profile

Since the survey was conducted in 2001, it is estimated that a small population of chillers that were 30 years old in 2001 would be taken of service already in 2005. The age profile for the CFC chillers in India is adjusted accordingly. Based on the 2001 survey results, there will only be 1,045 CFC chillers in operations in 2005.

Age of Chillers	% of Chiller Population*
0 – 5	0%
6 – 10	15%
11 - 15	32%
16 – 20	26%
20 – 25	20%
25 – 30	7%

*Based on the total number of chillers of 1,045 units that are still in operation in 2005.

Average Cooling Capacity

The profile of the cooling capacity of CFC chillers in India is shown below.

Cooling Capacity (TR)	% of Chiller Population*
200 - 400	68%
500 - 900	24%
1,000 – 1,200	8%

The weighted average of the cooling capacity of existing CFC chillers in India is 460 TR.

Power Consumption

Specific power consumption of CFC centrifugal chillers at rated capacity for each age range could be determined from the following empirical formula, which was developed on the basis of survey results.

P = 0.28 * Ln (A + 5); where

P = Power consumption (kW/TR);
Ln = Natural logarithmic function; and
A = Age of the chiller.

Age of Chillers	Energy Consumption (kW/TR)
0 – 5	0.64
6 – 10	0.76
11 - 15	0.84
16 – 20	0.90
21 – 25	0.95
26 – 30	1.00

Cost of Electricity

The price structure for electricity in India is complex as it varies from state to state and also application or user specific. However, in average the cost of electricity applicable to the industry is Rs. 4.40/kWhr or US$ 0.10/kWhr.

ANNEX 4 - CHILLER DATA FOR INDONESIA

Country Indonesia

Total Number of CFC Centrifugal Chillers: 714 chillers
(based on the most current survey done in September 2005))

Data Collection Process

The inventory of CFC centrifugal chillers was developed on the basis of information provided by the four chiller manufacturers – York, Trane, Carrier, and McQuay. Currently, there are at least 714 CFC centrifugal chillers still in operations in Indonesia. This figure includes a few CFC centrifugal chillers produced by other manufacturers.

Age Profile

Based on the manufacturers' survey described above, the age profile of the existing CFC centrifugal chillers could be derived as shown in the table below. The majority of existing CFC chillers were installed after 1980 as only 43 chillers (or 6% of the total chiller population) were over 25 years old.

Age of Chillers	% of Chiller Population*
1 – 15	49%
16 – 20	26%
21 - 25	19%
26 – 30	6%
> 30	0%

*Based on the total number of chillers of 714 units that are still in operation in 2005.

Of the total 714 CFC centrifugal chillers, 451 units (64%) are running with CFC-11. The remaining units use CFC-12 as refrigerant.

Average Cooling Capacity

Based on the manufacturers' survey, the average size of the identified CFC centrifugal chillers in Indonesia is about 490 RT.

Power Consumption

Specific power consumption of CFC centrifugal chillers at rated capacity for each age range could be determined from the following empirical formula.

$$P = 0.28 * Ln(A + 5); \text{ where}$$

P = Power consumption (kW/TR);
Ln = Natural logarithmic function; and
A = Age of the chiller.

Age of Chillers	Energy Consumption (kW/TR)
0 – 5	0.64
6 – 10	0.76
11 - 15	0.84
16 – 20	0.90
21 – 25	0.95
26 – 30	1.00

Cost of Electricity

The cost of electricity in Indonesia varies from one application to another. For industrial and commercial applications, the cost of electricity is about Rp 455 - 520/kWh or US$0.05/kWhr. For hospitals, the cost of electricity is substantially lower, Rp 265/kWhr or US$ 0.03/kWhr. However, the survey results suggest that most of CFC centrifugal population is in the industrial and commercial applications.

ANNEX 5 - CHILLER DATA FOR MALAYSIA

Country Malaysia

Total Number of CFC Centrifugal Chillers: 683 chillers
(as of 2003)

Data Collection Process

A national chiller survey was conducted by the Malaysian Department of Environment (DOE) in 2003. Eight distributors of chillers were identified by the survey, including Trane, Carrier, York, Daikin, Hitachi, McQuay, OYL, and Dunham-Bush. Based on the input from these distributors, it is indicated that there are approximately 800 CFC-based chiller systems operational in Malaysia.

Detailed information including type of refrigerant, cooling capacity, and age range, of 683 CFC centrifugal chillers was obtained.

Age Profile

Based on the national survey described above, the age profile of the existing CFC centrifugal chillers could be derived as shown in the table below. The majority of existing CFC chillers was installed during 1978 to 1988.

Age of Chillers	% of Chiller Population*
1 – 5	0%
6 – 10	2.9%
11 - 15	30.2%
16 – 20	39.4%
21 – 25	19.5%
26 - 30	8.0%

*Based on the total number of chillers of 683 units that are still in operation in 2003.

Average Cooling Capacity

The inventory of the existing CFC centrifugal chillers includes information on the cooling capacity of each unit. Based on this information, an average cooling capacity could be determined. The average cooling capacity is 512 RT.

Power Consumption

Specific power consumption of CFC centrifugal chillers at rated capacity for each age range could be determined from the following empirical formula.

P = 0.28 * Ln (A + 5); where

P = Power consumption (kW/TR);
Ln = Natural logarithmic function; and
A = Age of the chiller.

Age of Chillers	Energy Consumption (kW/TR)
0 – 5	0.64
6 – 10	0.76
11 - 15	0.84
16 – 20	0.90
21 – 25	0.95
26 – 30	1.00

Cost of Electricity

The average cost of electricity applies to industrial facilities and commercial buildings, is US$0.05/kWhr.

ANNEX 6 - CHILLER DATA FOR PHILIPPINES

Country Philippines

Total Number of CFC Centrifugal Chillers: 193 chillers
(as of September 2005)

Data Collection Process

The inventory of CFC centrifugal chillers was developed on the basis of information provided by the two larger chiller suppliers – York and Trane. While there are other chiller suppliers in the Philippines, including Carrier, Westinghouse, McQuay, Daikin and Hitachi), York and Trane are the dominant players. Based on the information provided by York and Trane there are at least 193 CFC centrifugal chillers still in operations in the Philippines. Information for each of these 193 CFC centrifugal chillers including the installation dates and locations has been collected.

Age Profile

Based on the manufacturers' survey described above, the age profile of the existing CFC centrifugal chillers could be derived as shown in the table below. The majority of existing CFC chillers was installed during 1975 and 1990.

Age of Chillers	% of Chiller Population*
1 – 5	1%
6 – 10	3%
11 - 15	30%
16 – 20	23%
21 – 25	26%
26 - 30	12%
> 30	5%

*Based on the total number of chillers of 193 units that are still in operation in 2005.

Average Cooling Capacity

The inventory of the existing CFC centrifugal chillers includes information on the cooling capacity of each unit. Based on this information, an average cooling capacity could be determined. The average cooling capacity is 430 RT.

Power Consumption

Specific power consumption of CFC centrifugal chillers at rated capacity for each age range could be determined from the following empirical formula.

P = 0.28 * Ln (A + 5); where

P = Power consumption (kW/TR);
Ln = Natural logarithmic function; and
A = Age of the chiller.

Age of Chillers	Energy Consumption (kW/TR)
0 – 5	0.64
6 – 10	0.76
11 - 15	0.84
16 – 20	0.90
21 – 25	0.95
26 – 30	1.00

Cost of Electricity

The cost of electricity for the industrial and commercial applications varies from the lower rate (PP1.87/kWhr or US$ 0.3/kWhr) during the off-peak hours to the higher rate (PP 6.06/kWhr or US$ 0.11/kWhr) during the peak hour. For household users, the electricity cost is significantly higher.