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EXECUTIVE COMMITTEE OF
THE MULTILATERAL FUND FOR THE
IMPLEMENTATION OF THE MONTREAL PROTOCOL
Seventy-fifth Meeting
Montreal, 16-20 November 2015

PROJECT PROPOSALS: SAUDI ARABIA

This document consists of the comments and recommendations of the Secretariat on the following project proposals:

Foam

- Demonstration project for the phase-out of HCFCs by using HFO as foam blowing agent in the spray foam applications in high-ambient temperatures — UNIDO

Phase-out

- HCFC phase-out management plan (stage I, third tranche) — UNIDO and UNEP

Refrigeration

- Demonstration project at air-conditioning manufacturers to develop windows and packaged air-conditioners using lower global warming potential refrigerants — World Bank

PROJECT EVALUATION SHEET – NON-MULTI-YEAR PROJECT

SAUDI ARABIA

PROJECT TITLE(S)	BILATERAL/IMPLEMENTING AGENCY
(a) Demonstration project for the phase-out of HCFCs by using HFO as foam blowing agent in the spray foam applications in high-ambient temperatures	UNIDO

NATIONAL CO-ORDINATING AGENCY	Presidency of Meteorology and Environment

LATEST REPORTED CONSUMPTION DATA FOR ODS ADDRESSED IN PROJECT

A: ARTICLE-7 DATA (ODP TONNES, 2014, AS OF OCTOBER 2015)

HCFCs	1,376.63

B: COUNTRY PROGRAMME SECTORAL DATA (ODP TONNES, 2014, AS OF OCTOBER 2015)

HCFC-22	1,121.9
HCFC-123	1.5
HCFC-141b	253.2

HCFC consumption remaining eligible for funding (ODP tonnes)	765.40

CURRENT YEAR BUSINESS PLAN ALLOCATIONS		**Funding US $**	**Phase-out ODP tonnes**
	(a)	n/a	n/a

PROJECT TITLE:	
ODS use at enterprise (ODP tonnes):	3.08
ODS to be phased out (ODP tonnes):	3.08
ODS to be phased in (ODP tonnes):	n/a
Project duration (months):	24
Initial amount requested (US $):	274,016
Final project costs (US $):	
Incremental capital cost:	195,000
Contingency (10 %):	19,500
Incremental operating cost:	107,097
Total project cost:	321,597
Local ownership (%):	100%
Export component (%):	n/a
Requested grant (US $):	274,016
Cost-effectiveness (US $/kg):	9.79
Implementing agency support cost (US $):	19,181
Total cost of project to Multilateral Fund (US $):	293,197
Status of counterpart funding (Y/N):	N
Project monitoring milestones included (Y/N):	Y

SECRETARIAT'S RECOMMENDATION	For individual consideration

PROJECT DESCRIPTION

1. On behalf of the Government of Saudi Arabia, UNIDO as the designated implementing agency has submitted to the 75th meeting a request for funding a demonstration project for the phase-out of HCFCs using HFO as foam blowing agent in the spray foam applications in high-ambient temperatures at the amount of US $274,016 plus agency support costs of US $19,181.

2. In line with decision 72/40[1] the Executive Committee approved funding for project preparation in the amount of US $30,000, on the understanding that its approval did not denote approval of the project or its level of funding when submitted (decision 74/33(a)(vii)). The proposal is contained in Annex I to the present document.

Project description

3. Preliminary estimates reported by UNIDO indicate that the polyurethane (PU) spray foam sub-sector accounted for 26 per cent of the total 2014 consumption of HCFC-141b in Saudi Arabia. In 2014, the Ministry of Municipal and Rural Affairs made thermal foam insulation compulsory for new buildings.

Objectives

4. The project objectives are to:

(a) Demonstrate benefits from the use of HFO-1233zd(E) and HFO-1336mzz(Z) co-blown with water in replacement of HCFC-141b in terms of lower GWP and CO_2 release and insulation properties in the PU spray foam sector;

(b) Demonstrate the easy applicability of the technology and the replicability of the results;

(c) Demonstrate that a lower cost structure, as compared with other alternatives, can be obtained by means of lower foam density and lower thermal conductivity;

(d) Establish the possibility of reducing overall incremental operating cost (IOC) in similar future projects through the use of an optimized water/physical foam blowing agent; and

(e) Establish the possibility of reducing the costs for safety and ventilation systems in pentane-based plant conversions, thereby reducing overall incremental capital costs (ICC) in future projects.

Methodology

5. The project will be implemented in Sham Najd, an enterprise that has indicated its commitment to undertake the demonstration project with UNIDO using one line of their production process. It has also agreed to phase-out the use of HCFC-141b when the use of HFO-1233zd(E) and HFO-1336mzz(Z) as blowing agents in place of HCFC-141b is demonstrated as being successful. Both HFO-1233zd(E) and HFO-1336mzz(Z) have very low-GWPs, higher boiling points, lower vapour pressure, and lower lambda values as compared to HCFC-141b; this may result in increased thermal efficiency, better handling, a smoother foam surface, and shorter spray time.

[1] The Executive Committee decided *inter alia* to consider at its 75th and 76th meetings proposals for demonstration projects for low-global warming potential (GWP) alternatives to HCFCs within the framework established, and provided criteria for such projects.

6. Sham Najd has five spray foaming units. For the conversion to HFO blowing technology (two molecules, HFO-1233ze(E) and HFO-1336maam(z), will be tested), a new spray foaming unit, spray foam applicator and HFO pre-blended polyol is requested. The basic properties of the PU systems (free rise density, reactivity, foam thermal conductivity, compression strength, dimensional stability, short-term water absorption, and influence of aging reactivity) will be evaluated.

7. At the system house Saptex, the polyol mixing vessel will be replaced or upgraded with a cooling and heating unit to allow HFO-1233zd(E) to be mixed at a lower temperature. This conversion is funded through another project under stage I of the HCFC phase-out management plan (HPMP) for Saudi Arabia.

Project budget

8. The summary of the project cost is provided in Table 1.

Table 1. Proposed project cost

Description	Cost (US $)
Production	
Provision of spray foaming unit with accessories (hoses, transfer pumps, air-compressor and mixing head	55,000
General works	
Purchase of materials for full scale field testing (3 testing) (1,000 m2)	30,000
Field test foaming product physical property testing in Saudi-Arabian Certified testing house	50,000
Technology transfer, trials and commissioning	40,000
Workshop for the results and experienced gained for information dissemination	20,000
Sub-total	195,000
Contingency	19,500
Total	**214,500**
Total according to the threshold	274,016
IOC estimate for one year	107,097
Grand total	**321,597**

SECRETARIAT'S COMMENTS AND RECOMMENDATION

COMMENTS

9. HCFC-141b is still used in several Article 5 countries in a large number of small- and medium-sized enterprises (SMEs) with limited technological and capital investment capabilities, which impede the introduction of some low-GWP technologies, particularly those using flammable blowing agents or those that could represent a larger capital and/or operational cost. Efforts focused on spray foam and technologies that can be made accessible to SMEs in countries where there are no systems houses could be particularly meaningful. Upon completion of the demonstration project, the results would be broadly available, including in countries with no local systems houses.

10. The Secretariat noted that Saudi Arabia has no remaining consumption of HCFC-141b eligible for funding. Therefore the 3.02 ODP tonnes of HCFC-141b associated with the project cannot be deducted.

11. The Secretariat reviewed the demonstration project in light of stage I of the HPMP for Saudi Arabia[2] approved at the 68th meeting. Stage I included technical assistance to the five locally-owned systems houses, including Saptex, for customizing formulations using hydrocarbons and HFOs ensuring the availability of cost-effective alternatives, particularly to the SMEs, and reducing the associated capital and operating costs. As HFO formulations would be available in the country after stage I of the HPMP had been completed, the demonstration project would appear not to be required. UNIDO explained that the funding under stage I for the systems houses was for customizing formulations using non-HCFC alternatives that are already well-proven. The requested funding is to determine the conditions and parameters for HFO-use in spray foam operations in hot ambient climates. Once the conditions and parameters for HFO use are determined, the systems houses, including Saptex, will use this technology to customize HFO-based formulations to the needs of the downstream clients with the funding provided under the HPMP.

12. The Secretariat noted that ambient temperatures in high-ambient temperature countries can frequently exceed 40^{o}C; moreover, the surface temperature of materials onto which the spray foam is applied may be even higher. Such temperatures will have a profound effect on a spray system reactivity rates and other properties. However, it was unclear to the Secretariat why such effects would be specific to HFOs and would not also apply to HCFC-141b. For example, the boiling points of the HFOs to be tested are similar to that of HCFC-141b, with one of them having a boiling point within 1^{o}C. UNIDO explained that while one of the HFOs to be tested, HFO-1336mzz(Z), has a boiling point of 31°C so it is expected to be an easier foaming agent, the other HFO, HFO-1233zd(E), has a boiling point of 19°C, which is more challenging. Moreover, UNIDO would test the possibility to reduce the operating costs through optimization of the water/blowing agent mixture composition, which is key to enabling the use of reduced HFO formulations. A water/blowing agent formulation may react differently to high surface temperatures than an HCFC-141b formulation with no water. UNIDO also pointed to a further challenge associated with the storage conditions of HFOs, since certain chemicals in the polyol systems (amine and tin catalysts) react with the HFO reduce the foam reactivity during storage of the formulation. The demonstration project would investigate this issue as well.

13. Under stage I, technical assistance was provided to 91 SMEs (including Sham Najd) consuming 1,211 metric tonnes (133.21 ODP tonnes) of HCFC-141b supplied by the systems houses. UNIDO explained that the assistance to downstream SMEs of the systems houses would be provided through dedicated trials and training. The exact list of the SME enterprises is not available due to the volatile nature of the SME sector. Given the limited duration of the field tests and the activities in the foam sector that have been funded under the stage, the Secretariat proposed that instead of providing a new dispenser (at US $55,000) to conduct the field-testing consideration should be given for the enterprise to use one of its five spray foaming units. UNIDO indicated that the enterprise may then encounter limitations and delays to the schedule implementation since it would have to wait until one of the existing units used by the enterprise is available for the demonstration project. The Secretariat also noted that the request for field tests, technology transfer, trials and commissioning (at US $90,000) appear to be higher than other similar projects. UNIDO clarified that the laboratories have indicated that the cost of three sets of testing described in the proposal amount to US $50,000; while US $40,000 includes commissioning of the foam system with the new foaming unit, validation documentation, international travel and travel on sites for all stakeholders.

14. The Secretariat sought clarification of the nexus between the demonstration project and the lesser focus on flammable gas detection and ventilation indicated in the proposal. UNIDO clarified that the project would analyse if it is possible to reduce the use of flammable blowing agents (e.g., hydrocarbons, methyl formate, HFC-365mfc and methylal), in which case it would be easier to operate systems houses, particularly in high-ambient temperatures.

[2] UNEP/OzL.Pro/ExCom/68/39.

Conclusion

15. The Executive Committee may wish to consider approval of this project in light of the guidelines and other projects being considered under the allocated window of US $10 million for this purpose.

RECOMMENDATION

16. The Executive Committee may wish to consider:

(a) The demonstration project for the phase-out of HCFCs by using HFO as foam blowing agent in the spray foam applications in high-ambient temperatures in Saudi Arabia in the context of its discussion on proposals for demonstration projects for low-global warming potential (GWP) alternatives to HCFCs as described in the document on the overview of issues identified during project review (UNEP/OzL.Pro/ExCom/75/27); and

(b) Approving the demonstration project for the phase-out of HCFCs by using HFO as foam blowing agent in the spray foam applications in high-ambient temperatures in Saudi Arabia, in the amount of US $274,016, plus agency support costs of US $19,181 for UNIDO, in line with decision 72/40.

PROJECT EVALUATION SHEET – MULTI-YEAR PROJECTS

Saudi Arabia

(I) PROJECT TITLE	AGENCY	MEETING APPROVED	CONTROL MEASURE
HCFC phase out plan (Stage I)	UNEP, UNIDO (lead)	68th	40% by 2020

(II) LATEST ARTICLE 7 DATA (Annex C Group l)	Year: 2014	1,376.63 (ODP tonnes)

(III) LATEST COUNTRY PROGRAMME SECTORAL DATA (ODP tonnes)									Year: 2014
Chemical	Aerosol	Foam	Fire fighting	Refrigeration		Solvent	Process agent	Lab use	Total sector consumption
				Manufacturing	Servicing				
HCFC-22				509.4	612.5				1,121.9
HCFC-123					1.5				1.5
HCFC-141b		253.2							253.2

(IV) CONSUMPTION DATA (ODP tonnes)			
2009 - 2010 baseline:	1,468.7	Starting point for sustained aggregate reductions:	1,468.7
CONSUMPTION ELIGIBLE FOR FUNDING (ODP tonnes)			
Already approved:	703.29	Remaining:	765.41

(V) BUSINESS PLAN		2015	2016	2017	2018	2019	2020	Total
UNEP	ODS phase-out (ODP tonnes)	11.4		5.6			2.6	19.6
	Funding (US $)	281,418		138,378			63,920	483,716
UNIDO	ODS phase-out (ODP tonnes)	54.6	80.4	38.7	47.7	18.2	8.5	248.1
	Funding (US $)	1,284,000	1,890,262	909,500	1,120,691	428,000	198,574	5,831,027

(VI) PROJECT DATA			2012	2013*	2014*	2015	2016	2017	2018	2019	2020	Total
Montreal Protocol consumption limits			n/a	1,468.7	1,468.7	1,321.8	1,321.8	1,321.8	1,321.8	1,321.8	954.7	n/a
Maximum allowable consumption (ODP tonnes)			n/a	1,468.7	1,378.4	1,321.8	1,321.8	1,321.8	980.8	980.8	881.2	n/a
Agreed funding (US $)	UNEP	Project costs	290,400	0	0	250,400	0	123,125	0	0	56,875	720,800
		Support costs	35,973	0	0	31,018	0	15,253	0	0	7,045	89,288
	UNIDO	Project costs	2,169,600	2,971,487	1,200,000	1,766,600	850,000	1,047,375	400,000	185,583	170,625	10,761,270
		Support costs	151,872	208,004	84,000	123,662	59,500	73,316	28,000	12,991	11,944	753,289
Funds approved by ExCom (US $)		Project costs	2,460,000		2,971,487							5,431,487
		Support costs	187,845		208,004							395,849
Total funds requested for approval at this meeting (US $)		Project costs				1,200,000*						1,200,000
		Support costs				84,000*						84,000

*Second tranche planned for 2013 but approved at the 72nd meeting; third tranche planned for 2014 but submitted to the 75th meeting.

Secretariat's recommendation:	For individual consideration

PROJECT DESCRIPTION

17. On behalf of the Government of Saudi Arabia, UNIDO as the lead implementing agency, has submitted to the 75th meeting a request for funding for the third tranche[3] of stage I of the HCFC phase-out management plan (HPMP), at the amount of US $1,200,000, plus agency support costs of US $84,000 for UNIDO only. The submission also included a request for US $250,400 plus US $31,018 for UNEP for the fourth tranche. The submission includes a progress report on the implementation of the second tranche, the verification report on HCFC consumption in 2014 and the tranche implementation plan for 2015 to 2016.

<u>Report on HCFC consumption</u>

HCFC consumption

18. The Government of Saudi Arabia reported a consumption of 1,376.63 ODP tonnes of HCFC in 2014. The 2010-2014 HCFC consumption is shown in Table 1.

Table 1. HCFC consumption in Saudi Arabia (2010-2014 Article 7 data)

HCFC	**2010**	**2011**	**2012**	**2013**	**2014**	**Baseline**
Metric tonnes						
HCFC-22	20,110.0	22,172.0	24,315.0	20,216.0	20,397.7	18,393.5
HCFC-123	16.5	14.0	16.0	0	76.9	9.5
HCFC-141b	3,200.0	3,557.0	3,912.0	2,696.0	2,302.0	3,100.0
HCFC-142b	1,800.0	2,150.0	2,365.0	389.0	0	1,782.5
Total (metric tonnes)	**25,126.5**	**27,893**	**30,608**	**23,301**	**22,776.6**	**23,285.5**
ODP tonnes						
HCFC-22	1,106.1	1,219.5	1,337.3	1,111.9	1,121.9	1,011.6
HCFC-123	0.3	0.3	0.3	0.0	1.5	0.2
HCFC-141b	352.0	391.3	430.3	296.6	253.2	341.0
HCFC-142b	117.0	139.8	153.7	25.3	0	115.9
Total (ODP tonnes)	**1,575.4**	**1,750.8**	**1,921.7**	**1,433.7**	**1,376.6**	**1,468.7**

19. The consumption of HCFC-22, HCFC-141b and HCFC-142b started to decrease in 2013 after a steady growth, caused by an increased demand for manufacturing and servicing residential and commercial air-conditioning (AC) equipment. There is a small decrease in total consumption from 2013 to 2014; however, there is a slight increase in HCFC-22 consumption from 1,111.9 ODP tonnes to 1,121.9 ODP tonnes. For 2014, Article 7 data shows that 81 per cent of the consumption in ODP tonnes was HCFC-22.

Verification report

20. The verification report confirmed that the Government is implementing a licensing and quota system for HCFC import and export and that the total consumption of HCFCs for 2014 was 1,376.63 ODP tonnes. The verification concluded that Saudi Arabia has established an effective HCFC imports control and was in compliance with the Montreal Protocol targets and the maximum allowable consumption in 2014.

[3] The third tranche was originally planned for 2014 but only submitted to the 75th meeting.

Country programme (CP) implementation report

21. The Government of Saudi Arabia reported HCFC sector consumption data under the 2014 CP implementation report which is consistent with the data reported under Article 7.

Progress report on the implementation of the second tranche of the HPMP

Legal framework

22. The Government of Saudi Arabia has adopted Unified Regulations on Ozone Depleting Substances for Gulf Cooperation Council (GCC) States as guideline for monitoring and controlling ODS as required by the Montreal Protocol. The ban on import and use of HCFC-142b which was introduced on 1 January 2014, as result no HCFC-142b was imported into the country.

23. The ban on HCFCs and products containing HCFCs is being under discussion with the tentative schedule developed (Table 2). In addition, a ban on disposable cylinders is currently being studied.

Table 2. Tentative schedule of future actions for the control of HCFCs

Proposed action	Date
Mandatory recovery and recycling of HCFCs and other ODS refrigerant	30 June 2016
License/certification required for purchasing refrigerant	1 January 2017
Ban on import of new or used refrigeration and air-conditioning (RAC) systems or equipment containing HCFC-22 or any refrigerant or refrigerant blend containing HCFC	1 January 2017
Ban on import of HCFC-22 either in pure form or as a component of blended refrigerants, for the purpose of placing on the market, assembling or installing new refrigeration equipment	30 June 2018
Ban on import of HCFC-141b either in pure form or as a component of blended chemicals for the purpose of placing on the market or use in the production of polyurethane foams or as solvents or any other application	1 January 2018

24. The development of an e-licensing system is still ongoing and planned to be finalized in early 2016.

Activities in the extruded polystyrene (XPS) foam manufacturing sector

25. *Eligible enterprises (55 ODP tonnes of HCFC-22/HCFC-142b):* Arabian Chemical Company (ACC) completed the conversion of all three lines (only one funded by the Multilateral Fund) to isobutane and carbon dioxide (CO_2) in April 2015. Al-Watania Plastics experienced delays in equipment procurement, and the contract for the supplier was finally issued in March 2015. The equipment delivery is expected by the end of 2015 and installation in early 2016. The enterprise will be converted to a blend of isobutene, CO_2 and HFO-1234ze.

26. *Non-eligible enterprises (125.6 ODP tonnes of HCFC-22/HCFC-142b):* Both enterprises, Bitutherm and Saptex, have now been converted. Bitutherm has been using a mixture of HFC-134a and HFC-152a as blowing agent. The enterprise is considering buying equipment for the use of isobutane in the future. Saptex initially replaced HCFCs with HFC-152a and dimethyl ether (DME). The enterprise is also using a mixture of HFC-134a and HFC-152a. It is planned to use CO_2 as a co-blowing agent in the future.

Activities in the polyurethane (PU) rigid foam manufacturing sector

27. Under the first tranche it was foreseen to assist three eligible enterprises (HESCO, Saptex, and SPF) with a total consumption of 30.8 ODP tonnes of HCFC-141b to convert to pentane. The equipment for the conversion of the three enterprises reached the Port of Jeddah at the end of July 2014; however, project implementation was delayed due to customs clearance issues related to tax exemptions. As a result the enterprises were only able to clear the equipment after they agreed to pay import tax and demurrage fees. The equipment was delivered to HESCO and SPF in September 2015. Part of the equipment for Saptex was found damaged and a survey was arranged with an authorized representative of the shipment enterprise. The installation is expected to be completed by December 2015 for HESCO and SPF. The completion of the installation at Saptex depends on the condition of the equipment which is presently unknown.

28. Three enterprises with a total consumption of 27.8 ODP tonnes of HCFC-141b were selected for the conversion to pentane in the second tranche (Alba Factory for Steel Industries (Alba), Alamdar Vapotherm Co. Ltd. (Alamdar), and Al-Essa for Refrigeration and Air-Conditioning (Al-Essa)). The equipment for Alba was cleared by customs in September 2015. The contract for the equipment supply to Alamdar and Al-Essa was awarded in March 2015 and the shipment is estimated to take place in October/November 2015. The conversion will be completed by January 2016.

29. Stage I included technical assistance to five locally-owned systems houses to customize formulations using hydrocarbons and HFOs ensuring the availability of cost-effective alternatives, particularly to SMEs, and reducing the capital and operating costs required for their conversion to non-HCFC blowing agents. Of the five, two systems houses, namely, B.N. Jundi and Saptex, indicated that they were ready to convert. Discussions with a third systems house, Henkel Polybit Industries, have started. For the conversion at the B.N. Jundi the contract to a supplier was awarded in September 2015 and a technical visit of the supplier's specialist to the project site is scheduled for October 2015. The systems house will test, evaluate and customize several formulations based both on pentane and methyl formate.

Refrigeration-servicing sector

30. The agreement between the Presidency for Meteorology and Environment (PME), where the national ozone unit (NOU) is based, and UNEP is expected to be signed only by the end of October 2015. The agreement is required for funds to be transferred to the NOU. Despite the delay in the signature of the agreement some progress in implementing activities was made, in particular: the curriculum on technical and vocational training on RAC has been updated and another revision is currently undergoing, a train-the-trainers workshop was organized with 29 participants, and 65 technicians participated in workshops on installation and maintenance of RAC equipment in August 2015.

<u>Level of fund disbursement</u>

31. As of October 2015, of the US $7,677,388 funding approved (which includes US $307,000 remaining funds from the national ODS phase-out plan (NPP) and funds for previously approved XPS foam project), US $3,599,293 had been disbursed (US $2,877,758 for UNIDO, US $26,999 for UNEP and US $694,536 for the XPS foam project). The balance of US $4,078,095 will be disbursed in 2015/2016 (Table 3).

Table 3. Financial report of stage I of the HPMP for Saudi Arabia (US $)

Agency	First tranche		Second tranche		Total approved	
	Approved	Disbursed	Approved	Disbursed	Approved	Disbursed
UNIDO	2,169,600	1,953,444	2,971,487	924,314	5,141,087	2,877,758
Funds from NPP	307,000		n/a	n/a	307,000	
UNEP	290,400	26,999	0	0	290,400	26,999
Subtotal	2,767,000	1,980,443	2,971,487	924,314	5,738,487	2,904,757
Previously approved phase-out of HCFC-22 and HCFC-142b from XPS panel in Arabian Chemical Company and Al-Watania plastics*	1,938,901	694,536	n/a	n/a	1,938,901	694,536
TOTAL	4,705,901	2,674,979	2,971,487	924,314	7,677,388	3,599,293
Disbursement rate (%)		57		31		47

*The Agreement between the Government of Saudi Arabia and the Executive Committee also covers two projects approved at the 62nd meeting for implementation by UNIDO and the Government of Japan with an associated phase-out of 180.6 ODP tonnes of HCFC-22 and HCFC-142b from the manufacture of XPS foam at a funding level of US $1,938,901 plus agency support costs (decision 62/35).

Implementation plan for the third tranche of the HPMP

32. The third funding tranche of the HPMP will be implemented between October 2015 and December 2016, and the following activities will be undertaken:

(a) Procurement of equipment for 3 to 4 eligible PU foam enterprises to convert to pentane (to be combined with the remaining funds from the second tranche) (UNIDO) (US $650,000);

(b) Procurement of equipment for process modification to non-HCFC alternatives for two systems houses (UNIDO) (US $360,000);

(c) Ten-fifteen workshops organized by the converted systems houses for their downstream clients (UNIDO) (US $90,000);

(d) Ten training workshops for a total of 250-300 technicians (UNIDO) (US $60,000);

(e) Regulatory and policy strengthening, including banning of disposable refrigerant containers for HCFC refrigerants, introducing a certification scheme for refrigeration technicians and a system regulating access to refrigerant only to entities where certified technicians are carrying out and supervising the work (UNEP) (remaining funds from the first tranche);

(f) Technical assistance to PU foam sector, including 10 to 15 training workshops organized by the converted systems houses for their downstream clients (UNEP/UNIDO) (remaining funds from the first tranche); and

(g) Project monitoring (UNIDO) (US $40,000).

SECRETARIAT'S COMMENTS AND RECOMMENDATION

COMMENTS

Report on HCFC consumption

33. The Secretariat noted the decrease in total HCFC consumption from 2013 to 2014 that kept Saudi Arabia in compliance with the established Montreal Protocol targets and the maximum allowable consumption. The 2014 consumption was still slightly above the 10 per cent reduction step required in 2015. UNIDO confirmed that the country has adopted all necessary policies and control measures to ensure full compliance with the HPMP requirements and is expected to achieve the 2015 control target.

Progress report on the implementation of the second tranche of the HPMP

Legal framework

34. The Government of Saudi Arabia has already issued an HCFC import quota for 2015 at 1,302.9 ODP tonnes.

PU foam manufacturing sector

35. The Secretariat noted with concern the challenges in clearing customs for the equipment needed for the PU foam conversions at three enterprises (HESCO, Saptex, SPF) resulting in a delay in the implementation of the project by over one year. The Secretariat recalled decision 22/5 where it was decided that no taxes or duties on equipment would be financed by the Multilateral Fund. UNIDO confirmed that no import tax or duty will be paid by the Multilateral Fund. UNIDO however noted that demurrage fees were sometimes unavoidable and could be covered by the HPMP budget. The demurrage fees totalled US $46,792 and were within the 10 per cent contingency for the equipment. The Secretariat also noted the verification report which indicated that the communication and documentation between the NOU and the customs department were found to be in place and effective without mention of the issue of import duty and demurrage fees. UNIDO and UNEP would address the issue with the customs and the Ministry of Trade and Industry.

36. The Secretariat requested UNIDO to provide an update on the status of the equipment for Saptex, in particular, if it can be repaired or new equipment is needed. UNIDO indicated that an initial survey by the insurance company was unable to determine the condition of the equipment, but will be determined when the supplier's installation team will visit the enterprise in November 2015.

37. Noting that the planned ban on the import of HCFC-141b either in bulk or as a component of blended chemicals has been proposed for 1 January 2018, the Secretariat inquired about the possibility to implement the ban earlier to ensure that the clients of converted systems houses do not import HCFC-141b-based pre-blended systems from abroad. UNIDO replied that advancing the date of the ban was not feasible at this stage, but might be considered in 2016 depending on the progress in the conversion of foam enterprises included in the project.

38. With regard to decision 68/37(h) where UNIDO was requested not to implement any conversion to HFC-245fa in the spray foam sector prior to 1 January 2016, and pursue the establishment of low-GWP for that sub-sector prior to that date, UNIDO indicated that tests of low-GWP formulation for spray foam applications were performed in 2014 in Finland in collaboration with Huntsman. HFO were used for testing with overall positive results showing that the dimensional stability, density, thermal conductivity and surface smoothness of foam were similar or even better than those produced with HCFC-141b. Furthermore, UNIDO has submitted to the 75th meeting a request for a demonstration project for the

phase-out of HCFCs by using HFO as foam blowing agent in the spray foam applications in high ambient temperatures.

Refrigeration-servicing sector

39. The submission included a request for additional funding for activities in the servicing sector to be implemented by UNEP. The Secretariat noted that the request was not consistent with the Agreement between the Government of Saudi Arabia and the Executive Committee, which only foresees the requested funding during the next (fourth) tranche; and the lack of a signed agreement with the Government which had resulted in limited progress in the servicing sector and low level of disbursement from the first tranche. Finally, the letter of endorsement from the Government did not request forward-funding from the fourth tranche for UNEP. Under these circumstances the Secretariat was unable to recommend such a request and it was withdrawn.

40. The lack of a signed agreement between PME and UNEP, combined with delays in the release of equipment for the PU foam enterprises, raise a concern on the effective implementation of the HPMP. At the 68th meeting,[4] concerns were expressed already regarding the lack of progress in the servicing sector, particularly during the implementation of the NPP. For this reason, Appendix 8-A to the Agreement was added to provide Saudi Arabia with some time to implement the outstanding NPP activities for the servicing sector and to prepare HCFC-related activities (e.g., outstanding training under the NPP; development of training modules for the HPMP; introduction of a certification system for technicians). Most of these activities have not been completed, in part because of the lack of the signed agreement with PME. For this reason, the Secretariat recommends that the release of funds for the third tranche be contingent on signature of the agreement with the PME and UNEP.

41. Moreover, the Secretariat, recalling decision 22/5(b), recommended that the release of funds also be contingent on the assurance that there will not be delays in the delivery of equipment to beneficiary enterprises due to unnecessary delays in customs clearance. With regard to the potential tax issue with the equipment for the three PU foam enterprises selected during the second tranche (Alba, Alamdar and Al-Essa) and the systems houses, UNIDO clarified that the tax exemption certificate from the Ministry of Trade and Industry was obtained in advance for Alba (the enterprise has paid the import duty and will claim it back from the customs after the release of the equipment). The same approach is being pursued with the equipment for Alamdar and Al-Essa, the systems houses and XPS foam enterprises.

<u>Conclusion</u>

42. The Secretariat noted that sufficient level of implementation of the second tranche of the HPMP has been achieved. The import licensing and quota system is operational and will enable the country achieving compliance with the Montreal Protocol's phase-out schedule for HCFCs. The verification report confirms that the country is in compliance with the Montreal Protocol control targets as well as with the targets specified in its Agreement with the Executive Committee. There is progress in the conversions in the foam sector, though some delays have been encountered. The 2014 ban on HCFC-142b appears to be effective and the country is on track to issue the ban on import of HCFC-141b either in pure form or as a component of blended chemicals for any application. There are indications that the agreement between PME and UNEP could be signed in October 2015, and the steps identified to avoid the delays in customs clearance and the associated demurrage charges in the future (i.e., beneficiary enterprises will pay the import duty on guarantee and will claim it back from the customs after the release of the equipment and completion of the required paperwork) should help ensure that customs clearance process will be smooth.

[4] UNEP/OzL.Pro/ExCom/68/39

RECOMMENDATION

43. The Executive Committee may wish to consider:

(a) Noting:

(i) The progress report on the implementation of the second tranche of stage I of the HCFC phase-out management plan (HPMP) in Saudi Arabia;

(ii) With concern the delay of more than one year in the customs clearance of equipment for Saptex, HESCO and SPF, the associated demurrage fees, and the corresponding delay in implementation of the conversion of those enterprises, despite decision 22/5(b) which urged all recipient Governments operating under Article 5 to expedite customs clearance and to refrain from levying any taxes or duties, in accordance with the terms of their agreement with the implementing agencies relating to the levying of taxes and duties on equipment and incremental costs during project implementation;

(iii) The new arrangement established by the Government whereby enterprises will pay the import duty on guarantee and will claim it back from the customs after the release of the equipment and completion of the required paperwork thereby ensuring that the customs clearance process will be smooth and potential for any demurrage cost will be minimized;

(b) Not approving any further funding for activities under subsequent tranches of stage I of the HPMP until assurances had been provided by the Government or UNEP and UNIDO that the problems with customs clearance had been resolved and that in cases where customs duties were required to release shipments purchased with Multilateral Fund funding, such duties will be covered from other sources outside the Multilateral Fund;

(c) Urging the Government of Saudi Arabia to sign the agreement between the Presidency for Meteorology and Environment with UNEP so that the activities addressing HCFC consumption in the servicing sector could commence; and

(d) Approving the third tranche of stage I of the HPMP for Saudi Arabia, and the corresponding 2015-2016 tranche implementation plan, at the amount of US $1,200,000, plus agency support costs of US $84,000 for UNIDO on the understanding that the approved funds would not be transferred to UNIDO until the agreement between the Presidency Meteorology and Environment and UNEP was signed.

PROJECT EVALUATION SHEET – NON-MULTI-YEAR PROJECT

Saudi Arabia

PROJECT TITLE(S) **BILATERAL/IMPLEMENTING AGENCY**

(a)	Demonstration project at air-conditioning manufacturers to develop windows and packaged air-conditioners using lower global warming potential refrigerants	World Bank

NATIONAL CO-ORDINATING AGENCY	Presidency of Meteorology and Environment

LATEST REPORTED CONSUMPTION DATA FOR ODS ADDRESSED IN PROJECT

A: ARTICLE-7 DATA (ODP TONNES, 2014)

HCFCs			1,376.63

B: COUNTRY PROGRAMME SECTORAL DATA (ODP TONNES, 2014)

HCFC-22	1,121.9
HCFC-123	1.5
HCFC-141b	253.2

HCFC consumption remaining eligible for funding (ODP tonnes)	765.4

CURRENT YEAR BUSINESS PLAN ALLOCATIONS		Funding US $ million	Phase-out ODP tonnes
	(a)	n/a	n/a

PROJECT TITLE:	
ODS use at enterprises (ODP tonnes):	8.31
ODS to be phased out (ODP tonnes):	3.59
ODS to be phased in (ODP tonnes):	0.00
Project duration (months):	12
Initial amount requested (US $):	1,306,800
Final project costs (US $):	
Incremental capital cost:	1,188,000
Contingency (10 %):	118,800
Incremental operating cost:	0
Total project cost:	1,306,800
Local ownership (%):	100
Export component (%):	0
Requested grant (US $):	1,306,000
Cost-effectiveness (US $/kg):	20
Implementing agency support cost (US $):	91,476
Total cost of project to Multilateral Fund (US $):	1,398,276
Status of counterpart funding (Y/N):	Y
Project monitoring milestones included (Y/N):	Y

SECRETARIAT'S RECOMMENDATION	For individual consideration

PROJECT DESCRIPTION

44. On behalf of the Government of Saudi Arabia, the World Bank as the designated implementing agency has submitted to the 75th meeting a request for funding a demonstration project to develop windows and packaged air-conditioners using lower global warming potential (GWP) refrigerant, at the amount of US $1,306,800, plus agency support costs of US $91,476. This project that was prepared without request of preparatory funding from the Multilateral Fund was submitted in response to decision 72/40[5].

45. At the 74thmeeting, the Executive Committee approved 13 requests for the preparation of projects to demonstrate low-GWP technologies (decision 74/21(a)). This proposal is not part of these projects, but it was submitted in line with decision 74/21(d)[6]. The proposal is contained in Annex II to the present document.

Project objective

46. The project proposes to build, test, and optimize prototypes of window and packaged air-conditioning (AC) units based on HFC-32 and HC-290 refrigerants; evaluate their energy performance and incremental cost; and disseminate the findings and results to interested manufacturers in Saudi Arabia and other countries.

Sector background and justification

47. Saudi Arabia is one of the world's largest markets for AC, expected to surpass US $2.5 billion in sales by 2019 due to growth in construction and urban expansion. It is estimated that 70 per cent of electricity consumption in Saudi Arabia is for the operation of AC systems. There is an estimate of 9 million window units, 7 million mini-split units, and 0.5 million rooftop (packaged) and ducted split units with capacity ranging from 6 to 30 tonnes of refrigeration.

48. Saudi Arabia manufactures the full range of refrigeration and AC equipment, including unitary and split air-conditioners up to 18 kW; central AC systems; air handling units; chillers and variable refrigerant flow (VRF) systems above 18 kW. In 2011, approximately 10,000 mt of HCFC-22 were used in the manufacturing of refrigeration and AC equipment. Local manufacturers include five large enterprises each consuming more than 500 mt of HCFC-22 and a number of smaller enterprises consuming less than 100 mt. There are also many small and medium-sized enterprises (SMEs) operating as manufacturers, assemblers, installers and servicing providers. As the refrigeration and AC manufacturing sector has not been addressed yet under the HPMP, successful demonstration of lower-GWP alternatives will have significant replication effects.

49. Article 5 countries, especially those with high-ambient temperature conditions, face serious challenges in finding out suitable alternatives to replace HCFC-22 in AC applications. To assist the countries, the Executive Committee approved at the 69th meeting a demonstration project to promote low-GWP alternatives for the AC industry in high-ambient countries (PRAHA[7]). The Government of Saudi Arabia and the World Bank identified that the PRAHA project did not include testing of HFC-32 and HC-290 in window and packaged AC and decided to demonstrate these alternatives. While, there

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[5] The Executive Committee decided *inter alia* to consider at its 75th and 76th meetings proposals for demonstration projects for low-global warming potential (GWP) alternatives to HCFCs within the framework established, and provided criteria for such projects.

[6] To allow the submission of a limited number of additional requests for the preparation of projects to demonstrate low-GWP technologies in the air-conditioning manufacturing sector, the resubmission of the two fully-developed demonstration projects, and additional feasibility studies on district cooling to the 75th meeting.

[7] Project: Promoting low-GWP potential refrigerants for air-conditioning sectors in high-ambient temperature countries in West Asia, approved for UNIDO and UNEP.

have been commercial production of AC using these two alternatives, most products are mini-split and not yet fully tested in countries with high-ambient temperature.

Enterprises included

50. The following enterprises will be participating in the project:

(a) *Saudi Factory for Electrical Appliances Co. Ltd.;* established in 1986, with an annual production capacity of 120,000 window AC units, consumes 90 mt of HCFC-22 per year. The factory has one assembly line and also manufactures heat exchangers. The enterprise will develop two sizes of windows AC (18,000 Btu/h and 24,000 Btu/h) with HFC-32 and HC-290; and

(b) *Petra Engineering Industries (KSA) Co. Ltd.;* established in 2010 with an annual production capacity of 852 packaged units, will address the issue of flammability in higher refrigerant charge units by demonstrating packaged AC systems that combine chiller and air-handling (40 to 100 kW), using HFC-32 and HC-290.

Project implementation

51. Technical assistance will be provided to:

(a) *Prototype design and production:* The two manufacturers will study characteristics of the two alternatives; design the prototypes and specify the main components (i.e., condensers, evaporators, fans and compressors) based on the required efficiency. Availability of components and suppliers for high ambient temperature conditions will be identified. The manufacturers will fabricate and build the prototype taking into consideration safety precautions; and

(b) *Testing and evaluation:* Tests to assess performance of HFC-32 and HC-290-based prototypes on low and high ambient conditions will be carried out in Petra's laboratory in accordance with international standards such as air-conditioning, heating and refrigeration institute (AHRI). Performance, quantity of charge, and prices will be compared to those of HCFC-22-based equipment.

Project budget

52. The estimated cost of the project is detailed in Table 1.

Table 1. Project cost by activity

Activity	**Quantity**	**Unit cost (US $)**	**Total cost (US $)**
Saudi Factory for Electrical Appliances Co. Ltd.			
Development window AC (18,000 Btu/h) using rotary compressor and reciprocating compressor	2	55,000	110,000
Development for window AC (24,000 Btu/h) using rotary compressor and reciprocating compressor	2	55,000	110,000
Petra KSA			
Conceptual design including development of new software for HFC-32 and HC-290 (one senior software engineer and two HVAC engineers for developing new software)		38,000	38,000
Prototypes fabrication (6 prototypes (40, 70, and 100 kW) for 2 alternative refrigerants)	6	70,000	420,000
Prototypes testing	6	50,000	300,000

Activity	Quantity	Unit cost (US $)	Total cost (US $)
Research and development engineers for study, development, research, design, test, and approval	6		170,000
Technical assistance			
International expert	1	30,000	30,000
Technology dissemination workshop	1	10,000	10,000
Sub-total incremental capital cost			**1,188,000**
Contingencies (10%)			118,800
Total cost			**1,306,800**

SECRETARIAT'S COMMENTS AND RECOMMENDATION

COMMENTS

53. The Secretariat noted the World Bank's efforts to formulate a proposal in the AC manufacturing sector in line with decision 74/21(d) and without a request for preparatory funds from the Multilateral Fund.

54. The Secretariat noted that the enterprise Petra KSA was founded in 2010 (i.e., after the cut-off date of 21 September 2007), and therefore is not eligible for funding under the Multilateral Fund. The World Bank indicated that as the purpose of the demonstration project only involves technical assistance to develop prototypes for testing and Petra's conversion will be self-funded, the cut-off date would not apply.

55. At the 74th meeting, the Executive Committee approved funding for UNIDO for the preparation of a demonstration project on promoting HFO-based low-GWP refrigerants for AC sector in high-ambient temperature conditions in Saudi Arabia. The project will convert a manufacturing line of AC equipment (enterprise Al-Essa) to an HFO alternative (choosing from L-20 L-41, DR-3 or HFC-32), based on the results of the demonstration project PRAHA. Upon request for clarification on possible overlaps between this project and the project under current preparation by UNIDO, the World Bank explained that they were not aware of any overlap between both projects.

56. The proposal included an annex prepared by Petra KSA which indicates *inter alia* the willingness from the enterprise to undertake the demonstration. No written indication on whether the enterprise would cease to use HCFCs was provided. The World Bank considered that a written indication is not applicable at this point as the project does not include conversions.

57. The Secretariat considers that including manufacturing conversion would have been useful to demonstrate the feasibility of commercial production; however, considering the limited availability of resources under this window, the current approach would favor the approval of more proposals. The World Bank explained that only after the prototypes meet performance and safety standards the enterprise could decide on commercial manufacturing. There is also a commercial risk for early adopters of flammable refrigerants-based technology. In the case of Saudi Arabia, given the competitive nature of the sector, a coordinated conversion of the sector would be the preferable option. For this, Saudi Arabia would need first to develop and modify standards and building codes to allow safe installations of AC based on flammable refrigerants. Furthermore, technicians should also receive specific training and certification to work with flammable refrigerants.

58. The Secretariat expressed concern on the need to sign new contracts with the enterprises, a process that has proven lengthy in the case of several HCFC phase-out management plans (HPMPs). The World Bank indicated that is currently exploring with its country office in Saudi Arabia options to implement the project.

59. With regard to the funds requested for “prototype fabrication” and “development cost”, the World Bank indicated that the prototype fabrication costs (related to packaged units) involve all material for six different prototypes, three different capacities and two types of refrigerants, outsourcing of special components, refrigerants and shipping. The development cost (related to window units) includes engineering work to design the prototypes, review of the refrigerant properties, optimization of the system, design of heat exchangers, software development, laboratory testing and completion of the final report.

60. Upon request for clarification on potential overlaps or synergies identified with the work being done by PRAHA, the World Bank explained that Petra KSA was involved in PRAHA. The HFC-32 and HC-290 technologies proposed in the demonstration project have not been tested under the PRAHA project for windows and packaged AC. Only HFO blends have been tested for these applications but there is concern about their commercial availability and price.

61. The Secretariat considers that this project addresses one of the priority sectors under decision 72/40 and could, potentially have a positive impact on the introduction of low-GWP technologies for AC operating in countries with high ambient temperatures, noting that manufacturing of AC units with HFC-32 and HC-290 is already taking place in several countries. In light of the cut-off date for establishment of HCFC-based enterprises under decisions 60/44 and 74/50, the Secretariat considers that the demonstration project component related to Petra KSA established in 2010 is ineligible. The Secretariat also notes that the demonstration project submitted by the World Bank appears to be similar to the demonstration project being prepared by UNIDO with preparatory funds approved at the 74th meeting. However, an assessment could only be done once the project approved for UNIDO had been submitted.

RECOMMENDATION

62. The Executive Committee may wish to consider:

(a) The demonstration project at air-conditioning manufacturers to develop windows and packaged air-conditioners using lower global warming potential (GWP) refrigerants, in the context of its discussion on proposals for demonstration projects for low-GWP alternatives to HCFCs as described in the document on the overview of issues identified during project review (UNEP/OzL.Pro/ExCom/75/27);

(b) Approving the demonstration project at air-conditioning manufacturers to develop windows and packaged air-conditioners using lower GWP refrigerants, in the amount of US $355,905, plus agency support costs of US $24,913 for the World Bank, in line with decision 72/40; and

(c) Deducting 3.59 ODP tonnes of HCFCs from the starting point for sustained aggregate reduction in HCFC consumption.

Annex I

PROJECT COVER SHEET

COUNTRY: **Kingdom of Saudi-Arabia**

IMPLEMENTING AGENCY: UNIDO

PROJECT TITLE: Demonstration Project for the Phase-out of HCFCs by Using HFO as Foam Blowing Agent in the Spray Foam Applications in High Ambient Temperatures

PROJECT IN CURRENT BUSINESS PLAN	Yes
SECTOR	Foams
SUB-SECTOR	PU In-situ formed spray foam
ODS USE IN SECTOR (Average of 2014)	600 MT of HCFC-141b
ODS USE AT ENTERPRISES (Average of 2014)	28 MT
PROJECT IMPACT	28 MT (3.08 ODP tones) of HCFC-141b
PROJECT DURATION	24 months
TOTAL PROJECT COST:	
Incremental Capital Cost	US$ 195,000
Contingency	US$ 19,500
Incremental Operating Cost	US$ 107,097
Total Project Cost	US$ 321,597
LOCAL OWNERSHIP	100%
EXPORT COMPONENT	Nil
REQUESTED GRANT	US$ 274,016
COST-EFFECTIVENESS	US$ 9.79/ kg
IMPLEMENTING AGENCY SUPPORT COST (7.0%)	US$ 19,181
TOTAL COST OF PROJECT TO MULTILATERAL FUND	US$ 293,197
STATUS OF COUNTERPART FUNDING	
PROJECT MONITORING MILESTONES	Included
NATIONAL COORDINATING/ MONITORING AGENCY	Presidency of Meteorology and Environment (PME)

Project summary

HCFC-141b is used by Sham Najd International in in-situ formed sprayed rigid polyurethane (PUR) and polyisocyanurate foam (PIR) for insulating and water proofing walls, ceilings, roofs, suspended ceilings and floors at the construction sites and industrial sites in the Kingdom of Saudi-Arabia. Sham Najd will phase-out HCFC-141b by converting to HFO foaming agent technology. The chosen technology is a non-ozone depleting and low GWP foaming agent. This HFO technology, which is a definitive alternative under the Montreal Protocol and additionally has a positive impact on climate, and is in compliance with Decision XIX/6.

Impact of project on Country's Montreal Protocol Obligations

Immediate impact of this individual project is the phase-out of 28.00 MT of HCFC-141b, thereby, contributing to the country's obligation to meet 4.7% reduction target in 2018. With the successful implementation of this project, there will be no consumption of HCFC-141b for foam blowing purposes in this company.

Prepared by: UNIDO — Date: 9 September 2015

Reviewed by: — Date: ______________

1 BACKGROUND AND JUSTIFICATION

In 2007, the Parties to the Montreal Protocol agreed to accelerate the phase-out of the hydrochlorofluorocarbons (HCFCs) as the main ozone depleting substances largely because the of the substantive climate benefits of the phase-out. In the following years, Parties operating under the Montreal Protocol's Article 5 (mostly developing countries) have formulated their HCFC Phase-out Management Plans (HPMPs) for implementation under financial assistance from the Multilateral Fund for the implementation of the Montreal Protocol (MLF).

The Executive Committee in decision 72/40 agreed to consider proposals for demonstration projects for low-GWP alternatives and invited bilateral and implementing agencies to submit demonstration project proposals for the conversion of HCFCs to low-global warming potential (GWP) technologies in order to identify all the steps required and to assess their associated costs.

In particular, Par (b)(i)a. of Decision 72/40 indicates that project proposals should propose options to increase significantly in current know-how in terms of a low-GWP alternative technology, concept or approach or its application and practice in an Article 5 country, representing a significant technological step forward.

The use of the HFOs in the hot climate for the application of alternatives in the spray foaming sector to HCFCs fully fits the actual ExCom decision on Demonstration project proposals as defined in ExCom Decision 72/40.

The Executive Committee of Multilateral Fund for the Implementation of the Montreal Protocol approved at its 74nd meeting held in Montreal, Canada in May 2015, the preparation of the demonstration project for foam and refrigeration sectors. The project was approved for UNIDO implementation in the Kingdom of Saudi-Arabia.

HFO-1233zd(E) and HFO-1336mzz(Z) have very low GWP, both less than 5, and HFO-1233zd (E) is claimed to be even less than 1. In calculations within this project proposal GWP factor 5 is used. The HFOs have higher boiling point and lower vapour pressure which improves handling and yields smoother foam surfaces. Due to the very low thermal conductivity, less than 10,7 mW/mK, which is comparable to the HCFC-141b's same of approximately 10 mW/mK, the HFOs provide a substitute chemical for the HCFC-141b with lower GWP.

Replacing HCFC-141b in spray foam in the Kingdom of Saudi Arabia (KSA) presents an opportunity and technical challenge, making it worthy of a demonstration project. The preliminary 2014 HCFC consumption estimates show that 600 MT of HCFC-141b or 66 ODP tonnes were consumed in 2014 for spray foam in the Kingdom of Saudi-Arabia (these figures include import of pre-blended polyurethane systems). Also in 2014, the Ministry of Municipal and Rural Affairs of KSA has made thermal insulation compulsory for all new buildings in the 24 districts of the country covering 80% of the populations. The addition of thermal insulation in new building is expected to reduce 40% of energy use in air conditioning. Today, air conditioners account for 70% of electricity consumption in the region and with 1.5 Million new homes needed to keep up with the population growth, energy demand is anticipated to double by 2030 if energy conservation measures are not put in place.

2 OBJECTIVE

- Demonstrate benefits from the use of the HFO-1233zd(E) and HFO-1336mzz(Z), which have very low GWP in replacement of HCFC-141b with water, in terms of lower GWP and CO2 release and insulation properties in the PU spray foam insulation sector
- Demonstrate the easy applicability of the technology and, consequently, the replicability of the results

- Demonstrate that lower cost structure than with other alternatives can be obtained by means of lower foam density and lower thermal conductivity
- Objectively analyze, if the incremental operating cost could be reduced overall in similar future projects by means of using optimized water / physical foam blowing agent applied in the foaming process. Thus, providing means of reducing the overall incremental operating cost. The operating cost comparison is analyzed in the section 5.2, in particular in the last paragraph of the section.
- Objectively analyze, if the incremental capital cost at the System Houses can be utilized by means of lesser focus on the flammable gas detection and ventilation. In particular the extensive exhaust ventilation in the hot countries may result unexpected expenses in the production area air-conditioning during the hot summer periods

3 METHODOLOGY

The range of properties exhibited by PUR products is very wide. The same is true for PIR products and these two ranges often overlap. Although not in every case, generally PIR products have a higher upper service temperature and can perform better in reaction to fire tests. In all cases, for both PIR and PUR products, their individual performance claimed by the manufacturer are described by the levels of properties obtained. Accordingly, therefore, all the declaration clauses will be completed using the term PU to include both PUR and PIR products.

<u>This demonstration project</u> is to provide means for the evaluation of spray foam manufactured with new technology in comparison and in regards to European in-situ formed sprayed PU foam standard EN 14315;

- Thermal resistance and thermal conductivity
  - Measurement of lambda values (thermal conductivity W/mK)
  - Ageing of lambda value
- Reaction to fire of the products
  - The reaction to fire classification of the products shall be determined in accordance with EN-13501-1 and using data obtained from tests carried out according to procedures EN ISO 11925-2 and EN 13823
- Dimensional stability under specified temperature and humidity conditions
  - Dimensional stability under specified temperature and humidity conditions shall be determined in accordance with EN 1604
- Reaction profile and free-rise density
- Durability characteristics
  - Durability of reaction to fire against ageing/degradation
  - Durability of thermal resistance against ageing/degradation
  - Durability of compression strength against ageing/degradation
  - Closed cell content
- Short-term water absorption by partial immersion
- Compressive stress or compressive strength

All tests above will be conducted according to EN 14315 (*Thermal insulating products for buildings — In-situ formed sprayed rigid polyurethane (PUR) and polyisocyanurate (PIR) foam products*)

3.1 Description of process expectations

Quality of in-situ formed spray PU spray foam relies, in most of the application, on the insulation property. Considering the PU physical properties, insulation of final construction can be influenced by the thermal conductivity of the blowing agent and the thickness of the foam.

Therefore, one of the critical points in the converting from 141b to blowing agents with lower thermal conductivity value (e.g. HFOs), is the losses in insulation properties.

Aim of this demonstration project is to recgnize the advantages of HFO use in in-situ formed sprayed foam process, when using HFO-1233zd(E) and HFO-1336mzz(Z) as foam blowing agent instead of HCFC-141b.

The HFO technology will give advantages to HFC and other alternative foaming agent converted products in term of:

- Decreased lambda value
- Smoother foam surface, which can be benefitted in the consumption of acrylic water barrier applied on the top of sprayed PU foam
- Decreased spraying time compared to the other alternatives of 10% due to the faster cure between laying down new foam layers

The above is expected to generate substantial technical improvements in the final insulation as well as reduction of operation costs in comparison the other alternatives (reduction of time for spraying as well as reduction of raw materials).

The project results will be extremely relevant for those sectors where spray foaming is applied in hot countries and insulation property of final products is crucial and thickness of insulation cannot be increased

3.2 Detailed description of Methodology

In the selection of the most suitable partner for the application of the HFO technology, priority was given a company, which is eligible and willing for the HFO conversion.

Sham Najd is willing and eligible beneficiary which was selected and the project will include the implementation of:

1- HFO conversion of their spray foaming needs
2- Testing procedure described in para 3 (Methodology)

The HFO conversion will include:

1. Provision of new spray foaming unit and necessary changes in the mixing process at the System House

- The System House operations must be converted so that the polyol mixing vessel is to be replaced or upgraded with cooling and heating unit, so that HFO-1233zd(E) (boiling point of 19 C) can be mixed at lower temperature i.e. at 12 C, and to be kept at that temperature for 24 hrs. After that temperature can be raised to 25 C, and the mixed polyol (preblend) can be moved in the drums for the customer supply.

- It is anticipated that the other HFO, HFO-1336mzz(Z) can be mixed without any changes in the mixing process.

- The cost of equipment changes at the System House is covered by the other project, which is under implementation

2. At the spray foam applicator, the provision of HFO preblended polyol and provision of new spray foaming unit for the demonstration project needs.

4 COMPANY BACKGROUND

System House:

Insulation Products Factory (SAPTEX) was formed in 1981. Its plant in Riyadh has a licensed capacity of 14,000 metric tons per year. It can manufacture insulation boards in a wide range of densities and thicknesses and with a variety of facing materials. In 1986, a new unit was added, which produced up to 90,000 linear meters per year of pre-formed polyurethane pipe insulation. In 1988, SAPTEX acquired the expanded polystyrene business of SAPPCO, creating one company to produce and sell both polyurethane and polystyrene insulation materials. The polystyrene plant, also located in Riyadh, has a licensed capacity of 4,200 metric tons per year. In 2000, SAPPCO acquired Texaco's share, and SAPTEX became 100% owned by SAPPCO.

Saptex has also the polyurethane System House operations, and they are part of the System House project with UNIDO.

The company's consumption of HCFC-141 b in recent years is as follows:

Consumption in years	2010	2011	2012	2013
HCFC-141 (MT)	380	395	515	515

Systems Chemicals in 2013	Boards/Slabs	Injection Applicat.	Spray Foam
HCFC-141 (MT)	267	134	134

Company name
Insulation Products Factory Saptex
Address
P.O. Box: 40042, Riyadh, Saudi Arabia
Phone
00966 1 4482644
Fax
00966 1 4461454

Spray foam applicator:

Sham Najd International Co. Ltd is a 100% Saudi-Arabian national public company, originally founded in 2004. Their core focus is on quality in-situ formed sprayed rigid polyurethane (PUR) and polyisocyanurate foam (PIR) for insulating and water proofing walls, ceilings, roofs, suspended ceilings and floors at the construction sites (over metal, concrete and wooden substance) and industrial sites, where one of the most import application is the thermal energy storage tanks (TES). Sham Najd International is a successful business employing over 185 staff members. The spray foaming operation is operated with five teams with five spray foaming units, with three Gracos and two Gusmer machines. Each foaming machine unit consists closed trailer with one electrically operated spray foaming machine, 100 meters foaming hoses, electrical generator, air compressor, pneumatically operated transfer pumps to deliver PU chemicals from drums to the intermediate tanks of 2,000 liters or directly to the spray foaming machine, spare mixing heads and all maintenance tools and spare parts for the independent operations anywhere in the Kingdom of Saudi-Arabia.

Sham Najd International is based in Riaydh, and their operations are all over the Kingdom of Saudi-Arabia. Their address details are below.

Address:

Contact person: Eng. Abdulrazak Zahal (General Manager)
P.O. Box 27994
Riyadh
Tel office: +966 1 2064070
Tel: 00966505241420
Fax: +966 1 2064074
Website:
Members: Public Company
Reg No: C.R. 1010195476

4.1 PRODUCTION PROCESS

The raw materials, including polyol blend with HCFC-141b as a pre-blend from the local system house, and isocyanate is being procured in 200 liter drums. The polyol-blend and isocyanate are sifted by means of pneumatic pump to the intermediate working tanks within the trailer unit or directly in the spray foaming machine. The company Najd Sham has 5 foaming machines. The PU chemicals are in-situ sprayed on the construction sites in the desired quantity to achieve the required foam parameters. The production process is manual and fully man operated. The average foam per square meter applied is 3.125 kg.

The chemical composition of various chemical uses in the manufacturing in-situ formed PU sprayed foam is provided in the table below:

Description	HCFC 141b	Polyol	Isocyanate
Volymetric %-age mixing ratio	9%	41%	50%
Mass %-age	7 %	45 %	48 %

The description of the foaming machines is provided below.

Baseline Equipment

Sr. #	Type of Equipment	Model	No.	Design Capacity	Manufacturer Type	Year
1	Graco	E-XP1	3	12 kg/min	Spray foam	2007
2	Gusmer	H2	2	12 kg/min	Spray foam	2004
3	Graco	Mark V	4	7 kg/min	Coating / acrylic	2004
4	Trailer	30 m3	5	See below*	Locally made	2004 -2007

*Each foaming machine unit consists closed trailer with one electrically operated spray foaming machine, 100 meters foaming hoses, electrical generator, air compressor, pneumatically operated transfer pumps to deliver PU chemicals from drums to the intermediate tanks of 2,000 liters or directly to the spray foaming machine, spare mixing heads and all maintenance tools and spare parts for the independent operations anywhere in the Kingdom of Saudi-Arabia

Within this demonstration project it is proposed to provide comprehensive one foaming unit package for Sham Najd Company in order to be able to conduct the full-scale field-testing without compromising their normal foaming operations elsewhere in the Kingdom of Saudi-Arabia.

Two photographs taken at the company are provided below:

Sham Najd International Co., Ltd HQ

Graco electrically driven E-XP1 applicator

4.2 ANNUAL PRODUCTION PROFILE IN 2014

Sham Najd spray foam operations are applied to walls, ceilings, roofs, suspended ceilings and floors at the construction sites (over metal, concrete and wooden substance) and industrial sites, where one of the most important is the thermal energy storage tanks (TES).

<u>Total annual foaming operations</u>

Total sprayed area	128,000 m^2 average consumption 3.125 kg/m^2
Total consumed PU	400,000 kg
HCFC-141b (7%)	28,000 kg equivalent to 3.08 ODP tons

5 TECHNOLOGY OPTION

5.1 Overview of alternatives to HCFC-141b for PU foam application

Although this project proposal is for demonstrating HFOs suitability as ozone depleting HCFC-141b replacement chemical, we are providing the other alternatives below.

HCFC-141b has mainly been used as a foam blowing agent in various formulations in the manufacturing of PU foam for the production of PU sprayed foam in the Kingdom of Saudi-Arabia.

Factors that influence the technology selection include consideration of the following major features for PU foam.

- Mechanical properties
- Density
- Insulation properties
- Water absorption
- Reaction to fire
- Durability
- Costs

5.2 Alternate Technologies Considered

In accordance with the 2014 report of the rigid and flexible foams technical options committee, there are a number of alternatives that are available to replace the use of HCFC 141b in rigid polyurethane foam. Several foaming technologies including the following are used as alternate technology.

- Cyclopentane
- HFC-245fa
- HFC-365mfc/227ea
- HFC-134a
- Methyl formate
- CO_2 (Water)
- u-HFC
- Liquid unsaturated HFC/HCFC (HFOs) as emerging technology (subject for this demonstration project)

The below table provides an overview of the blowing agents that has been used in various sub-sectors of foam sector.

Sector	***HCFCs***	***HFCs***	***HCs***	***HCOs***	***HFOs***	***CO2-based***
PU Appliances	HCFC-141b HCFC-22	HFC-245fa HFC-365mfc/227ea	cyclo-pentane cyclo/iso-pentane	Methyl Formate	HFO-1233zd(E) HFO-1336mzzm(Z)	CO2 (water)*
PU Board	HCFC-141b	HFC-365mfc/227ea	n-pentane cyclo/iso pentane		HFO-1233zd(E) HFO-1336mzzm(Z)	
PU Panel	HCFC-141b	HFC-245fa HFC-365mfc/227ea	n-pentane /iso pentane		HFO-1233zd(E) HFO-1336mzzm(Z)	CO2 (water)*
PU In-situ formed spray foam	HCFC-141b	HFC-245fa HFC-365mfc/227ea			HFO-1233zd(E) HFO-1336mzzm(Z)	CO2 (water)* Super-critical CO2
PU In-situ / Block	HCFC-141b	HFC-245fa HFC-365mfc/227ea	n-pentane cyclo/iso pentane		HFO-1233zd(E) HFO-1336mzzm(Z)	CO2 (water)*
PU Integral Skin	HCFC-141b HCFC-22	HFC-245fa HFC-134a		Methyl Formate Methylal		CO2 (water)*
XPS Board	HCFC-142b HCFC-22	HFC-134a HFC-152a		DME	HFO-1234ze(E)	CO2 CO2/ethanol
Phenolic	HCFC-141b	HFC-245fa HFC-365mfc/227ea	n-pentane cyclo/iso pentane		HFO-1233zd(E) HFO-1336mzzm(Z)	

*CO_2 (water) blown foams rely on the generation of CO_2 from reaction of isocyanate with water in the PU system itself.

The pros & cons for commercially available options as well as emerging options as highlighted in the UNEP 2014 report of the rigid and flexible foams technical options committee for the manufacturing of PU foam are provided in the below tables:

Commercially Available Options

Option	Pros	Cons	Comments
Cyclopentane & n-Pentane	Low GWP	High flammable	High incremental capital cost, may be uneconomic for SMEs
	Low operating costs		
	Good foam properties		
HFC-245fa, HFC-365mfc/227ea, HFC-134a	Non-flammable	High GWP	Low incremental Capital Cost
	Good foam properties	High Operating Cost	Improved insulation (cf. HC)
CO2 (water)	Low GWP	Moderate foam properties -high thermal conductivity-	Low incremental Capital Cost
	Non-flammable		
Methyl Formate/Methylal	Low GWP	Moderate foam properties -high thermal conductivity-	Moderate incremental capital cost (corrosion protection recommended)
	Flammable although blends with polyols may not be flammable		

Emerging Options

Option	Pros	Cons	Comments
Liquid Unsaturated HFC/HCFC (HFOs)	Low GWP	High operating costs	First expected commercialization in 2013
	Non-flammable	Moderate operating costs	Trials in progress
			Low incremental capital cost

The Indicative assessment of criteria for commercially available options as well as emerging alternatives in PU foam is provided in the table below:

Assessment of criteria for commercially available options

	c-pentane	i-pentane n-pentane	HFC-245fa	HFC365mfc/ 227ea	CO_2 (water)	Methyl Formate
Proof of performance	+	++	++	++	++	+
Flammability	---	---	++	+(+)	+++	--
Other Health & Safety	0	0	+	+	-	0
Global Warming	+++	+++	--	---	++	++
Other Environmental	-	-	0	0	++	-
Cost Effectiveness (C)	--	---	++	++	++	0
Cost Effectiveness (O)	++	+++	--	--	+	+
Process Versatility	++	++	+	++	+	+

Assessment of criteria for Emerging Technology options

	HFO-1234ze(E)	HFO-1336mzzm(Z)	HFO-1233zd(E)
	Gaseous	liquid	Liquid
Proof of performance	0	+	+
Flammability	++	+++	+++
Other Health & Safety	+	+	+
Global Warming	+++	+++	+++
Other Environmental	+	+	+
Cost Effectiveness (C)	++	++	++
Cost Effectiveness (O)	--	--	--
Process Versatility	+	+	+

IOC comparison between major alternatives

IOC	HCFC-141b			HFO-1233zd			Methyl Formate			Water-blown / Formic Acid		
	Formula	%	Cost/kg	Formula	%	Cost/kg	Formula	%	Cost/kg	Formula	%	Cost/kg
Polyol	100	44,29%	2,70	100	46,08%	2,70	100	37,88%	2,70	100	37,95%	2,70
B.A	15,8	7,00%	2,70	7	3,23%	11,00	9	3,41%	2,70	3,5	1,33%	2,70
MDI	110	48,72%	2,70	110	50,69%	2,70	155	58,71%	2,70	160	60,72%	2,50
Total	**225,8**	**100,00%**	**2,70**	**217**	**100,00%**	**2,97**	**264**	**100,00%**	**2,70**	**263,5**	**100,00%**	**2,58**
Thermal conductivity mW/mK			**21**			**21**			**23**			**31**
Foam density			42			42			42			42
Equivalent cost USD			**2,70**			**2,97**			**2,96**			**3,81**
Total PU consumption 2015	400000	27,99	1080000	400000		1187097	400000		1182857	400000		1522577
IOC / year USD						**107097**			**102857**			**442577**

5.3 Selection of alternative technology for the Demonstration project

The technology chosen has been HFOs due to the following:

Spray foam is used to insulate, provide air sealing and improve structural strength in buildings. The insulation potential of spray foam is dependent upon the insulating gas in the cells of the polyurethane foam. In addition to the insulation performance, polyurethane foams used for the insulation purpose require inherently superior dimensional stability and resistance to fire.

The current zero ODP options for replacement of HCFC-141b in foam applications include hydrofluorocarbons (HFCs) and hydrocarbons. Both HFCs and hydrocarbons are characterized by increased thermal conductivities compared to the HCFC, resulting in inferior insulation performance.

Few alternatives exist for replacing 141b in spray foam. Hydrocarbons are not a viable alternative for spray foam, and HFC-245fa and HFC-365, while viable, have high global warming potential (GWP). Also, the low boiling point of HFC-245fa and the flammability of hydrocarbons and HFC-365mfc present significant challenges to blowing agents processing and handling that are critically important in spray foam applications. On the other hand, foam blowing agents HFO-1233zd(E) and HFO-1336mzz(Z) have very low GWP, both less than 5, and HFO-1233zd (E) is claimed to be even less than 1. These molecules are also non-flammable and stable liquids at ambient temperatures. The HFO-1233zd(E) is already commercialized and HFO-1336mzz(Z) will be commercially available from the year 2016.

6 Activities required for conversion

6.1 Modification of production process

- The project proposal includes provision of necessary equipment in order to conduct full scale foam testing on the real construction and industrial sites as "field testing" around the Kingdom of Saudi Arabia in various climate situations in both summer and winter conditions
- It is not expected that new technology is required for the foaming equipment. However, in order to allow the beneficiary company Sham Najd to operate their normal spray foam business operations, the baseline existing foaming units cannot be used for the testing and evaluation program. Therefore, it is foreseen that project provides similar type of foaming units for the demonstration project duty

7 PROJECT COST

7.1 Project Cost as per MP Guideline decision 55/47

The conversion plan and costs are following the guidelines of decision 55/47 to the extent possible. Based on table **I**.1 (Sectoral cost-effectiveness threshold values established by the Executive Committee) of above referenced guideline, the sectoral cost effectiveness threshold value established by the executive committee for the PU foam is US$ 7.83 per kg.

Recently, in accordance with clause 162 (C) (i, iii & iv) of UNEP document 3 UNEP/OzL.Pro/ExCom/74/56 (Decision 74/50), the cost effective threshold is US$7.83/kg for phasing out of HCFCs in Stage-II HPMP projects. Further, the following is stipulated:

- Funding of up to a maximum of 25 per cent above the cost-effectiveness threshold is available for projects when needed for the introduction of low-GWP alternatives; however, for SMEs in the foam sector with consumption of less than 20 metric tonnes, the maximum would be up to 40 per cent above the cost-effectiveness threshold.

- Incremental operating costs for projects in the polyurethane foam sector would be considered at US $1.60/metric kilogram for HCFC-141b; however, for projects that make the transition to low-GWP alternatives, incremental operating costs would be considered at up to US $5.00/metric kilogram;

The cost effective threshold for this sub-sector is US$9.79/ kg (US$7.83+25%) for consumption greater than 20 metric ton and US$10.96/ kg (US$7.83+40%) for consumption less than 20 metric ton. In this demonstration project at Sham Najd, the cost-effectiveness threshold of US$9,79/kg is applied.

7.2 Incremental capital cost

Expenses	Cost USD
Production	
Provision of Spray foaming unit with accessories	55 000
100 meters foaming hoses	
Pneumatically operated transfer pumps	
Air compressor	
Mixing head	
General Works	
Purchase of materials for full scale field testing (3 testing) (1,000 m2)	30 000

Field test foaming product physical property testing in Saudi-Arabian Certified testing House	50 000
*Technology transfer, Trials and Commissioning	40 000
Workshop for the results and experienced gained for information dissemination	20 000
Total	195 000
Contingency	19 500
Grand Total	**214 500**
Total according to the threshold (USD9,79/kg x 28,000 kg)	274 016
IOC estimate for one year	107 097
Total project budget	321 597

The above budget in "General Works" includes expert fees and travel as well as organization of consultation meetings with national stakeholders.

***Trials and commissioning include testing mentioned in the methodological chapter and according to the standard EN 14315:**

- Thermal resistance and thermal conductivity
  - Measurement of lambda values (thermal conductivity W/mK)
  - Ageing of lambda value
- Reaction to fire of the products
  - The reaction to fire classification of the products shall be determined in accordance with EN-13501-1 and using data obtained from tests carried out according to procedures EN ISO 11925-2 and EN 13823
- Dimensional stability under specified temperature and humidity conditions
  - Dimensional stability under specified temperature and humidity conditions shall be determined in accordance with EN 1604
- Reaction profile and free-rise density according to the standard requirements
- Durability characteristics
  - Durability of reaction to fire against ageing/degradation
  - Durability of thermal resistance against ageing/degradation
  - Durability of compression strength against ageing/degradation
  - Closed cell content
- Short-term water absorption by partial immersion
- Compressive stress or compressive strength

7.3 Incremental operating cost

In calculating the Incremental Operating Costs it has been assumed based on the expectation that:

- The use of HFO-1233zd(E) or HFO-1336mzz(Z) is only about 46.1% of the use of HCFC 141b.

- It is expected that the foam insulation performance will not be substantially affected.

Incremental operating cost related to the conversion of the foaming technology was calculated based on the formulations as applicable at Sham Najd. Current prices are as follows:

- HCFC-141b: US$ 2.70/kg
- Polyol: US$ 2.70/ kg
- Isocyanate: US$ 2.70/ kg
- HFO: US$ USD11.00/kg (in preblend)

IOC	HCFC-141b			HFO-1233zd		
	Formula	%	Cost/kg	Formula	%	Cost/kg
Polyol	100	44,29%	2,70	100	46,08%	2,70
B.A	15,8	7,00%	2,70	7	3,23%	11,00
MDI	110	48,72%	2,70	110	50,69%	2,70
Total	**225,8**	**100,00%**	**2,70**	**217**	**100,00%**	**2,97**
Equivalent cost USD			**2,70**			**2,97**

Difference: USD 0.27 /kg foam

The IOC is calculated based on 1 year as provided in the table below

Is	Before conversion	Year I
Foam production [kg]	400,000	400,000
Total annual cost of chemicals used	1,080,000	1,187,097
Cost difference per annum - Total IOC, US$		107,097

7.4 Total project cost

	US$
Incremental Capital Cost (ICC)	214,500
Incremental Operating Cost (IOC)	107,097
Total Cost	**321,597**
Eligible cost up to threshold	**274,016**

7.5 Cost Effectiveness

The total HCFC-141b planned to be phased out in this demonstration project is 28.00 MT and grant requested is up to the maximum threshold **US$ 274,016**. Thus, representing of Cost Effectiveness of US$9,79/kg phased out of HCFC-141b.

8 GLOBAL WARMING IMPACT ON THE ENVIRONMENT

8.1 Project Impact on the Environment

The project impact on the environment was studied for both the chemicals i.e. HCFC 141b and HFOs. The CO_2 emission before conversion (using HCFC 141-b as blowing agent with Global Warming Potential of 713) is expected as 154,529 metric ton per year whereas after conversion to HFO with GWP 5, it is estimated 64.5 metric ton per year. The net impact on the environment is positive. The CO_2 emission is expected to be reduced by 19,900 MT after implementing the new technology. The net effect is provided in the table below:

Name of Industry	Substance	GWP	Phase out amount MT/ year	Total equivalent warming impact CO2 eq. MT/ year
Before Conversion				
Total CO_2 emission in M tonnes	HCFC 141b	713	28	19,964
After Conversion				
Total CO_2 emission in M tonnes	HFO	5	12.9	64,5
Net Impact				-19,900

9 PROJECT IMPLEMENTATION MODALITIES

9.1 Implementation structure

The National Ozone Unit reporting to Presidency of Meteorology and Environment in Kingdom of Saudi-Arabia is responsible for the overall project, coordination, assessment and monitoring. The National Ozone Unit will clear agreements on implementation procedures and letters of commitments with the industries and other counterparts of this plan to ensure that outputs for different tasks and outcomes for different components of this plan are met to contribute to meeting project objectives. Terms of Reference (TOR) for each activity will be prepared by UNIDO in close collaboration and Sham Najd International (recipient company), which participate in implementation of different components of this plan and thus contributing to different outputs and outcomes of the Plan. Main objective of this Plan is to ensure project successful implementation and provision of process replication to the other parts of The Kingdom of Saudi-Arabia and other Article 5 countries.

UNIDO as the implementing agency is responsible for the financial management of the respective grant. UNIDO will also assist the Sham Najd International in equipment procurement, technical information update, monitoring the progress of implementation, and reporting to the ExCom. The counterpart/enterprise is responsible to achieve the project objective by providing financial and personnel resources required for smooth project implementation. Financial management will be administered by UNIDO following UNIDO’s Financial Rules and Regulation.

9.2 Working arrangement for implementation

After the approval of the project by the Executive Committee, the above parties will sign the working arrangement, where the roles and responsibilities of each party are detailed.

9.3 Modification of production process

Procurement of equipment required for the production line modification will be done through competitive bidding purchase according to respective regulation stipulated by UNIDO’s Financial Rules and Regulations. Smaller equipment and parts may be procured locally, if local procurement is found to be more economical. Local procurement will also be done based on UNIDO’s Financial Rules and Regulations. This applies also for contracting with contractors for provision of technical services. Terms of references and technical specifications for the procurement of contracts and equipment will be prepared by UNIDO in consultation and agreement with the enterprise and the NOU.

9.4 Project monitoring

Project monitoring is done by the executing and implementing agencies through regular missions to the project sites and continuous communications through e-mails and telephone/skype discussion. Occasional visits and communication by the NOU are also to be done to ensure adequate project implementation.

9.5 Project completion

Project completion report will be submitted by UNIDO within 6 months after project completion. Necessary data and information for the preparation of the project completion report is to be provided by the enterprise/NOU.

9.6 Timetable for implementation

Milestone	**2015**	**2016**				**2017**				**2018**			
	Q4	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
Approval													
Working arrangement													
Preparation of TORs													
Bidding & contract award													
Equipment Delivery													
Field testing													
Staff training													
Testing and result dissemination													
Project completion													

In conformity with the Montreal Protocol Executive Committee's decision 23/7 on standard components on monitoring and evaluation, milestones for project monitoring are proposed as follows:

Sr. #	**Milestone**	**Months**
1	Project approval	-
2	Start of implementation	1
3	Grant agreement submitted to beneficiary	2
4	Grant agreement signature	3
5	Bids prepared and requested	9
6	Contracts awarded	14
7	Equipment delivered	20
8	Field testing, commissioning and trial runs	22
9	De-commissioning/destruction of redundant baseline equipment	24
10	Submission of project completion report	24-30

Annex II

THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER

PROJECT COVER SHEET

COUNTRY:	Kingdom of Saudi Arabia	
PROJECT TITLE:	Demonstration project at air-conditioning manufacturers in Saudi Arabia to develop windows and packaged air-conditioners using lower-GWP refrigerant	
SECTOR COVERED:	Refrigeration and Air-Conditioning	
ODS USE IN SECTOR:	10,000 MT HCFC-22 in 2010 (RAC manufacturing)	
PROJECT IMPACT:	N/A	
PROJECT DURATION:	One year	
TOTAL PROJECT COST:	Incremental Capital Costs (Incl. 10% contingencies)	1,306,800 USD
	Incremental Operating Costs	0 USD
	Total Project Cost	1,306,800 USD
PROPOSED MLF GRANT:		1,306,800 USD
SUPPORT COST:		91,476 USD
TOTAL COST:		1,398,276 USD
COST-EFFECTIVENESS:	N/A	
IMPLEMENTING ENTERPRISE:	1. Saudi Arabia Factory for Electrical Appliances Co., Ltd 2. Petra KSA Co., Ltd	
IMPLEMENTING AGENCY:	The World Bank	
COORDINATING AGENCY:	Presidency of Meteorology and Environment	

PROJECT SUMMARY

Saudi Arabia is one of the world's largest market for air-conditioning. Due to high-ambient temperature, the air-conditioning industry is facing difficult challenges in finding suitable alternatives to HCFC-22 that work well in high-ambient temperature while meeting existing minimum energy performance standards.

Main objective of the project is to:

1. Building, testing, and optimizing prototypes with two alternatives: HFC-32 and HC-290, including safety feature.
2. Evaluate energy performance of prototypes and assess incremental cost implications
3. To disseminate the findings and results to interested manufacturers in Saudi Arabia and other countries.

This project will develop prototypes for windows and packaged air-conditioning using abovementioned alternatives that are commercially available. These a but not yet covered by previous demonstration project, PRAHA. Two manufacturers will be involved in developing and testing prototypes. One will develop 4 prototypes for window air-conditioner and another to develop 6 prototypes for packaged AC system at 40, 70, and 100 kW cooling capacity.	
Prepared by:	Thanavat Junchaya
Reviewed by:	Piotr Domanski, OORG

1. PROJECT OBJECTIVE

The Article 5 parties, especially those in high-ambient conditions, face serious challenge in finding out suitable alternatives to replace HCFC-22 in air-conditioning applications while maintaining minimum energy performance standards. To assist these Parties, the Executive Committee funded the demonstration project, PRAHA, to promote low-GWP alternatives for the A/C industry in high-ambient countries. PRAHA regional manufacturers develop prototypes according to the following test matrix:

Alternatives	Window	Decorative	Ducted	Packaged
Base	R22	R22	R22	R22
HFC base	R407	R410	R410	R407/R410
HFC-32	No	Yes	Yes	No
HFO-1	Yes	Yes	Yes	Yes
HFO-2	Yes	Yes	Yes	Yes
HC-290	No	Yes	No	No

As shown above, there are gaps in testing HFC-32 and HC-290 with window and packaged air-conditioners. Given the uncertainty in commercial availability of HFOs, the Government decides to demonstrate HFC-32 and HC-290 alternatives which are commercially available. While, there have been commercial production of air-conditioner using these two alternatives, most products are mini-split and not yet fully tested in high-ambient conditions.

HFC-32 or R-32 is a single component refrigerant and is one of the two main components of R-410A (50:50 mixture with HFC-125). It is one of the potential candidates to replace HCFC-22 in the manufacture of residential and commercial air-conditioners due to its excellent refrigeration properties. The efficiency of HFC-32 systems are higher than R-410A but less than HCFC-22. Discharge temperatures are higher than R-410A and HCFC-22 and thus some mitigation device or controls may be necessary for handling the discharge temperature of the compressor especially at high ambient temperatures. There is a slight trade-off due to its GWP of 675 which is approximately one-third of R-410A. Furthermore R-32 is considered to be mildly flammable and is classified by ASHRAE Standard 34-2010 to be under a new "A2L" rating for very mildly flammable refrigerants. Pressure and capacity are around 1.5 times higher than HCFC-22 and slightly higher than R-410A.

HC-290 has thermodynamic properties similar to HCFC-22, although slightly lower pressure and capacity. It is classified as A3. Due to its excellent thermophysical properties the efficiency is good under most conditions, including high ambient, as well as having low discharge temperatures. It is the most frequently used hydrocarbon refrigerant in air conditioning applications. It is also used as a major component in many

HC blends.

The table below shows the key parameters of HFC-32 and HC-290 compared to HCFC-22 and R410A.

Table 6.16: Physical Properties of R-22 and Alternatives

Physical properties	HCFC-22	R-410A	HFC-32	HC-290
LFL (kg/m3)	Not flammable	Not flammable	0.307	0.038
GWP*	1,810	2,090	675	5
Molecular weight	86.47	72.58	52.03	44.1
Boiling point (C)	-40.8	-51.6	-51.7	-42.1
Critical temperature (C)	96.2	72.5	78.25	96.7
Critical pressure (Mpa)	4.99	4.95	5.808	4.25
Specific heat of Liquid (KJ/(Kg˚C)	0.31	1.78	2.35	1.64
Theoretical COP (kW/kW)	9.85	9.29	9.55	

* Sources: IPCC the fourth assessment report

This projects proposes to fill in the missing gap through the development of prototypes and testing of windows and packaged air-conditioner with HFC-32 and HC-290 for operation in high-ambient conditions. Therefore the objectives of the project would be:

4. Building, testing, and optimizing prototypes with two alternatives: HFC-32 and HC-290, including addressing safety feature
5. Evaluate energy performance of prototypes and assess incremental cost implications
6. To disseminate the findings and results to interested manufacturers in Saudi Arabia and other countries.

2. SECTOR BACKGROUND

Saudi Arabia is the one of the world's largest markets for air conditioning - expected to surpass US$2.5 billion by 2019. Due to surge in constructions of educational institutions, hotels, office spaces, residential areas and expansions of development cities, there have been a massive increase in demand for air conditioning solutions. Increasing affluence, a developing tourism industry and high population growth have also contributed to increased demand in the industry. It has been estimated that air conditioning is responsible for 70% of electricity consumption in Saudi Arabia.

Saudi Arabia has active and diverse refrigeration and air-conditioning sector, with many medium and small companies operating in what can be generally categorized as manufacturer, assembly, and installation and servicing. There are a number of appliance manufacturers and manufacturers of commercial refrigeration equipment as well as companies assembling and installing unitary, packaged and central air-conditioning systems. There are also several companies supplying large scale and industrial refrigeration systems on a design and build basis to a relatively well developed industrial refrigeration sector serving food processing, brewing, fishing, cold storage, chemicals and other process industries. The petrochemical industry is also a major consumer of refrigerants, used in the installation and service of large scale refrigeration and air-conditioning equipment used refining and processing and liquefaction of gases.

Equipment manufactured and assembled in Saudi Arabia includes the full range of refrigeration and air-conditioning equipment, including ductless and ducted air-conditioners, packaged AC units, condensing units, large and small-scale commercial refrigeration equipment, cold stores, and process cooling. Chillers are imported through distributors and joint venture companies.

The approved HPMP for Saudi Arabia is focusing on the phase-out of HCFC-141b from the foam sector.

There is no investment component for the refrigeration and air-conditioning under stage I HPMP. Successful demonstration of low and lower-GWP alternatives will have significant replication effects.

There are 5 large-scale manufacturers with HCFC-22 more than 500 MT and a number of enterprises with consumption below 100 MT. A major sub-sector is the production of Unitary and split air conditioners up to 18 kW installed in residential homes, restaurants, hotels, offices, shops, schools, computer rooms, clinics, laboratories etc and central air-conditioning systems air handling units and chillers or large VRF (Variable Refrigerant Flow) systems above 18 kW installed in hospitals, hotels, office buildings, shopping malls. According to Saudi Arabia HPMP Stage I, approximately 10,000 MT of HCFC-22 was used in the manufacturing of refrigeration and air-conditioning equipment in 2011 and similar amount was used for servicing purpose. Table below shows some of the larger AC manufacturers in Saudi Arabia.

Company	Brand
Al Salem Johnson Controls (AJIC)	York
Alessa for Refrigeration and Air-Conditioning Co. (ARAC)	Crafft, Gibson, Haas, Hitachi
Heating and Air Conditioning Enterprises (HACE)	Hace, Royal Temp, Goldenstar
LG Shaker Company (LGSC)	LG
Petra Engineering Industries Co. Ltd.	Petra
Saudi Air Conditioning Manufacturing Co. Ltd. (SAMCO)	Carrier
Saudi Factory For Electrical Appliances Co. Ltd. (SELECT)	Mitsubishi
Zamil Air Conditioners (ZAC)	Zamil, Cooline, Classic

In terms of installations, Saudi Arabia estimated about 9 million window and 7 million mini-split units. For rooftop (packaged) and ducted split, there are approximately 0.5 million units with capacity ranging from 6 to 30 tons of refrigeration.

3. PROJECT DESCRIPTION

The project will provide technical assistance to two air-conditioner manufacturers in Saudi Arabia to build, test, and optimize prototypes with HFC-32 and HC-290.

3.1 Participating enterprises

Saudi Factory for Electrical Appliances Co. Ltd. and Petra Engineering Industries Co. Ltd will be participating in the demonstration project. Saudi Factory for Electrical Appliances Co. Ltd. will focus on window air-conditioner and Petra KSA on the packaged air-conditioner.

3.1.1 Saudi Factory for Electrical Appliances Co., Ltd.

Saudi Factory for Electrical Appliances Co. Ltd. was established in 1986 and commenced its production on June 1st 1988 under Mitsubishi technical collaboration. The factory is located in Industry City, Jeddah and now produces their own brand “SELECT” window air conditioners with annual production capacity of 120,000 units. Annual consumption of HCFC-22 is approximately 90 MT/year. The factory has one assembly line and make their heat exchanger in house. The company would like to develop two sizes (18,000 BTHU and 24,000 BTUH) of their windows AC with HFC-32 and HC-290.

3.1.2 Petra Engineering Industries (KSA) Co., Ltd

Petra KSA was established in 2010, and located in King Abdullah Economic City, Rabigh. There are 7

R&D engineers working on AC system development and production. Head of R&D has more than 20-year experience in air-conditioning sector and is also a member of RTOC. Its products are widely used in the Saudi Arabia and other gulf countries. To address the issue of flammability in higher refrigerant charge unit, Petra KSA want to demonstrate a packaged air-conditioning system that combine chiller and air-handling unit.

3.2 Technical Assistance Component

Based on their past experiences in development of new air-conditioner, the development process will be as followed:

3.2.1 Design and planning

In this phase, the manufacturer will study characteristics of the two alternatives based on the latest developments, scientific researches, reports, papers, case studies, etc. The R&D engineers will then design the prototypes and specify the main components (condensers, evaporators, fans and compressors) based on the required efficiency and existing manufacturing conditions. Supplier and availability of components for T3 conditions will be identified.

3.2.2 Prototype production

Under this phase, the manufacturer will fabricate and build the prototype. Safety precautions and training for production engineers and factory workers must be addressed during the production process (vacuum, charging and welding) since the two alternatives are flammable gas.

3.2.3 Testing and evaluation

This phase is considered to be the most important and critical phase for the success of the project. The test should be carried out in accredited laboratory which is equipped with the appropriate equipment to simulate any required conditions. The test will conduct in accordance with international standards such as AHRI under different ambient conditions (low and high ambient), to verify the performance of HFC-32 and HC-290 at all conditions. After analyzing test results, a full comparison included performance, quantity of charge, and prices will be prepared for HFC-32, HC-290 and HCFC-22.

3.3 IMPACT ON GWP

There is no impact on GWP at this stage. The impact will occur when the manufacturers convert their production to chosen alternatives.

4. PROJECT BUDGET

4.1 Technical Assistance

Cost include conceptual design, software development, components specification, prototype fabrication and testing and R&D engineer staff costs. Cost also included an international consultant to support the prototypes development and testing. Three full one-week visits are needed. The first visit is to carry out detailed planning of the project implementation (concept design, components specification and testing). The second visit is planned during the middle of the implementation to do a detailed project follow-up. Finally the third visit is to discuss the final report preparation including support on the incremental cost/performance analysis and, in parallel, participate in the dissemination seminar.

4.2 Dissemination workshop

Cost to organize the dissemination workshops is included. One workshop will be organized in Saudi Arabia to AC manufacturers in Saudi Arabia and other from countries in the region.

4.3 Incremental operating cost

According to the supplier, the cost of the HFC-32 and HC-290 will be slightly higher than HCFC-22. Cost of components for T3 conditions for HFC-32 and HC-290 will also be higher than HCFC-22 or R-410A refrigerant.

However, IOC is not requested for participating AC manufacturers in the present demonstration project.

The summary of the project cost is as follows:

ITEMS	Qty.	Unit Cost (US$)	Total (US$)	Remark
Saudi Factory for Electrical Appliances Co. Ltd.				
• Development cost window AC (18,000 BTHU capacity) using rotary compressor and reciprocating compressor	2 sets	55,000	110,000	
• Development cost for window AC (24,000 BTHU capacity) using rotary compressor and reciprocating compressor	2 sets	55,000	110,000	
Petra KSA				
• Conceptual design including development of new software for HFC-32 and HC-290			38,000	One senior software engineer and two HVAC engineers for developing new software
• Prototypes fabrication	6	70,000	420,000	6 prototypes (40, 70, and 100 kW) for 2 alternative refrigerants
• Prototypes testing	6	50,000	300,000	
• R&D engineer			170,000	6 R&D engineers for study, develop, research, design, test, and approve.
International Expert			30,000	
Technology dissemination workshop	1	10,000	10,000	
Sub-total			1,188,000	
Contingencies (10%)			118,800	

ITEMS	Qty.	Unit Cost (US$)	Total (US$)	Remark
Total			1,306,800	

5. PROPOSED MULTILATERAL FUND GRANT

The proposed grant request is US$ 1,262,800, the calculated cost based on actual situation of all participants.

6. PROJECT IMPLEMENTATION

The project will be implemented under the supervision of the Presidency of Meteorology and Environment. The following proposed schedule will be effective after the proposed MLF grant approved:

Activity	Month after approval											
	1	2	3	4	5	6	7	8	9	10	11	12
Project approval	X											
Project appraisal	X											
Sub-project agreement		X										
Conceptual design for AC system development and planning for testing			X	X								
Specification of AC Prototypes				X								
Procurement of components and fabrication of Prottypes				X	X							
Trials/testing/analysis						X	X	X	X			
Report and Review meeting.										X		
Technology dissemination workshop											X	
Completion report												X

7. PROJECT IMPACT

Not applicable.

8. ANNEXES

ANNEX-1: OORG Review