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

PROJECT COVER SHEET

COUNTRY: CUBA **IMPLEMENTING AGENCY:** UNDP

PROJECT TITLE: Demonstration project for integrated management of the centrifugal chiller sub-sector in Cuba, 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) 32 MT ODP
PROJECT IMPACT: Reflecting the net ODP value not applicable MT ODP (* demonstration)

PROJECT DURATION: 3 years (2006 – 2008)

		MLF	UNDP	Gov't of Canada	CDN Private sector	Cuba	TOTAL
PROJECT COSTS & FUNDING:	US$	1,000,000[1]	40,000[2]	850,000[3]	150,000	1,000,000[4]	3,040,000
AGENCY SUPPORT COSTS:	US$	75,000	n/a	n/a	n/a	n/a	75,000
TOTAL COSTS:	US$	1,075,000	40,000	850,000	150,000	1,000,000	3,115,000

LOCAL OWNERSHIP: 100%
EXPORT COMPONENT: 0%

STATUS OF COUNTERPART FUNDING: As described above
PROJECT MONITORING MILESTONES: Included
NATIONAL COORDINATING BODY: Oficina Tecnica de Ozono (OTOZ), Ministerio de Ciencia, Tecnologia y Medio Ambiente (CITMA)

PROJECT SUMMARY

This project aims at facilitating integrated management of the centrifugal chiller sub-sector in Cuba, through application of environmentally sound and energy-efficient alternative technologies for sustainable replacement of CFC-based centrifugal chillers. Upon completion, the project will have the following primary outcomes: (a) creating conditions favorable for removal of barriers to early replacement of CFC-based chillers (b) a strategy for elimination of the residual consumption of Annex-A, Group-I substances (CFCs) in servicing of CFC-based centrifugal chillers Cuba; (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 29 chiller installations, representing the priorities of the Government of Cuba in terms of ownership and end-use profiles, a representative sample of 9 chillers will be selected for retrofitting and 10 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 by leveraging other potential funding sources which could include carbon finance, other multilateral and bilateral sources and counterpart funding at national level.

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

[1] $800,000 provided via UNDP and $200,000 provided via Canada's 2005 bilateral allocation.
[2] Funds sourced through UNDP's Thematic Trust Fund on Energy for Sustainable Development
[3] A project submission has been made to Canada's Climate Change Action Plan's, Technology Early Action Measures (TEAM) programme. A preliminary response should be provided prior to the 47th Meeting of the Executive Committee.
[4] In-kind contribution on the part of the Government of Cuba.

CUBA

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

Prepared jointly by

OTOZ/CITMA
United Nations Development Programme
4 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 Cuba
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 CUBA

Demonstration Project for Integrated Management of the Centrifugal Chillers Sub-sector in Cuba, 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[5] 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);

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[5] 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 Cuba, 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 barriers to early replacement of CFC-based chillers;
b) Reduction/elimination of the residual consumption of Annex-A, Group-I substances (CFCs) in servicing of CFC-based centrifugal chillers Cuba;
c) 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;
d) Demonstration of energy cost savings through application of energy-efficient replacement technologies; and,
e) 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 by leveraging a number of funding sources that could include carbon finance and other multilateral and bilateral funding sources, as well as counterpart funding at the national level.

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 19 chillers, drawn from a sample set of 29 nationally-owned chiller installations, representing the priorities of the Government of Cuba in terms of ownership and end-use profiles, have been selected for this replacement demonstration.

3. BACKGROUND

3.1 Introduction

Cuba, bordered to the south by the Caribbean Sea and to the north by the Gulf of Mexico and the Straits of Florida, has a tropical climate. The mean temperature is about 77ºF (25 ºC) in winter and in the range of 80ºF to 85ºF (26ºC) in summer. Averages range only between 70°F (21°C) and 82°F (27°C) for the coldest and warmest months. Summer readings can reach as high as 100°F (37°C).

From the political-administrative standpoint, the country is divided into 14 provinces and 1 municipality with special status (Isla de la Juventud). These areas have populations ranging from 0.5 to 1 million, with the exception of Havana, which has a population numbering slightly more than 2 million inhabitants. The urban population has increased from 69.0% in 1981 to 74.5% in 1995, according to census estimates of the National Statistics Bureau of Cuba.

The situation in Cuba since 1989 has been characterized, above all, by a profound economic crisis that has affected virtually all spheres of national life following the withdrawal of former Soviet subsidies and the ongoing US embargo. The severity of the crisis is evidenced by the fact that between 1989 and 1993 the country's gross domestic product (GDP) fell 35% and exports declined by 75%. In 1994, the downward trend of the economy began to reverse. By 1996 the GDP had increased by 7.8%. Although the overall negative trend seems to be in reverse and the economy appears to be growing, the country still faces difficulties as a result of unfavorable foreign borrowing terms, especially high short-term interest rates.[6]

3.2 Cuba's Montreal Protocol Activities

Cuba ratified both the Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol on Substances that Deplete the Ozone Layer in July 1992. Subsequently in October 1998, it ratified both the 1990 London Amendment, and the 1992 Copenhagen Amendment, to the Montreal Protocol. The Montreal and Beijing Amendment were signed in July 2005.

Cuba is classified as a country operating under Article 5 of the Montreal Protocol as its consumption per capita of Annex A, Group I chemicals is less than 0.3 kg ODP per year. Cuba does not produce any the Annex A Group I substances (CFCs) and the demand for CFCs is met through imports.

The Cuba Country Programme (CP), based on 1991 ODS consumption data, was approved in July 1993. Under the CP the Government proposed to eliminate 35% of CFC consumption between 1993 and 1996 by implementing training programmes for service technicians in the refrigeration sector. The remaining consumption was to be phased out by other activities by the year 2010. The six objectives of the CP are the following:

- Institutional building and strengthening of the NOU (OTOZ)
- Implementation of a recovery, recycling and destruction network for ODS
- Promote good refrigeration practices in the service and maintenance sector
- Follow up on mobile air-conditioning for private and transport vehicles
- Make available hydrocarbons as refrigerants
- Effectuate the substitution of methyl bromide by non ODS

6 Pan American Health Organisation (http://www.paho.org)

A survey was conducted to support the National Phase-out Plan preparation process, approved by the Executive Committee at its 37th meeting. The survey showed that the main use of CFCs in Cuba is found in the commercial refrigeration and air-conditioning sectors, principally in cold rooms in supermarkets, hotels, food processing and storage facilities in restaurants, as well as air conditioning systems in office buildings (chillers).

Cuba's average consumption level of Annex A Group I CFCs for the three years 1995 – 1997 was 625 ODP tonnes. In 1999, in order to ensure compliance with the first MP control step, Cuba froze the imports of Annex A Group 1 substances at the baseline level.

The maximum levels of annual CFC consumption allowed in order toensure that Cuba remain in compliance with the Montreal Protocol are as follows:

2005 – 2006	(50% of the "Baseline Consumption")	–	*313 ODP tonnes*
2007 – 2010	(15% of the "Baseline Consumption")	–	*94 ODP tonnes*
2010		-	*Zero consumption*

The most recent official CFC consumption reported to the Multilateral Fund Secretariat shows the following distribution by sector:

Table 1 – CFC consumption breakdown by sector (Year 2004)

Substances	*Aerosols*	*Foams*	*Refrigeration*	*Solvents*	*Total*	*Import*	*Export*
Anex A group 1							
CFC-11	34,72		42.00		76,72	76,72	
CFC-12	94,25		272,72		366,97	397,86	30,89
CFC-113			000	0,09	0,09	0,09	
CFC-114			1,08		1,08	1,08	
CFC-115			0,42		0,42	0,42	
TOTAL	128,97	000	316,22	0,09	445,28	476,17	30,89

Cuba's National Phase-out Plan (NPP) aiming CFC elimination was approved by the Executive Committee of the Multilateral Fund at its 43rd meeting in July 2004. The objective of the National Phase-out Management Plan is to completely phase-out consumption of chlorofluorocarbons by the year 2009, one year earlier than the provisions required under the Protocol. The NPP contains projects and technical assistance activities that contribute to the phase out of CFCs in the industrial, refrigeration and air-conditioning service sectors, as well as selected refrigeration and air-conditioning end-users sectors.

The main activities programmed within the NPP are:

- Training and certification programme for refrigeration service technicians;
- Further development of ODS regulations, public awareness and information dissemination to main stakeholders;
- Technical assistance programme for the refrigeration servicing sub-sector, to address specific needs that might arise during project implementation; for example, provide more recycling machines in the event of a steep rise in the price of CFCs, to purchase basic service tools should technicians experience difficulties in implementing good practices; or promote cost-effective and sustainable end-user retrofit programmes. To the extent possible, this programme would be

implemented in stages so that resources could be diverted to other activities, such as additional training or procurement of service tools, if the proposed results are not achieved; and
- Monitoring and management unit.

The Government of Cuba is fully committed to meeting its compliance target for CFC consumption in 2005, 2007 and 2010 according the phase-out schedule stipulated by the Montreal Protocol and to assure full compliance for reaching complete phase out by December 31, 2009.

With a baseline Ozone Depleting Substances (ODS) consumption of 585.7 ODP tonnes, Cuba's targeted consumption and phase-out rates are outlined in the table below:

All figures in ODS tones	2005	2006	2007	2008	2009	2010
Max allowable total consumption of first substance/sector	312	195	150	93	0	0
Reduction from MDI project	45	72	0	0	0	0
New reduction under plan	84	145	45	57	93	0
Total annual reduction of first substance	129	117	45	57	93	0

National CFC Phase Out Management Plan for Cuba, Phase Out of ODS in the Refrigeration and Air-conditioning Sector, Submitted to: The Multilateral Fund for the Implementation of the Montreal Protocol, by Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH Financed by Federal Ministry for Economic Co-operation and Development (BMZ), April 12th, 2004, pg. 57.

3.3 Cuba's Montreal Protocol Institutional Framework

There are 25 governmental organizations and institutions in Cuba that work in the area of environmental protection. Activities related to the protection of the ozone layer and implementation of the Montreal Protocol are coordinated by the Ministry of Science, Technology and Environment (Ministerio de Ciencia, Tecnología y Medio Ambiente (CITMA). CITMA consists of 4 large departments. The Ozone Technical Office (OTOZ) is situated in the Agencia de Medio Ambiente (Environmental Agency) of CITMA. The OTOZ is mandated as the state body responsible for the implementation of the Montreal Protocol in Cuba. Additionally, there are 15 officials in each province that assist OTOZ in its work.

Law 81 of the Environment, approved by the Cuban Parliament in July 1997 is the framework for ODS related regulations. It contains a section relating to the Atmosphere, which establishes the appropriate responsibilities regarding the technological processes and the importation of technologies appertaining to the emission of ODS.

The legislative basis for atmospheric protection has been reviewed and revised. The Ministry of Science, Technology and Environment Resolution Nº 65 dated 10 June 1999 establishes the national timetable for the reduction in the importation, exportation and manufacture of ODS.

In addition to the above, some of the main specific CFC related regulations established in Cuba are:

- Resolution 116/2005 compliments resolutions 65/1999 and 59/2000 which establish the system of licenses, the ODS elimination timetable, functions of each part and the information system.
- Regulation 107/2004 of CITMA establishes the prohibition of intentional ODS emissions in the atmosphere. Furthermore it makes it obligatory that personnel such as mechanics and technicians are trained in BPR as well as it obligates the refrigeration and AC shops to have R&R equipment and recuperate CFCs.

- Resolution 29/2004 of CITMA establishes the permission of a national recognition for entities that have eliminated CFCs, MeBr, or other ODS. They are delivered by the Minister of CITMA.
- Resolution 114/2004 establishes the voluntary agreements and the procedures for such terms.

3.4 Cuba's Energy Demand Scenario

Cuba is the second-largest producer and consumer of electricity in the Caribbean region, following on the heels of Puerto Rico. In 2002, Cuba's electricity consumption was 13.4 billion kWh.[7] Cuba experiences significant constraints with regard to its electricity supply and there is general acceptance of the weakness inherent in it's National Electric Energy System (SEN). The government is committed finding alternative solutions in order to alleviate strains on the system, as the National Electric Power System (SEN) is not able to maintain a stable supply of electricity due to repeated breakdowns in its main thermoelectric power stations, most of which have been in use for nearly four decades. Interruptions in service, which are frequent, become even more acute during hurricane season, from June to October, when torrential rains and gusting winds wreak havoc with the power grid.

In late 2004 the Government adopted a number of measures to try to alleviate the situation. In order to help cope with the present ebb in generating capacity, a rotating power-saving programme based on a series of regulatory measures was announced. These included, but were not limited to, the following: suspension of certain production-related processes that could accept downtime; limitation on use of electric irrigation systems to off-peak hours only; reduction of non-essential use of air conditioners; and, discontinuation of all commercial activities not related to the food sector be discontinued at 7 p.m.

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

[7] CIA World Factbook (www.cia.gov/cia/publications/factbook/)

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. According to studies on the subject, in several countries annual charge lost per year could reach 25 % (Chillers and Refrigerant Management Training Manual, UNEP, 1994) and in some cases 30% (Report of the TEAP Chiller Task Force, UNEP, 2004).

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. 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
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 Cuba provide an average energy efficiency of 0.77 Kw/TR[8] 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 to bring about chiller retrofit and conversion in Cuba with the following objectives:

a) Creating conditions favorable for removal of barriers to early replacement of CFC-based chillers;
b) Reduction/elimination of the residual consumption of Annex-A, Group-I substances (CFCs) in servicing of CFC-based centrifugal chillers Cuba;
c) 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;

[8] Source: World Bank/ICF – Global Overview of the Chiller Sector – World Bank Financial Agents Workshop, 2004.

d) Demonstration of energy cost savings through application of energy-efficient replacement technologies; and,
e) 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. The focus sectors to be addressed during the demonstration phase will be hospitals and public buildings.

5.1 Chiller Population

According to information collected by GTZ during the preparation of the National Phase-Out Plan, the chiller sector in Cuba consumes approximately 50% of the country's total CFC consumption. This was explained as being due to the fact that Cuba operates a significant number of Soviet Union type AC consoles which use CFC 11 and CFC 12 chillers. The exercise conducted by GTZ also concluded that 7000 CFC12 consoles, as well as 200 CFC 11 and CFC 12 chillers can be found in Cuba. Most of the systems are operated in public areas like hospitals, office buildings and restaurants.

The demand for R&R activities is very high. Air-conditioning systems contain between 0.5 kg to 500kg refrigerant charge. Recovery and immediate reuse of the refrigerant, where the refrigerant is not contaminated, can be recommended.

The following ministries operate air conditioning and chillers systems:

- MINTUR – Ministry of Tourism
- MINSAP – Ministry of Health
- Polo Científico – Scientific counsel
- MINCULT – Ministry for Culture

Each of the Ministries operates at least one workshop that repairs and services air-conditioning and chiller systems. In addition, MINSAP has a general maintenance unit that repairs turbo compressors (chillers) in hospitals.

The 2004 ODS consumption report by sector submitted to the Multilateral Fund Secretariat indicates that the use of CFC 11 in refrigeration servicing is 32 ODP tonnes. A significant portion of this consumption is allocated to the maintenance of chillers.

5.2 Energy Efficiency Analysis

An analysis was carried out for the 29 selected chiller installations (all were CFC-11 based) representing a range of 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

Assumptions

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

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

b) Electricity costs in Cuba (US$/Kwh): 0.09

c) Average Energy Efficiency of current Chiller Installations in Cuba is 0.63 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 Cuba is 0.773 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:

  - For replacement, a total of 15 chillers with installed capacity amounting to 2,330 TR (35%) will be retrofitted to HCFC-123 technology and remaining 14 chillers will be replaced with HFC-134a technology
  - Annual leakage rate in the baseline is 10% of the initial refrigerant charge. For replacement, the annual leakage rate is 3% of the initial refrigerant charge.
  - The GWPs are: CFC-11 – 4,000 HCFC-123 – 93 HFC-134a – 1,320. Based on the proposed retrofitting and replacement plan, the average GWP of refrigerant leaking through converted chillers is 891 (35% HCFC-123 and 65% HFC-134a).

  The results of the energy efficiency analysis based on the above are tabulated below:

Table-1: Cuba – Energy Efficiency Analysis of Chiller Conversions

End-use Profiles/Parameters	Commercial Buildings	Office Buildings	Hospitals	Total (or weighted averages)
Number of sample installations	5	5	19	**29**
Range of dates of installations	1974-1989	1975-1980	1979-1985	**1974-1989**
Carbon intensity of power (Kg-C/Kwh)	0.773	0.773	0.773	**0.773**
Baseline Scenario (CFC-based Chillers)				
Available Economic Lifetime (years)	10	10	10	**10**
Total Installed Capacity (TR)	1,640	2,120	2,930	**6,690**
Total Refrigerant Charge (Kg)	2,450	2,900	4,480	**9,830**
Equivalent Full Load Hours (Hrs/year)	3,000	3,000	5,000	**4,310**
Energy Costs (US$/Kwh)	0.09	0.09	0.09	**0.09**
Energy Efficiency (Kwh/TR)	0.63	0.63	0.63	**0.63**
Annual Energy Use (Kwh)	3,099,600	4,006,800	9,229,500	**16,335,900**
Annual Energy Costs (US$)	278,964	360,612	830,655	**1,470,231**
Lifetime Energy Costs (US$)	2,789,640	3,606,120	8,306,550	**14,702,310**
Lifetime Indirect CO_2 Emissions (t-C)	23,960	30,970	71,340	**126,270**
Lifetime Direct CO_2 Emissions (t-C)	9,800	11,600	11,920	**33,320**
Lifetime Total CO_2 Emissions (t-C)	33,760	42,570	83,260	**159,590**
Replacement Scenario (non-CFC Chillers)				
Comparable Economic Lifetime (years)	10	10	10	**10**
Total Installed Capacity (TR)	1,640	2,120	2,930	**6,690**
Total Refrigerant Charge (Kg)	1,640	2,120	2,930	**6,690**
Equivalent Full Load Hours (Hrs/year)	3,000	4,000	5,000	**4,310**
Energy Costs (US$/Kwh)	0.09	0.09	0.09	**0.09**
Energy Efficiency (Kwh/TR)	0.56	0.56	0.56	**0.56**
Annual Energy Use (Kwh)	2,755,200	3,561,600	8,204,000	**14,520,800**
Annual Energy Costs (US$)	247,968	320,544	738,360	**1,306,872**
Comparable Lifetime Energy Costs (US$)	2,479,680	3,205,440	7,383,600	**13,068,720**
Lifetime Indirect CO_2 Emissions (t-C)	21,300	27,530	63,420	**112,250**
Lifetime Direct CO_2 Emissions (t-C)	440	570	780	**1,790**
Lifetime Total CO_2 Emissions (t-C)	21,730	28,100	64,200	**114,030**
Energy Efficiency Savings				
Lifetime Energy Cost Savings (US$)	309,960	400,680	922,950	**1,633,590**
Lifetime CO_2 Emission Reductions (t-C)	12,030	14,470	25,060	**51,560**
Net/Weighted Average Energy Efficiency Savings per Chiller Installation				
Average installed capacity (TR)				**231**
Annual Energy Cost Savings (US$)				**6,272**
Lifetime (10-year) Energy Cost Savings (US$)				**62,720**
Lifetime Total CO_2 Emission Reductions (t-C)				**1,836**

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

- Impact of overall air conditioning system optimization
- Demand-side management

5.3 Identification of Barriers to Conversion

In Cuba, the role of the private sector is limited and therefore, the present analysis of chiller conversion potential focuses solely on the public sector. Within the Cuban public sector, the Government of Cuba cites as its main barrier(s) to conversion:

- High cost of upfront investment. Since the majority of chillers reside under the purview of the Government of Cuba, adequate access to funding to replace this equipment is limited.
- Risk of downtime. The on-site work required to convert an existing chiller to a non-CFC chiller requires the modification of all electrical and plumbing arrangements for the building the chiller is attached to. Over half of government chillers belong to hospitals which play a critical role in the provision of crucial health services such as surgical rooms, neonatology, burned patients wards, blood banks, and laboratories. Any disruption in these services is expected to adversely impact the health of the people so that all means are used to keep even inefficient systems running while economic and environmental considerations are often neglected.[9]
- Lack of specialized knowledge for maintenance. Maintenance is a problem because technicians lack the specialized knowledge to service new units. There are additional incremental operating costs related to higher price of various components and spares required for maintenance of the new systems.
- Lack of knowledge of alternatives. There is limited knowledge regarding the range of alternative and substitute refrigerants available which adequately meet Cuban specific conditions. More knowledge on the availability and cost of these technologies is required in order to make informed investment decisions. In some cases, the Cuban Government has taken the lead to develop alternatives such as INPUD's production of domestic refrigerators with environmental friendly technology and Cuba's production of LB12.[10] The LB12 constitutes a direct substitute to CFC-12, it is a ternary mixture of hydrocarbons (R290, R600, R600a).[11]
- Lack of awareness on the remaining time for conversion. Continued awareness on ozone issues is necessary to support existing phase out projects in Cuba. There are several indications that the level of understanding of the main stakeholders regarding the phase out schedules for future reduction of CFC supply and its consequences is quite low, and needs to be increased.

5.4 Sector Wide Strategies and Funding Options

Since the primary obstacles for conversion are the high cost of upfront investment and the risk of downtime for replacing CFC chillers, the strategy for the demonstration project will tackle both obstacles directly in an attempt to discern the most appropriate approach for eventually converting all government chillers to non-ODS technology.

1. Address highest downtime risk by targeting hospital chillers. An analysis of chillers by sector suggests that hospitals are one of the most important large scale consumers of CFCs. Without consideration to the substitution of CFCs in hospitals, a terminal phase-out cannot be achieved.

Sector	Percent of all chillers
Hospitals	66%
Government buildings	17%
Other	17%

[9] National CFC Phase Out Management Plan (NPMP) for Cuba, Phase Out of ODS in the Refrigeration and Air-conditioning Sector, Submitted to: The Multilateral Fund (MLF) for the Implementation of the Montreal Protocol, by Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH Financed by Federal Ministry for Economic Co-operation and Development (BMZ), April 12th, 2004, pg. 36.

[10] The Cuban Government sought financial assistance from the GEF when it made the decision to invest in a new home refrigerator manufacturing line, in which the use of ODS in the manufacturing process is eliminated. INPUD **was** established as the public agent for this manufacturing line. NPMP, pg. 22.

[11] Ibid, pg. 35.

Cuba has 62 priority hospital facilities, such as maternal, clinical-surgical, pediatric, general and specialized hospitals. There are upwards of 20 building chillers housed in these various facilities and an estimated total of in the range of 60 chillers in the public sector as a whole. There has been little effort to convert existing systems in hospitals to non-ODS technology because: (1) hospitals belong to the public sector and therefore depend on scarce public funds; and, (2) disruption of public health services may adversely impact the health of the Cuban people.

2. Combine replacement with conservation. The overall strategy for the chillers sector in Cuba identifies all chillers in the public sector, allocates them into three categories, and applies the most cost effective and environmentally efficient technology based upon the specifications of the particular chiller identified. The graphic below summarizes the overall strategy for the chillers sector in Cuba.

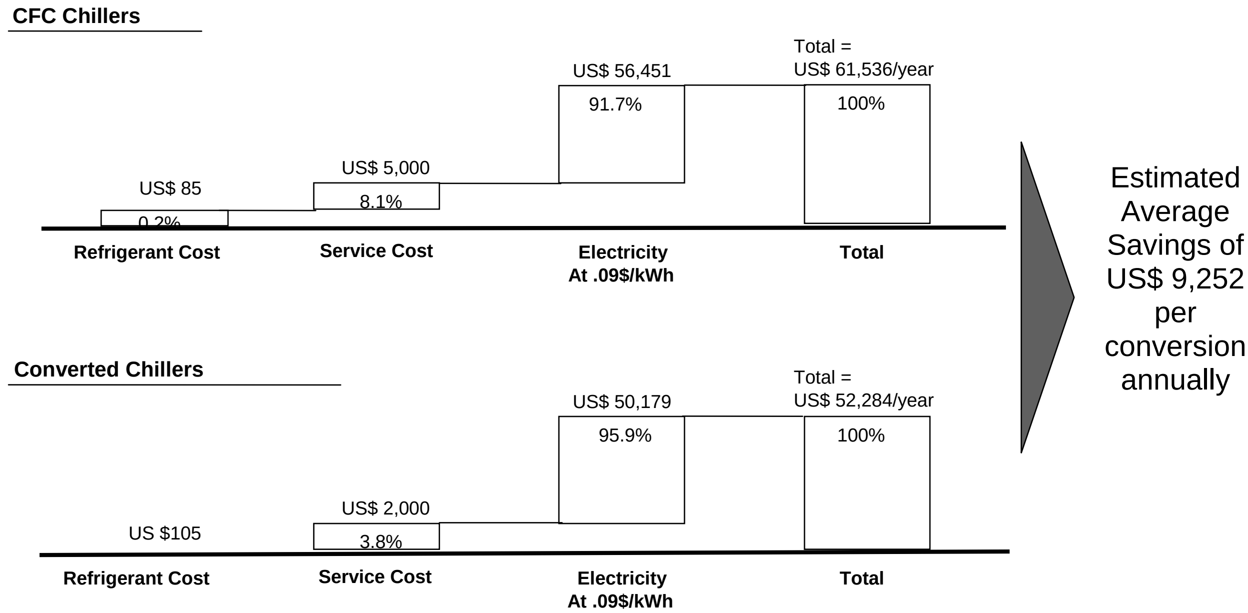
MAKE THE MOST OUT OF EXISTING EQUIPMENT WHILE ACHIEVING ENVIRONMENTAL AND ECONOMIC TARGETS

Equipment Description	Solution	Solution Description
Old equipment (Balance economic life: 0-5 years) • Chillers that have surpassed or are close to the end of their economic lifespan • Chillers that have high leakage rates and maintenance costs	**Replace**	• Purchase and install a new non-CFC chiller • Modify all electrical and plumbing arrangements for the building the chiller is attached to
Mid-life equipment (Balance economic life: 5-10 years) • Chillers at the middle of their economic lifespan • Chillers that have medium-to high leakage rates and maintenance costs	**Retrofit**	• Replace the compressor and motor assembly to use alternative refrigerant • Replace the purge unit on the chiller itself
Relatively new equipment (Balance economic life: Over 10 years) • Chillers recently purchased in the 1990s & far from completing their economic lifespan • Chillers with no to low leakage rates and maintenance costs	**Conserve**	• No change or modification to existing equipment • Ensure good maintenance to minimize leakage • Reuse CFCs recycled from other chiller replacements and retrofits to reduce/eliminate imports of CFCs

For the demonstration project proposal, a representative sample of 29 chillers has been identified for retrofitting and replacement based on the criteria listed above.

The chillers chosen for the demonstration project will validate the economic and environmental rationale to catalyze conversion for the rest of the Cuban chiller sector. In the demonstration phase, 15 chillers will be retrofitted with HCFC-123 technology and 14 chillers will be replaced with HFC-134 technology over the course of the project. Conversion of these chillers is expected to result in average annual savings in operating costs of US$ 9,252 The figures below display the economics of a sample chiller to be converted. The baseline and replacement energy efficiency analysis for this sample chiller is presented in Annex-I. The sample chiller data is the result of weighted averages obtained from analyzing the 29 chillers surveyed.

ANNUAL OPERATING COSTS FOR A SAMPLE CHILLER CONVERSION



Current Refrigerant Costs are based on CFC-11 leak rates at 10% per year at US$ 2.50/kg
Projected Refrigerant costs are based on leak rates at 3% per year at an average of US$ 15.00/kg
Current Service costs are considered at US$ 5,000/year base
Projected Service costs are based on 40% of current service cost

These chillers constitute a representative sample of all public sector chillers that will be identified for Cuba's chiller sector strategy. Therefore, the final decision regarding exactly which chillers will be retrofitted and replaced under the demonstration project will depend upon which chillers in the total population produce the greatest cost savings, energy efficiency, and/or ODS consumption reductions after retrofitting and replacement.

3. Funding via matching and in kind contributions. Since Cuba's focus for chiller conversions is exclusively public sector chillers and market data is limited, the financing approach for Cuba's overall chiller sector strategy rests upon matching and in kind contributions. To implement its government wide chiller sector project, Cuba has requested counterpart commitments for funding in the following approximate proportions:

Financing Source for Sector-wide Implementation	Counterpart commitment
MLF	12.0%
Government of Canada (Public & Private)*	11.0%
UNDP's Energy Thematic Trust Fund (TTF)	0.5%
Government of Cuba	76.5%

* For details, refer to Section 6.3.2.
NOTE: Money already requested, to be requested, or currently committed from financing source. Total cost of strategy assumes cost of retrofit and replacement of $3M for 20 chillers with 60 total Cuban chillers in public sector.

In turn, the Government of Cuba has committed to matching counterpart funding by providing approximately 77% of overall funding and/or financing to replace or retrofit chillers not included in the proposed demonstration project and covering costs, such as new electrical and water installations, site re-conditionings, decommissioning of old chillers, and other elements required to replace government chillers to non-ODS technologies.[12]

Funding for the demonstration project will also be approached via a matching grants and in-kind contribution strategy. For the demonstration project alone, the breakdown in monies committed is as follows:

Funding Source for Demonstration Project	US$ for Demo Project	% of Demo $
MLF – UNDP	$1,000,000.00	32.9%
MLF – Agency Support Costs	$75,000.00	2.5%
Government of Canada (Public & Private)*	$1,000,000.00	32.9%
Government of Cuba**	$1,000,000.00	32.9%
UNDP-TTF	$40,000.00	1.2%
Total	$3,040,000.00	

* A submission has been made for financing in the amount specified. Of the $1 million, $850,000 has been requested for chiller equipment under TEAM (refer to Sections 6.3.2 and 6.4.2) and $150,000 will be donated through the private sector.
** Approximately $1 million in-kind contribution to cover the costs associated with the local commissioning of the chillers, including new electrical and water installations, site reconditioning, decommissioning of old chillers, compensation from down time during conversions, etc.

Thus, demonstration project funds constitute approximately 23% of all funds committed to Cuba's chiller sector project. These funds will be used to catalyze the remaining 77% of the funds required for the replacement or retrofit of all remaining public sector chillers in Cuba.

5.5 Project Components and Costs

Targeting hospitals and incorporating knowledge regarding the barriers to replacement faced by the Government of Cuba, the demonstration project will undertake to perform retrofits as well as replacements in order to minimize the impact (and reduce the opportunity cost) of hospital replacements. The graphic below outlines the demonstration project equipment related components and their corresponding estimated cost.

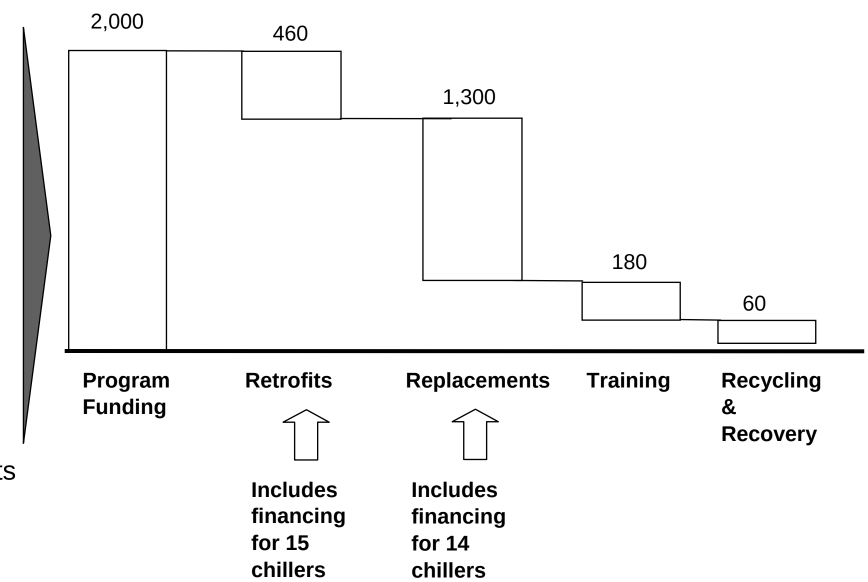
[12] Assumes that approximately 20 chillers will be retrofitted and converted in demonstration phase for $3 million and that Cuba will later follow up with conversion and retrofitting of additional 40 chillers remaining in country at similar cost.

CUBA DEMONSTRATION PHASE EQUIPMENT COMPONENTS AND COSTS

$000s

To create the conditions for full scale implementation, the demonstration phase will use $1M to:

- Match in-kind contribution from Government of Cuba and
- Match a grant from the Canada Climate Change Action Fund (CCAF) that will:
  - – Convert 29 chillers
  - – Purchase 3 Refrigerant R&R Kits
  - – Provide on-site and factory training for further retrofits and ongoing maintenance



NOTE: $2 million includes $1 million from MLF, $850,000 in sche duled equipment from Government of Canada via TEAM, and $150,000 from the Canadian private sector v ia TEAM.

Additionally, in order to ensure that the retrofits and replacements are performed in accordance to the needs and specifications tailored to Cuban conditions, the Government of Cuba has agreed to contribute approximately $1,000,000 worth of in-kind aide in order to provide for the local decommissioning of the chillers being retrofitted and replaced. In-kind aide includes but is not limited to new electrical and water installations, site reconditioning, and decommissioning of old chillers.

Also, $40,000 from UNDP's TTF will be used to address awareness among the main stakeholders in Cuba regarding the phase out schedules for future reduction of CFC supply and their consequences.

6. IMPLEMENTATION of DEMONSTRATION PHASE

6.1 Management

UNDP and the Government of Canada will manage the demonstration project according to UNDP's 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 replacement of chillers will be enabled.

6.2 Action Plan and Indicators of Success

COMPONENTS OF DEMONSTRATION PHASE

	1 **Target Retrofits and Replacements**	2 **Implement Retrofits and Replacements**	3 **Identify Lessons Learned**	4 **Awareness Raising Campaign**
Action	• Identify and obtain specifications on chillers to be retrofitted and replaced • Quantify expected costs and risks incurred during retrofit and replacement process • Draft retrofit and replacement plan • Obtain approval for implementation plan from appropriate stakeholders	• Obtain appropriate equipment for retrofitting and replacement • Work with government hospitals and appropriate officials to tailor/customize plan • Implement retrofit and replacement plans • Follow up with training and maintenance	• Monitor replacement results and impact • Evaluate implementation, training, and maintenance to identify possible adjustments • Identify indicators and variables of success	• Approach chiller stakeholders to discuss options • Obtain agreement on program overall and specific approaches to implement • Develop action plan to approach and retrofit or replace remaining chillers
Results Expected	• Draft retrofit and replacement plan that incorporates Cuba specific technological requirements and risks	• 9 hospital chillers retrofitted, 10 hospital and other government building chillers replaced • Long term training and maintenance needs identified	• Cuba specific process for replacement and retrofitting • Cuba specific technical, training, and maintenance specifications confirmed	• Strategy and action plan to retrofit or replace all CFC chillers • 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. Demonstrate downtime risk can be mitigated.
    a. Is the downtime associated with retrofitting actually less than that of replacement as suggested in this document?
    b. Can hospital service levels be better maintained by retrofits rather than replacement?
2. Demonstrate benefits and costs of chiller replacements in comparison to the alternative of chiller retrofits.
    a. Are the upfront costs of retrofitting as compared to replacement in line with those projected in this document?
    b. Are maintenance and operating procedures of the retrofitted systems very similar to the existing equipment as suggested in this document?
    c. Is more additional training required for replacement than retrofitting as suggested in this document?
    d. Are the annual servicing costs in line with the annual operating costs listed in this document?
    e. Does retrofitting rather than replacement still help to achieve the desired reduction in ODS consumption projected in this document?

3. Training of a sufficient core of Cuban technicians.
    a. Do technicians have the specialized knowledge they need to service new units?
    b. Have enough trainers of technicians been educated?
4. Conduct an effective awareness campaign.
    a. Have the majority of chiller stakeholders been reached out to?
    b. Do the majority of chiller stakeholders understand the phase out dates, alternatives available, costs and benefits involved with the chiller sector strategy?
5. Successfully implement demonstration projects
    a. Were all of the proposed retrofits and installations completed? If not, why?
    b. Did the new retrofits or chillers achieve the expected energy cost savings?
    c. Do the projects demonstrate an avoidance of significant increase in yearly cost?

6.3 Counterpart Funding

6.3.1. UNDP's Thematic Trust Fund on Energy for Sustainable Development

Energy services can provide cross-cutting influences on both social and economic development, thereby influencing a nation's ability to achieving Millennium Development Goals (MDGs). For the 2 billion people in the world who have no regular access to reliable energy services, electrification or the availability of clean cooking fuels could reduce poverty, improve health conditions, and increase standards of living.

In the fall of 2001, UNDP launched the Thematic Trust Fund on Energy for Sustainable Development to mobilise resources and promote coherency across UNDP in its approach to energy issues. The Trust Fund's principal aim is to promote energy as a means to achieve sustainable development. Of the four priority areas addressed by the Trust Fund, two priorities seek to achieve the same end result as the demonstration project being proposed to the Multilateral Fund: strengthening national energy policy frameworks; and, increasing access to investment financing for sustainable energy.

The demonstration project therefore, seeks to work in cooperation with the UNDP Energy TTF focal point to mobilize the sum of US $40,000 to support the efforts of the demonstration phase.

6.3.2. Government of Canada : Technology Early Action Measures (TEAM) programme

The Government of Canada's Technology Early Action Measures (TEAM) programme is an interdepartmental technology investment initiative established under the federal government's Climate Change Action Plan. TEAM supports projects that are designed to develop technologies that mitigate greenhouse gas (GHG) emissions nationally and internationally, and that seek in turn to sustain economic and social development.

TEAM has demonstrated that the best opportunities for benefiting from new technologies in international development require sharing the R&D risk among business and government partners in developed and developing companies. This approach has been a key factor in the successful implementation of TEAM small hydro projects in Nepal, Poland, and China.

A TEAM Concept Note that highlights partnership with the UNDP-Government of Canada demonstration project proposal being submitted to the Multilateral Fund has been prepared by Environment Canada for consideration of TEAM's Executive body. The Concept Note outlines the aim of the partnership effort which seeks to demonstrate the energy efficiency potential of chiller retrofit and replacement technology in Cuba. Successful consideration of the TEAM request would leverage US $850,000 on the part of the Government of Canada towards implementation of the demonstration project. . However, it should be noted that TEAM needs to consider the Concept Note proposal on the basis of its own funding criteria, so that approval can not be taken for granted. It is expected that at least a preliminary response from TEAM will be provided prior to the 47th ExCom meeting.

6.4 Demonstration Project Budget

6.4.1 Project Costs

Total chiller population in Cuba: Approx. 200
Total number of demonstrations: 29

No	Item/Description	Unit	Qty	Unit Cost (US$)	Total Cost (US$)
1	Retrofitting of existing chiller installations with HCFC-123 technology	Nos	15	54,000	810,000
2	Replacement of existing chiller installations with HFC-134a technology	Nos	14	154,000	2,156,000
3	Information dissemination and awareness activities	Lots	1	50,000	50,000
4	Technical assistance conversions through external experts	Lots	1	25,000	24,000
Total					**3,040,000**

Notes:

a) The retrofitting/replacement costs include costs for site preparation, installation, start-up, trials, commissioning and training.

b) It is understood that the implementing/bilateral agencies and the government would have flexibility in allocating the budget within the amounts mentioned above, in a manner that would be considered to best meet the project objectives and outcomes.

c) The chiller replacement and retrofitting costs are average costs., The actual costs would depend upon the capacity and technology,

6.4.2 Funding arrangements

To meet the project costs estimated above, the following funding sources/arrangements are proposed:

Funding Source	Amount (US$)
Montreal Protocol Multilateral Fund	1,000,000
Canada	1,000,000
Cuba	1,000,000
UNDP-TTF (pending approval)	40,000
Total	**3,040,000**

Note:
The above does not include UNDP agency support costs amounting to US$ 75,000 pertaining to the portion of funding from MLF of US$ 1,000,000. The co-financing from Canada includes US$ 850,000 from the Government of Canada and US$ 150,000 from the Canadian private sector.

ANNEX-1
ENERGY EFFICIENCY ANALYSIS

(For a capacity of 231 TR resulting from weighted-average of the selected sample of 29 chillers)

ENERGY EFFICIENCY ANALYSIS IN CHILLER REPLACEMENT/RETROFITTING

BASELINE SCENARIO		REPLACEMENT SCENARIO	
Installed chiller capacity (TR)	231	Replacement chiller capacity (TR)	231
Refrigerant Charge (Kg)	339	Refrigerant Charge (Kg)	231
Annual Leakage Rate (Kg/year)	34	Annual Leakage Rate (Kg/year)	7
Balance Economic Lifetime (Years)	10.00	Comparable Economic Lifetime (Years)	10.00
Energy Efficiency (Kw/TR)	0.63	Energy Efficiency (Kw/TR)	0.56
Energy Costs (US$/Kwh)	0.090	Energy Costs (US$/Kwh)	0.090
Equivalent Full Load operating Hours (EFLH/yr)	4,310	Equivalent Full Load operating Hours (EFLH/yr)	4,310
Annual Energy Use (Kwh)	627,234	Annual Energy Use (Kwh)	557,542
Annual Energy Costs (US$)	56,451	Annual Energy Costs (US$)	50,179
Lifetime Energy Costs (US$)	564,511		501,787
Annual Direct CO_2 Emissions (Tonnes-CO_2)	136	Annual Direct CO_2 Emissions (Tonnes-CO_2)	6
Annual Indirect CO_2 Emissions (Tonnes-CO_2)	485	Annual Indirect CO_2 Emissions (Tonnes-CO_2)	431
Annual Total CO_2 Emissions (Tonnes-CO_2)	621	Annual Total CO_2 Emissions (Tonnes-CO_2)	437

RESULTS	
Annual Energy Savings (Kwh)	69,693
Annual Energy Cost Savings (US$)	6,272
Lifetime Energy Cost Savings (US$)	62,723
Annual Total CO_2 Emission Reductions (Tonnes-CO_2)	184
Lifetime CO_2 Emission Reductions (Tonnes-CO_2)	1,836

ANNEX-2
REPLICATION OF THE STRATEGY

Two major lessons for purposes of replicability are expected to be extracted from Cuba's demonstration project:

- Hospital replacements. Since the technical solutions at hand for A2Cs are generally not appropriate to hospital conditions in A5Cs for various reasons, planning needs to incorporate the specific requirements in term of local climate and infrastructure services from the beginning. The installation requires experience in managing the shift towards the new system under prevailing conditions. The Government of Cuba is therefore hoping to learn from the demonstration project the most appropriate methods and process to replace its hospital chillers, and the replacement's impact upon the functioning of public hospitals and public health. Hospital chillers typically constitute a sizable portion of many developing country public sector chillers. Implementation lessons can be learned from Cuba's demonstration experience to apply to other country replacement programs.
- Centralized system replacements. Cuba's experience can serve as a model for funding or financing of centralized system(s) replacements, low volume country replacements, or for countries where the large majority of chillers belong to the public sector.

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 OTOZ/CITMA 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 OTOZ/CITMA 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.

OTOZ/CITMA will periodically carry out an independent verification of the reports.

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