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

PROJECT COVER SHEET

COUNTRY: REGIONAL CARIBBEAN[1] **IMPLEMENTING AGENCY:** UNDP

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

PROJECT DURATION: 3 years (2006 – 2008)

		MLF	Counterpart UNDP	Counterpart GEF MSP	Total
PROJECT COSTS & FUNDING:	US$	1,000,000	160,000	1,000,000	2,160,000
AGENCY SUPPORT COSTS:	US$	75,000	n/a	72,000	147,000
TOTAL COSTS:	US$	1,075,000	160,000	872,000	2,307,000

LOCAL OWNERSHIP: 100%
EXPORT COMPONENT: 0%

STATUS OF COUNTERPART FUNDING: As described above
PROJECT MONITORING MILESTONES: Included
NATIONAL COORDINATING BODIES: National Ozone Units from the respective Caribbean countries participating

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 the Caribbean region 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) a strategy for elimination of the residual consumption of Annex-A, Group-I substances (CFCs) in servicing of CFC-based centrifugal chillers in the Caribbean; (c) creation of a stockpile of CFCs recovered from replaced chillers to be used for servicing of those CFC-based chillers in the Caribbean, 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 of chiller installations representing the priorities of the governments participating in the demonstration project in terms of ownership and end-use profiles, a representative sample of 14 chillers has been selected for replacement demonstration.

Secondary outcomes of this demonstration project will include: (a) Compilation of a regional 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 the Caribbean region 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 region-wide replacement of CFC-based chillers in small island developing states (SIDS).

PREPARED BY: UNDP jointly with NOUs and chiller task force national team members **DATE:** 5 October 2005

[1] Focus countries involved in the preparation of the demonstration project included: Barbados, the Dominican Republic, Jamaica and Trinidad and Tobago.

REGIONAL CARIBBEAN

DEMONSTRATION PROJECT FOR INTEGRATED MANAGEMENT OF THE CENTRIFUGAL CHILLER SUB-SECTOR in the CARIBBEAN REGION*, WITH FOCUS ON APPLICATION OF ENERGY-EFFICIENT CFC-FREE TECHNOLOGIES FOR REPLACEMENT OF CFC-BASED CHILLERS

(* Barbados, the Dominican Republic, Jamaica and Trinidad and Tobago)

Prepared jointly by

National Ozone Units
United Nations Development Programme

5 October 2005

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LIST OF ABBREVIATIONS

ARI	American Refrigeration Institute
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigeration and Air-conditioning Engineers
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)

Demonstration Project for Integrated Management of the Centrifugal Chillers Sub-sector in the Caribbean Region, 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[2] 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);
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 Annex II); and,
5. The project proposal includes a general strategy for managing the entire CFC chiller sub-sector

[2] 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)

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 the Caribbean, 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 in the Caribbean;
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 nationally-owned, representing the priorities of the governments involved in the project in terms of ownership and end-use profiles, have been selected for this replacement demonstration.

3. BACKGROUND

3.1 Introduction

In the Caribbean region UNDP collaborates with a number of low-volume consuming countries (LVCs) on the implementation of refrigeration sector activities. In the Barbados, the Dominican Republic, Jamaica and Trinidad and Tobago, UNDP is working in collaboration with national partners to implement national CFC elimination programmes[3], projects for, with the exception of the Barbados, accelerated phase-out targets have been agreed to by the countries. In each case, in the absence of guidance from the Parties to the Montreal protocol and the Executive Committee of the Multilateral Fund, chiller sectors have been excluded from consideration within the context of the CFC phase-out programmes.

With the advent of Decision XVI/13, and further Decision 46/33, discussion between UNDP and these four specific countries underscored their interest in extending their CFC phase-out efforts to include the chiller sector and they expressed an interest in being able to benefit from the chiller demonstration window. Within the context of the region, these countries are considered to be a good representative sample for the region as a whole.

Countries	Size (sq. miles)	Population '000 July '99	Per Capita GDP	Openness X+M/Y % *
Barbados	166	259.2	8406	113.2
Dominican Republic	18,811	8,129.7	1697	103.1
Jamaica	4,242	2,652.4	2694	98.7
Trinidad and Tobago	1,979	1,102.1	4630	101.9

Sources: Caribbean Latin American Action, IMF Financial Statics and Inter American Development Bank.

* Note: Openness is calculated by adding Exports of goods and services to Imports of goods and services and dividing the total by GDP. X represents exports and M represents imports.

The Caribbean region covers an area of about 1,020,000 square miles or 2,640,000 square kilometers. The islands of the Caribbean are located from the southeastern areas of Mexico to the northwest of Venezuela. The region comprises at least 7,000 islands, islets and reefs.

With the exception of the Bahamas, the islands of the Caribbean are located in a tropical zone and usually experience warm, humid conditions, the result of the northeasterly trade winds which bring moisture in from the Atlantic Ocean. Temperatures in the region are not significantly variable as they range from around 28 degrees Celsius in the hotter months (July-August) to around 24 degrees Celsius in the cooler months (January-February).

[3] Barbados RMP in collaboration with UNEP, approved ExCom 43; Dominican Republic TPMP, approved at ExCom 45; Jamaica TPMP in collaboration with the Government of Canada, approved ExCom 37; and, Trinidad and Tobago TPMP, approved ExCom 40.

From an economic perspective, the economies of the 32 countries of the Caribbean archipelago are "mostly small, very open, are typically limited in their export base and are very vulnerable to natural disasters".[4] Barbados, Jamaica and Trinidad and Tobago are full members of the Caribbean Community and Common Market (CARICOM), which came into effect in 1973. CARICOM extends observer status to the Dominican Republic.

3.2 Montreal Protocol Legislative/Regulatory Activities Underway in the Participating Countries

3.2.1 Barbados

Barbados acceded to the Vienna Convention and the Montreal Protocol on October 16, 1993, the London and Copenhagen Amendments on July 20, 1994 and the Montreal and Beijing Amendments on December 12, 2002.

Barbados' Country Programme was approved by the Executive Committee at its 15th Meeting in December 1994. The CP addressed inter alia, the following activities:

- Adoption of regulations to control the level of imports of ODS;
- Duty concessions on ODS alternatives to encourage a transition to non-ODS substances;
- Encouragement to industry to take voluntary actions to switch to alternative technologies;
- Public education and awareness.

The Barbados Refrigerant Management Plan, approved by ExCom 43 includes, in addition, the development of an Import/export Licensing System and the Training of Enforcement Personnel, as well as the establishment of a Refrigeration and Air-conditioning Sector Association.

3.2.2. Dominican Republic

The Dominican Republic ratified both the Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol on Substances that Deplete the Ozone Layer on 18 May 1993. It has also subsequently ratified the 1990 London Amendment and the 1992 Copenhagen on 24 December 2001.

The Country Programme of the Dominican Republic was approved at the 17th Meeting of the Executive Committee in July 1995. The implementation of the CP in Dominican Republic has been successful and has enabled the country to be in compliance with the 1999 CFC freeze obligation.

Terminal Phase Out Plan for Annex A and Annex B Substances (Excluding Halons) approved by ExCom 45 in April 2005. The TPMP strategy is to focus on transition to appropriate, commercially available, substitute technologies for the various refrigeration and air conditioning sub-sectors that have been continuing to use CFCs.

The Dominican Republic's ODS regulatory framework includes:

- An import quota system;
- Establishment of the National Certification on Refrigeration Program for setup and enforcement of the licensing system;
- A ban on import of ODS consuming equipment;
- Identification and registration of ODS importers;
- A ban on expansion of existing units using ODS;

[4] World Bank, Caribbean Economic Review, Caribbean Group for Cooperation in Economic Development, 2000.

- Establishment of a 'licensing system' with an ODS import/export registration form and a quota system issued by the Ministry of Natural Resources and Environment; and,
- Mandatory registration for Importers with designated authorities.

3.2.3. Jamaica

The Government of Jamaica ratified the Vienna Convention and the Montreal Protocol in March 1993.

Jamaica's Country Programme was approved by the ExCom in October 1996. Jamaica's CFC Terminal Phase-out Management Plan was approved by the ExCom at its 37th meeting in July 2002. The aim of the TPMP is to build on the progress Jamaica had already undertaken under its Refrigerant Management Plan (RMP) to achieve a total phase-out of CFCs by the end of 2005.

The Government of Jamaica has adopted legislation that calls for the elimination of all ODS consumption effective January 1, 2006. Commitment to goal is reflected in its legislation.
~ Jamaica's Trade Order 1998, that prohibits import of equipment containing CFCs, came into effect on March 1, 1998. This was later amended to postpone the effective date by one year in order to facilitate development of an adequate infrastructure for its enforcement and to allow for smooth coordination with implementation of the country's CFC import licensing system.
~ Trade Order 1999 that restricts imports of CFCs came into effect on July 1, 1999. This legislation enables the government to administer import quotas of CFCs to 13 selected importers, through the granting of licenses based on a declining quota system.
~ Introduction of labeling requirements under Jamaican Standard Specification Part -29 for proper labeling of equipment and products containing ODS or manufactured using ODS.

3.2.4. Trinidad and Tobago

The Government of Trinidad and Tobago acceded to the Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol for the Phase-out of Ozone Depleting Substances in 1989.

Trinidad and Tobago's Country Programme was endorsed by the Government in September 1996. The CP adopted a multi sector, policy based approach to meet the country's commitments for phasing out ODS. Within the context of the implementation of its CP, the Government of Trinidad and Tobago has successfully put in place a number of activities supported by the MLF that have enabled the reduction in ODS consumption from 158 T total CFC in 1998 (the peak consumption year) to 81 T CFC consumption in 2001, a reduction in the order of 49%.

The CFC Terminal Phase-out Management Plan was approved by the Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol at its 40th meeting. The TPMP is a performance-based action programme to phase-out remaining consumption of CFCs, and incorporates an import quota reduction, recovery and recycling equipment provisions, training and other capacity building initiatives.

Trinidad and Tobago has adopted a regulatory framework that includes:

- Import quota and licensing system for ODS and ODS dependent technologies;
- Freeze agreement for CFCs (Annex A, Group 1) with a mandatory 10% annual reduction in import quotas and no import of technologies dependent on the use of CFC.

3.3 Energy Demand Scenario in the Region

The islands of the Caribbean basin are predominantly net energy importers, with the exception of Trinidad and Tobago. Agriculture and natural resource extraction activities continue to constitute the basis of the islands' economies, though the tourism and service sectors are growing. In recent years, the Caribbean countries have been worried that higher global oil prices will impair their efforts to expand economically. In response, the island nations have been discussing ways to better integrate their energy sectors, especially in regards to increased natural gas exports from Trinidad and Tobago to other islands.

In 2003, the Caribbean region had a total installed electricity-generating capacity of 16.6 gigawatts (GW); in that year, the region consumed 67.3 billion kilowatt hours (Bkwh) while producing 72.4 Bkwh. Most electricity produced in the region comes from conventional thermal sources, chiefly oil-fired power plants. The islands' reliance on fuel oil makes them highly vulnerable to international oil prices. As a result, many islands have begun to look to alternatives, such as LNG and renewables, as a way to reduce their dependence upon foreign oil. While the region runs an electricity surplus, there are specific parts of the Caribbean that need additional capacity. Several countries, including the Dominican Republic, experience power outages and blackouts on a regular basis.[5]

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.

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 two types of centrifugal chillers:

[5] Energy Information Administration, US Department of Energy (http://www.eia.doe.gov/emeu/cabs/carib.html)

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
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 the Caribbean provide an average energy efficiency of 0.77 Kw/TR[6] while commercially available high-efficiency non-CFC chillers consume 0.56 Kw/TR (ARI 550/590) or less. For selection of 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 the Caribbean Region, 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 the Caribbean;
d) In coordination with the ongoing activities being implemented under ongoing Terminal Phase-out Management Plan (TPMPs) and Refrigerant Management Plans (RMPs), create stockpiles 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 public buildings, as well as a number of private sector buildings (to be determined).

[6] World Bank/ICF – Global Overview of the Chiller Sector at the World Bank Financial Agents Workshop, 2004. Trinidad and Tobago used as a representative example for the Caribbean as a whole.

5.1 Energy Efficiency Analysis

While the regional nature of the project would necessarily imply calculation of energy efficiency impact potential from a regional perspective, time constraints experienced during the project's preparatory period meant that data sets received from participating countries were not all complete. As the data received from Trinidad and Tobago was the most comprehensive, it was decided to perform the energy efficiency analysis using their data and extrapolating from that to the regional context. The analysis was carried out on a representative number of chiller installations, covering a range of ownership profiles and end-use applications, and taking into consideration the parameters listed below.

- 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:

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

b) Electricity costs in Trinidad & Tobago are US$ 0.10/Kwh)

c) Average Energy Efficiency of Chiller Installations in Trinidad & Tobago is 0.77 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 Trinidad & Tobago 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:

- In the baseline all chillers are CFC-11 based. For replacement, 40% chillers would be HCFC-123 based and 60% 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 : Energy Efficiency Analysis for 5 selected installations

End-use Profiles/Parameters	Private Residential/ Commercial Buildings	Government Hotels	Government Office Buildings	Total (or weighted averages)
Number of sample installations	1	3	1	**5**
Range of dates of installations*	NM	NM	NM	**NM**
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)	300	670	200	**1,170**
Total Refrigerant Charge (Kg)	273	763	273	**1309**
Equivalent Full Load Hours (Hrs/year)	3,000	4,000	3,000	**3,600**
Energy Costs (US$/Kwh)	0.10	0.10	0.10	**0.10**
Energy Efficiency (Kwh/TR)	0.77	0.77	0.77	**0.77**
Annual Energy Use (Kwh)	693,000	2,063,600	462,000	**3,218,600**
Annual Energy Costs (US$)	69,300	206,360	46,200	**321,860**
Lifetime Energy Costs (US$)	693,000	2,063,600	462,000	**3,218,600**
Lifetime Indirect CO_2 Emissions (t-C)	5,360	15,950	3,570	**24,880**
Lifetime Direct CO_2 Emissions (t-C)	1,092	3,052	1,092	**5,236**
Replacement Scenario (non-CFC Chillers)				
Comparable Economic Lifetime (years)	10	10	10	**10**
Total Installed Capacity (TR)	300	670	200	**1,170**
Total Refrigerant Charge (Kg)	300	670	200	**1,170**
Equivalent Full Load Hours (Hrs/year)	3,000	4,000	3,000	**3,600**
Energy Costs (US$/Kwh)	0.10	0.10	0.10	**0.10**
Energy Efficiency (Kwh/TR)	0.56	0.56	0.56	**0.56**
Annual Energy Use (Kwh)	504,000	1,500,800	336,000	**2,340,800**
Annual Energy Costs (US$)	50,400	150,080	33,600	**234,080**
Comparable Lifetime Energy Costs (US$)	504,000	1,500,800	336,000	**2,340,800**
Lifetime Indirect CO_2 Emissions (t-C)	3,900	11,600	2,600	**18,100**
Lifetime Direct CO_2 Emissions (t-C)	6	111	4	**121**
Energy Efficiency Savings				
Lifetime Energy Cost Savings (US$)	189,000	562,800	126,000	**877,800**
Lifetime CO_2 Emission Reductions (t-C)	2,546	7,291	2,058	**11,895**
Net/Weighted Average Energy Efficiency Savings per Chiller Installation				
Average installed capacity (TR)				**234**
Annual Energy Savings (Kwh)				**176,904**
Annual Energy Cost Savings (US$)				**17,690**
Lifetime (10-year) Energy Cost Savings (US$)				**176,904**
Lifetime Total CO_2 Emission Reductions (t-C)				**2,120**

* All installations are reported to be of 1994 or earlier.

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

- Impact of system optimization
- Demand-side management

One of the main objectives of this project is to highlight the potential that energy expenditure savings can make to the early phase out of existing CFC based Chillers in the Caribbean island nations, and in small island developing countries in general. The low uptake of energy efficiency measures in small island states, even in situations where the financial paybacks appear highly attractive, has perplexed energy economists for a long time. Even in developed industrialized countries the uptake of energy efficiency measures falls well below what is considered economically viable. There are a range of market and non-market barriers that contribute to this perceived market failure. In reality, empirical evidence from industry sector experience in developed countries suggests that unless an energy efficiency measure has a payback of less than 2 years it is rarely implemented. Key barriers and issues include:

- lack of information and understanding of the existence of financially attractive energy efficiency measures – often financial decision makers are not even aware of the existence of these opportunities;
- limited availability of suitably skilled personnel to identify, implement and manage energy efficiency measures;
- internal or corporate inertia barriers – "If it isn't broken don't fix it" mentality or "it is not core business" viewpoints;
- categorization issues of capital versus operation and maintenance budgets – energy efficiency measures are usually categorized as O&M and not capital and therefore face different financial hurdles rates;
- absence of working capital or perverse budget incentives (if you reduce energy expenditure next years budget is reduced accordingly) – these are major issues and constraints in the public sector.

This project will identify existing market and non-market barriers to chiller replacement projects in the Caribbean, raise awareness of the economic opportunities that exist, identify payback periods that make chiller replacement actions attractive to building owners, and highlight areas where external assistance would be needed to bring chiller replacement decision forward. The energy efficiency business model developed through this project would be documented and disseminated to other small island developing countries to assist them in promoting CFC chiller phase out actions.

5.2 Economic Incentives for Replacement

A representative sample of Caribbean countries has been utilized for this analysis. They include: Trinidad Tobago, Barbados, Jamaica, and the Dominican Republic. Because of the diversity of their institutions and economies, their country experiences differ greatly with respect to their replacement of chillers to meet the requirements of the Montreal Protocol. However, there are commonalities among them in both the economic incentives and the barriers they face for replacement.

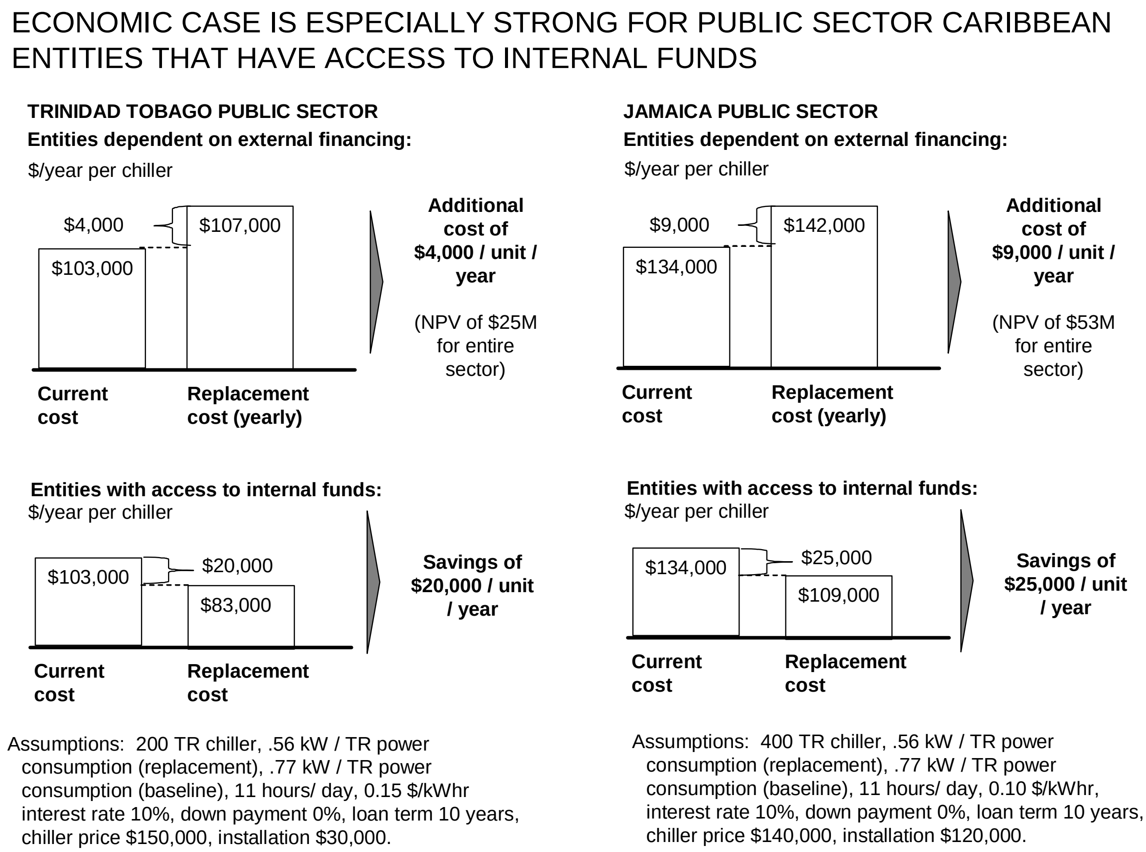
There is a relatively strong economic case for replacement in the Caribbean due to the high and fluctuating cost of electricity. Electricity in the Caribbean is typically fueled by generators that run on gasoline and thus electricity prices tend to be tied to the fluctuation in crude oil prices. [7]

Although the replacement of CFC chillers with non-CFC chillers results in energy savings of $20,000 to $30,000 annually for the public sector and $40,000 to $60,000 annually for the private sector, these savings are more than offset by the additional cost of equipment, taxes and financing costs. The total

[7] Refer to Section 3.4 above, page 8.

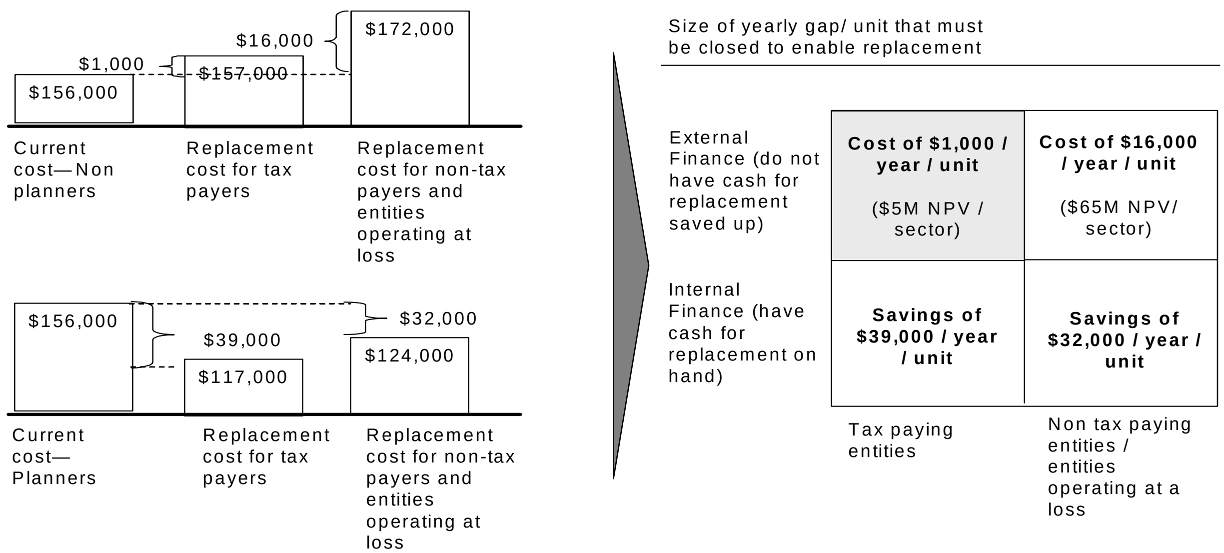
financial gap, once cost of equipment and capital is included, is vastly different for those with access to internal financing and those that must rely on external financing.

For public sector entities that have set aside budgets for replacement, there are savings of approximately $20,000 - $25,000 per year to be gained. This corresponds to approximately $30,000 - $50,000 in savings for private sector entities. The figure below summarizes an analysis of the gap in costs of CFC versus non-CFC based chiller operation for the public sectors in Trinidad Tobago and Jamaica.



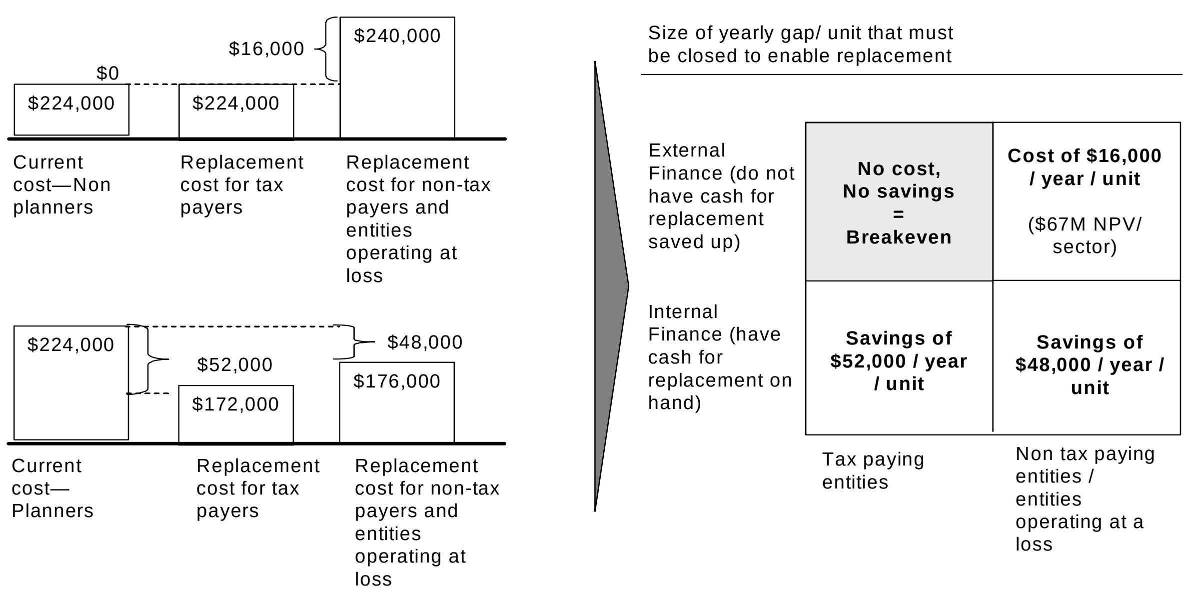
Potential savings in the private sector in Trinidad Tobago and Jamaica look even more favorable. The figures below summarize an analysis of the gap in costs of CFC versus non-CFC based chiller operation for the private sectors in Trinidad Tobago and Jamaica, respectively.

SAVINGS ARE SIGNIFICANT FOR PRIVATE SECTOR IN **TRINIDAD TOBAGO** AND COST GAP MINIMAL RANGING FROM $1,000 - $16,000 PER YEAR PER UNIT



Assumptions: 300 TR chiller, .56 kW / TR power consumption (replacement), .77 kW / TR power consumption (baseline), 10.5 hours/ day, interest rate 20%, 0.165 $/kWhr, aggregate upfront VAT & import taxes 35%, down payment 0%, loan term 10 years, chiller price $150,000, installation $30,000.

SAVINGS ARE SIGNIFICANT FOR PRIVATE SECTOR IN **JAMAICA** AND COST GAP MINIMAL RANGING FROM $0 - $16,000 PER YEAR PER UNIT



Assumptions: 400 TR chiller, .56 kW / TR power consumption (replacement), .77 kW / TR power consumption (baseline), 9.5 hours/ day, interest rate 20%, 0.20 $/kWhr, aggregate upfront VAT & import taxes 36.5%, down payment 0%, loan term 10 years, chiller price $140,000, installation $120,000.

Comparing the cost gap experienced by public and private entities in Trinidad Tobago and Jamaica demonstrates that:

1. In both countries for both the public and private sectors, entities with access to financing have a consistently sizable incentive to replace their CFC chillers with non-CFC chillers as compared to entities without financing and
2. The magnitude of the incentives for replacement facing the public and private sectors in both countries is similar.

Thus, one might expect to see the chiller replacement rate for both the public and private sectors in Jamaica to parallel or surpass the replacement rate in Trinidad Tobago, respectively. However, this is not the case. The table below summarizes the number of remaining CFC chillers identified as the representative sample for the countries.

Number of Remaining CFC Chillers*

Country	Public	Private	Total
Trinidad & Tobago	2	1	3
Barbados	0	0	0
Dominican Republic	0	4	4
Jamaica	12	18	30

* Estimates arrived at via interviews with representatives in the National Ozone Unites, environmental agencies, and private sector chiller owners in respective countries.

As the table shows, all but three CFC based chillers have been replaced in Trinidad Tobago while in Jamaica, there are approximately 30 remaining CFC chillers. This raises the question: Why have we seen more replacements in countries such as Trinidad Tobago, Barbados, and Dominican Republic than in Jamaica?

5.3 Identification of Barriers to Conversion

The difference in replacement rates between countries in the Caribbean can be explained in part by the common barriers to replacement they face and the variation in the intensity in which they face these barriers. These obstacles will need to be overcome in order to facilitate the replacement of CFC chillers with non-CFC chillers in the Caribbean.

- *Lack of awareness*
  - Lack of clarity on how government regulation applies specifically to their business; as a result, chiller operators are often unwilling to change equipment prior to end of economic life
  - Lack of awareness regarding incentives available for replacement

- *High upfront investment / opportunity cost*
  - Public sector
    - Typically dependent on budget appropriations, and therefore unlikely to have upfront capital for chiller replacement
  - Private sector
    - In addition to cost of equipment, private sector chiller owners in some Caribbean countries have to pay extremely high taxes on imports, amounting to almost 40% of the cost of the equipment
    - Opportunity cost of downtime required to replace chiller since the on-site work required to replace 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 potentially resulting in lost revenues.
  - In some countries, cost of installation is almost equivalent to the cost of equipment.

- *Limited access to capital; high costs of financing*
  - Public sector
    - Countries such as Trinidad Tobago and Barbados have access to natural gas and oil reserves and are thus less vulnerable to fluctuations in oil prices because they have access to more financial resources (credit, foreign exchange, etc.). In contrast, countries such as Jamaica expend their scarce financial resources to import oil especially when oil prices rise.
    - Leasing is an available option but is too expensive so that government entities who have replaced their CFC chillers with non-CFC chillers have typically purchased rather than leased.
  - Private sector
    - Locally based businesses that do not have easy access to capital have typically not replaced their CFC chillers. Companies (such as hotels) associated with American or multinational corporations have all been able to replace their CFC chillers with non-CFC chillers.
  - Outsourcing and performance contracting of chillers has not been tried

All these factors compounded together explain the remaining gap in replacement of chillers for the Caribbean. However, the relevance and intensity of each barrier varies from country to country.

INTENSITY OF BARRIERS FACED BY COUNTRIES VARY

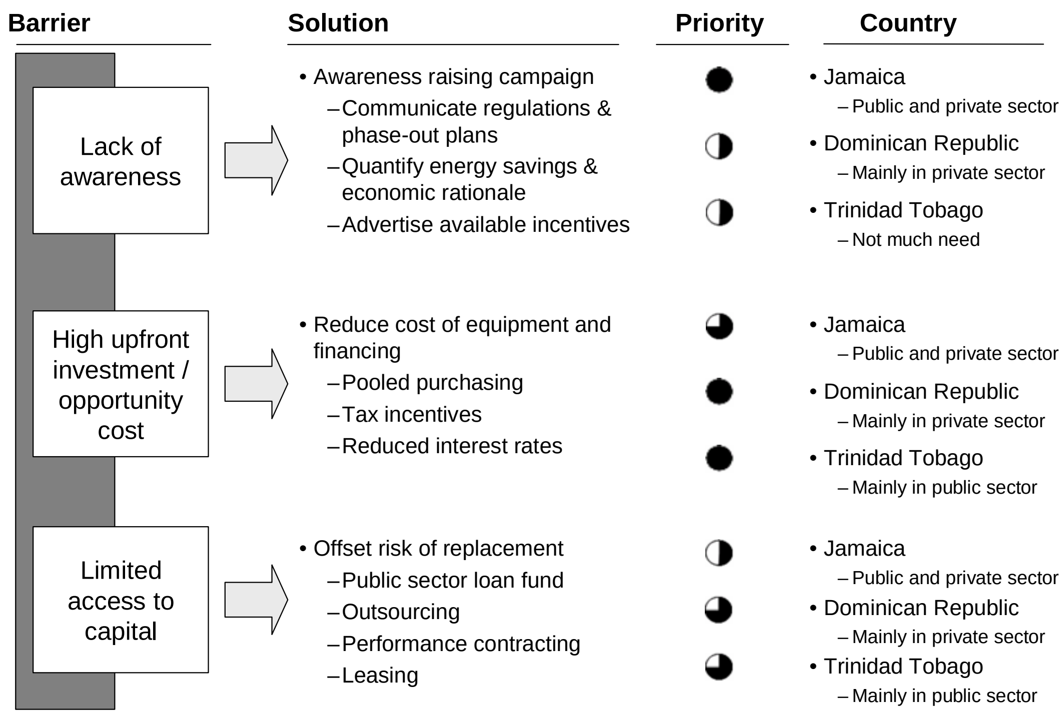
Barrier	**Trinidad & Tobago**	**Dominican Republic**	**Jamaica**
Lack of Awareness of: ▪ Regulations ▪ Phase-out timeline/plan ▪ Incentives available for replacement ▪ Quantity of potential savings	**Low**. • Interviews with private sector have revealed effective government information campaign.	**Low**. • Not generally a problem in either the public or private sector. Estimates of remaining CFC chillers indicate that all are owned by private sector.	**High**. • Economic incentives push to replace but many may be unaware of regulations, phase out timelines/plans, and 0% VAT and import tax for chillers.
High upfront cost of capital or opportunity cost ▪ High upfront cost of equipment & installation ▪ Downtime required to install	**High**. • Majority of remaining chillers are in the public sector – chiller replacement needs to be budgeted. • Low volume purchaser.	**Medium**. • Interest rates range from 16%-20% max and remaining chillers all owned by locally based private sector. • Low volume purchaser.	**High**. • Cost of installation almost 100% of cost of capital • Locally owned chillers located in hotels & key service industries. • Low volume purchaser.
Limited access to capital ▪ Locally based firms have fewer choices for accessing capital market	**Medium**. • Majority of remaining chillers are in the public sector – more access to capital.	**High**. • Estimates indicate that all remaining chillers are in private sector and are owned by locally based businesses.	**Medium**. • Several local companies offer financing. • Majority of private sector chillers locally owned.

NOTE: Barbados was not included because it is currently in the process of replacing its 2 remaining chillers located in the Sheraton Mall complex. These chillers have reached the end of their economic life.

5.4 Sector Wide Strategies and Funding Options

A first and important consideration rests on the fact that the solution to addressing the chiller sector must be tailored to country specific conditions. Thus, the approach in each country will vary according to the relevance and intensity of the barrier faced by that country.

TAILOR APPROACH TO OVERCOMING BARRIERS BY ASSIGNING PRIORITY TO EACH SOLUTION BASED ON COUNTRY SPECIFIC CONDITIONS



APPROACHES AND FUNDING OPTIONS

	1 **Conduct awareness-raising campaign**	2 **Reduce cost of equipment & financing**	3 **Offset risk of replacement**
Purpose	Inform chiller owners of benefit of replacement and incentives available	Create time-bound incentive for chiller owners to replace CFC chillers with non-CFC chillers	Offset risk associated with replacement; i.e., risk associated with trade off between long term savings & upfront investment
Examples	*Provide information on:* ❑ Regulation ❑ Timeline ❑ Available incentives ❑ Economic rationale ❑ Energy availability	*Reduce cost of equipment:* ❑ Pooled purchasing *Reduce cost of financing*: ❑ Interest rates	*Non-financial incentives*: ❑ Public sector loan fund ❑ Outsourcing ❑ Performance contracting ❑ Leasing

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

Discussions with various stakeholders indicate that an effective awareness and outreach 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. Educational Outreach Program: In the implementation, the awareness campaign 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 date), as well as the consequences of not replacing
    - On energy efficiency, stating that all equipment must conform to certain energy specifications, also by phase out date. The campaign should also clarify the consequences of not replacing
- High maintenance costs of old chillers
    - Leakage
    - Inefficiencies in old systems
    - Rising costs of R-12
- Increased energy efficiency and also resulting energy savings
    - Quantify example energy savings based on equipment options available
- Financing options and incentives, including
    - Existing tax incentives, etc/

- Involvement of key stakeholders in a single program.

b. Identification of catalysts to change, and provision of tools needed to make the replacement happen

Although the information campaign is a critical first step, financial barriers will also need to be addressed in order to make replacement a reality. Aside from the information campaign, the strategies needed for the public and private sectors will be tailored to address the unique challenges faced in each sector. The financial gap analysis indicated that the type of strategy needed will depend on whether the institution undergoing replacement has 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 ($20,000 - $25,000/year in the public sector, $30,000 - $50,000 in the private sector) when they replace the chillers.	This segment can likely be effectively targeted through *education* in the demonstration phase, and will most likely require no further strategy.
Institutions that do not have easy access to capital for replacement chillers, and must rely on external financing.	These institutions are unlikely to replace given the absence of a budget for capital investment.	In addition to education, the strategy for this segment is to reduce the overall cost and provide access to financing.

2. *REDUCE THE COST OF THE EQUIPMENT AND FINANCING*

PUBLIC SECTOR

As pointed out above, the country that faces the biggest challenge with respect to public sector population of chillers is Jamaica. And, as the figures above demonstrate, the funding needed to cover the cost gap for all of Jamaica's public sector is estimated at $53 million, out of a total capital cost of $3.12 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]:

- *Interest rates*: If the system is financed, the interest rate will play a major role in annual cost. The interest rate used in the analysis for Jamaica was 10%. Reducing the interest rate by 3% would achieve $30 M towards closing the funding gap. Interest rate can be reduced through programs such as those provided by US Export Import bank.

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

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

[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 46.5% in Jamaica. If applicable, reducing or eliminating this tax on replacement chillers will be a necessary funding component.

PRIVATE SECTOR

The private sector in the Caribbean is relatively mature, and as a result financing strategies in this sector need to be more focused on market-based mechanisms. Beyond the education campaign, the same two main strategies as for the public sector will be put in effect for the 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 *education* in the demonstration phase. The analysis in Jamaica suggests that Jamaican private sector chiller owners may see cost savings of approximately $48,000 - $52,000/year/installation when they replace the chillers.

Those that have not budgeted for replacement, however, will be unlikely to replace 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 ~40% in the Caribbean. Reducing or eliminating some of these taxes on replacement chillers for a defined period of time will be a necessary funding component. In Jamaica, there is a two week application process to obtain VAT and import exemption (0% tax rate) on imported chillers. Advertising the availability of this exemption, and explanation of the process to obtain it, will be included in the education campaign for Jamaica. Eliminating this fee in the analysis for Jamaica would close the funding gap entirely.

- *Reduction of interest rates*: The interest rate plays a role in annual cost. The interest rate used in the analysis for Jamaica was 20%. Reducing the interest rate to 17% would achieve approximately $25 M towards closing the funding gap for non-taxpaying entities in the Jamaican private sector.

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
  - 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

5.5 Project Components and Costs

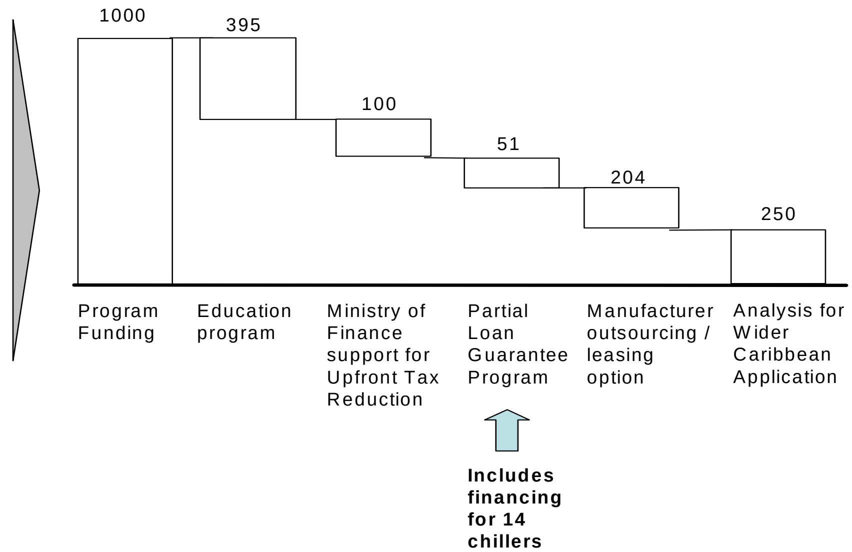
The graphic below displays an overview of the components and costs for the demonstration phase for a representative sample of three Caribbean countries – Jamaica, Dominican Republic, and Trinidad Tobago.

CARIBBEAN DEMONSTRATION PHASE COMPONENTS AND COSTS

$000s

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

- Implement a public sector loan fund vehicle
- Work with Ministry of Finance to structure time-limited tax incentive
- Implement a private sector loan fund vehicle
- Work with Manufacturers to create an outsourcing and/or leasing option
- Educate Public and Private Sector about benefits and consequences of chiller decisions
- Conduct a chiller sector assessment for other countries in the Caribbean to apply lessons learned from demonstration project



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

Depending upon the applicability and intensity of certain barriers, some of the components of the demonstration phase will be more applicable to some country circumstances than others. As a result, in those countries where the intensity of the barriers is less, some of the activities listed might not be necessary. The graphic below provides a summary of the range of activities that will be undertaken in our representative sample of Caribbean countries.

COMPONENTS OF DEMONSTRATION PHASE

	Identify and mitigate risks	**Validate business models**	**Assess success**	**Put in place conditions for implementation**	**Engage in awareness-raising 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. Loan structure
      ii. 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
   a. Were all of the proposed installations, or surrogates, completed?

   b. Did the new chillers achieve the expected energy cost savings?
   c. Do the projects demonstrate an avoidance of significant increase in yearly cost?
4. Conduct an effective awareness 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

6.3.1. GEF Medium Size Project (MSP)

A request for approval of a pdf A has been made to UNDP-GEF management, in order to allow for preparation of a MSP within the GEF 3 funding window (closes June 2006). The project would aim at removing barriers to energy efficiency development in the Caribbean, with specific emphasis on enhancing energy efficiency in building systems as a whole. Through specific actions to overcome financing barriers, through focus on capitalization of financial mechanisms and access to financing that would allow for provision of partial loan guarantees, as well as related policy, capacity building, enterprise development and awareness barriers, it is estimated that the contribution of energy efficiency to the region's energy balance can be significantly increased. As chillers form part of building systems, enhancing energy efficiency in this area, through partnership in the context of the MLF demonstration project, would form a logical first step of an overall regional building efficiency programme, as well as serve to build synergy between activities taken to meet the objectives of the Montreal Protocol and those of the UNFCCC. Should the submission bid be successful, MSP financing could allow for up to a 1:1: co-financing ratio with the funding request being made of the Multilateral Fund's demonstration window.

6.3.2. 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 $160,000 to support the efforts of the demonstration phase.

6.4 Demonstration Project Budget

Demonstration Phase							
Total demo units installed:			14				
Total funding required ($ 000s):			100				
Activity			**Detailed Breakout**	**Total Req'd**	**MLF**	**UNDP Energy TTF**	**GEF (pending approval)**
Total Project:				**2,160**	**1,000**	**160**	**1,000**
JAMAICA				**1,314**	**514**		**800**
1. Develop Awareness							
Awareness-raising campaign (6 months)				395	395		-
Develop materials							
Staff time to develop materials (incl. cost of marketing firm)			100				
Cost of materials (publications, billboards, advertisements, etc.)			200				
Target and contact chiller owners			95				
2. Put in Place Financing Mechanisms				819	19		800
	Units	*Total cost*	*Loan Guarantee Program*				
Public sector							
Conversion of selected units	5	1300	390				
Private sector							
Conversion of selected units	5	1300	390				
Set up partial loan guarantee (staff time)			39				
3. Create Enabling Conditions							
Working with manufacturers				100	100		-
Conduct feasibility assessment of performance contracting in Jamaica							
Develop concept			25				
Test program on selected units			25				
Negotiate terms			50				

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Activity	Units	Total cost	Detailed Breakout	Total Req'd	MLF	UNDP Energy TTF	GEF (pending approval)
Total Project:				**113**	**32**	**160**	**81**
DOMINICAN REPUBLIC				**273**	**154**		**119**
1. Put in Place Financing Mechanisms							
	Units	*Total cost*	*Loan Guarantee Program*				
Private sector				119	-		119
Conversion of selected units	2	360	108				
Transaction costs associated with creating enabling conditions			5				
Set up partial loan guarantee (staff time)			5				
2. Create Enabling Conditions							
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 manufacturers				54	54		-
Conduct feasibility assessment of performance contracting in Dominican Republic							
Develop concept			15				
Test program on selected units			15				
Negotiate terms			25				
TRINIDAD TOBAGO				**163**	**82**		**81**
1. Put in Place Financing Mechanisms							
	Units	Total cost	Loan Guarantee Program				
Public sector				113	32		81
Conversion of selected units	2	360	108				
Set up partial loan guarantee (staff time)			5				
2. Create Enabling Conditions							
Working with manufacturers				50	50		-
Conduct feasibility assessment of performance contracting in Trinidad Tobago							
Develop concept			13				
Test program on selected units			13				
Negotiate terms			25				
APPLICATION TO WIDER CARIBBEAN CONTEXT				**410**	**250**	**160**	**-**
Conduct chiller sector assessment of other countries in Caribbean							
Research all CFC chillers in remaining Caribbean countries			100		100		
Tailor approach to country conditions			25		25		
Determine estimated cost for 100% conversion			25		25		
Apply lessons learned from demonstration project			260		100	160	

	Other	Jamaica
cost per unit	180	260
loan guarantee needed	30%	
transaction costs	5%	
loan guarantee management	5%	

ANNEX-1
ENERGY EFFICIENCY ANALYSIS METHODOLOGY

N.B. The table below sets out the methodology used for the calculation of energy efficiency savings for Trinidad and Tobago, considered, for the purpose of this exercise, as representative for the energy savings potential in the countries in the Caribbean as a whole.

ENERGY EFFICIENCY ANALYSIS IN CHILLER REPLACEMENT

BASELINE SCENARIO		REPLACEMENT SCENARIO	
Installed chiller capacity (TR)	234	Replacement chiller capacity (TR)	234
Refrigerant Charge (Kg)	257	Refrigerant Charge (Kg)	234
Annual Leakage Rate (Kg/year)	26	Annual Leakage Rate (Kg/year)	5
Balance Economic Lifetime (Years)	10.00	Comparable Economic Lifetime (Years)	10.00
Energy Efficiency (Kw/TR)	0.77	Energy Efficiency (Kw/TR)	0.56
Energy Costs (US$/Kwh)	0.100	Energy Costs (US$/Kwh)	0.086
Equivalent Full Load operating Hours (EFLH/yr)	3,600	Equivalent Full Load operating Hours (EFLH/yr)	3,600
Annual Energy Use (Kwh)	**648,648**	Annual Energy Use (Kwh)	**471,744**
Annual Energy Costs (US$)	**64,865**	Annual Energy Costs (US$)	**40,570**
Lifetime Energy Costs (US$)	**648,648**	Lifetime Energy Costs (US$)	**405,700**
Annual Direct CO_2 Emissions (Tonnes-CO_2)	**163**	Annual Direct CO_2 Emissions (Tonnes-CO_2)	**4**
Annual Indirect CO_2 Emissions (Tonnes-CO_2)	**195**	Annual Indirect CO_2 Emissions (Tonnes-CO_2)	**142**
Annual Total CO_2 Emissions (Tonnes-CO_2)	**357**	Annual Total CO_2 Emissions (Tonnes-CO_2)	**145**

RESULTS	
Annual Energy Savings (Kwh)	**176,904**
Annual Energy Cost Savings (US$)	**17,690**
Lifetime Energy Cost Savings (US$)	**176,904**
Annual Total CO_2 Emission Reductions (Tonnes-CO_2)	**212**
Lifetime CO_2 Emission Reductions (Tonnes-CO_2)	**2,120**

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

The experiences drawn from the analysis conducted on the representative sample of countries in the Caribbean for the purposes of the development of the demonstration project constitute what are considered to be representative examples of some the challenges faced by Small Island Developing States (SIDS) in reaching full compliance with the timelines and requirements of the Montreal Protocol. SIDS represent a distinct sub-set of developing countries that typically face a unique set of challenges in seeking to attain sustainable development. In addition to the broader development challenges of such as weak social services, poor physical infrastructure and limited flows of investment, these states must also tackle limitations placed on them by geography. These include limited and costly access to energy and raw materials, high exposure to maritime natural disasters (e.g. hurricanes) and a lack of sustainable scale in domestic markets for most goods and services. Therefore, the experiences obtained through a Caribbean demonstration project for these representative countries may be highly applicable to the larger Caribbean context as well as to low volume consumers.

- Applicability to larger context of Caribbean. There are approximately 15 SIDS that belong to the Caribbean Community and Common Market (CARICOM), 5 SIDS that are associate members, and 9 SIDS that are considered part of the Caribbean but are not associated with CARICOM.[1] The profile of these countries varies widely. However, an entity such as CARICOM could leverage some of the business models tested in the demonstration project to address future projects in which pooled purchasing, low cost financing, performance contracting, and coordinated tax relief (for example) would help its member and associate states to achieve the targets of their international agreements.
- Applicability to other SIDS. To the degree that the challenges faced by SIDS in the Caribbean are similar to SIDS globally, lessons learned from this demonstration project could be applied to address the replacement of chillers in SIDS elsewhere.
- Applicability to low volume consumers. Given their status as SIDS, the Caribbean countries are natural low volume consumers so that their experiences in organizing and negotiating to address the challenges of meeting their Montreal Protocol Agreement targets may be applicable to other small states who are also by their nature small volume consumers.

[1] CARICOM: Antigua, Barbuda, The Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, Montserrat, St. Kitts & Nevis, Saint Lucia, St. Vincent & Grenadines, Suriname, Trinidad Tobago. Associate members: Anguilla, Bermuda, British Virgin Islands, Cayman Islands, Turks & Caicos Islands. Other: Aruba, Cuba, Dominican Republic, French Guiana, Guadeloupe, Martinique, Netherlands Antilles, Puerto Rico, St. Martin.

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 NOU 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 NOU 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.

NOU will periodically carry out an independent verification of the reports.