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EXECUTIVE COMMITTEE OF
THE MULTILATERAL FUND FOR THE
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Montreal, 9-13 May 2016

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

Refrigeration

- Demonstration project at air-conditioning manufacturers to develop windows and packaged air-conditioners using lower-global warming potential refrigerants — World Bank
- Demonstration project on promoting HFO-based low-GWP refrigerants for the air-conditioning sector in high-ambient temperatures — UNIDO

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 APRIL 2016)

HCFCs	1,376.63

B: COUNTRY PROGRAMME SECTORAL DATA (ODP TONNES, 2014, AS OF APRIL 2016)

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):	n/a
ODS to be phased in (ODP tonnes):	n/a
Project duration (months):	16
Initial amount requested (US $):	274,016
Final project costs (US $):	
Incremental capital cost:	87,500
Contingency (10 %):	8,750
Incremental operating cost:	107,097
Total project cost:	203,347
Local ownership (%):	100%
Export component (%):	n/a
Requested grant (US $):	96,250
Cost-effectiveness (US $/kg):	n/a
Implementing agency support cost (US $):	8,663
Total cost of project to Multilateral Fund (US $):	104,913
Status of counterpart funding (Y/N):	Y
Project monitoring milestones included (Y/N):	Y

SECRETARIAT'S RECOMMENDATION	For individual consideration

PROJECT DESCRIPTION

1. At the 75th meeting, UNIDO submitted 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, as originally submitted[1]. Further to a discussion at a contact group that was established to consider all projects to demonstrate low-global warming potential (GWP) technologies submitted to the 75th meeting, the Executive Committee decided to defer consideration of the seven demonstration projects including the HFO spray foam project for Saudi Arabia, to the 76th meeting (decision 75/42).

2. On behalf of the Government of Saudi Arabia, UNIDO has re-submitted to the 76th meeting the above-mentioned demonstration project, at the same level of funding[2].

Project objectives

3. HCFC-141b as a spray foam blowing agent 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. In the case of the use of spray foam in countries with high-ambient temperatures, those high temperatures could substantially affect the foaming process and thus the quality of the foam relative to its use in countries with milder temperatures. On this basis, the project proposes to:

(a) Demonstrate the benefits, applicability and replicability from the use of HFO-1233zd(E) and HFO-1336mzz(Z)[3] co-blown with water in replacement of HCFC-141b in the polyurethane (PU) spray foam sector; and

(b) Assess capital and operating costs reductions compared with other alternatives through the use of an optimized water/physical foam blowing agent, lower foam density and lower thermal conductivity.

Project implementation

4. The project will be implemented in Sham Najd, an enterprise that has five spray foaming units. For the conversion to HFO blowing technology (HFO-1233ze(E) and HFO-1336maam(z)), 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. The enterprise has committed to phase-out 3.02 ODP tonnes of HCFC-141b.

[1] UNEP/OzL.Pro/ExCom/75/64.

[2] Funding for the preparation of this project was approved in the amount of US $30,000, plus agency support costs of US $2,100, on the understanding that its approval did not denote approval of the project or its level of funding when submitted (decision 74/33).

[3] 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.

Project budget

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

Table 1. Proposed project cost

Description	**Cost (US $)**
Spray foaming unit with accessories (hoses, transfer pumps, air-compressor and mixing head)	55,000
Materials for field testing (3 testing) (1,000 m2)	30,000
Foaming product physical property testing in Saudi-Arabian Certified testing house	50,000
Technology transfer, trials and commissioning	40,000
Workshop for information dissemination	20,000
Sub-total	195,000
Contingency	19,500
Total	**214,500**
Total according to cost-effectiveness threshold	274,016
Incremental operating costs	107,097
Total cost	**321,597**

SECRETARIAT'S COMMENTS AND RECOMMENDATION

COMMENTS

6. As suggested by the Secretariat a stability study has been included as part of the demonstration project whereby drums of blowing agent/polyol blend could be stored in a hot, unconditioned warehouse, and then be sprayed under the same conditions as fresher, properly handled blends.

7. The Secretariat noted the proposal to purchase a new spray machine and then decommission a spray machine after the project had been completed. Considering that the spray machine can work with either HCFC-141b-based or HFO-based foam systems, it was agreed that a new spray machine would not be purchased.

8. As suggested by the Secretariat the proposed timeline has been adjusted to complete the field testing, commissioning and trial runs in 16 months and the submission of the project completion report in an additional one or two months.

9. In light of decision 74/21(c), the Secretariat suggested that UNIDO consider possibilities to rationalize the costs of the demonstration project to ensure that a larger number of demonstration projects could be approved under the US $10 million window, either by reducing the scope without compromising the main objective or through other means. Furthermore, it was noted that there was no remaining consumption of HCFC-141b in Saudi Arabia, as all the consumption has been funded under stage I of the HCFC phase-out management plan (HPMP)[4]. Accordingly, the incremental operating costs (US $107,097) would not be eligible for funding. UNIDO carefully considered the Secretariat's comments and reduced the project costs as shown in Table 2, and reflected in the revised project proposal as contained in Annex I to the present document.

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

Table 2. Revised project cost

Description	Cost (US $)
Overall spray foaming unit for testing purpose	6,000
Materials for field testing (3 testing) (1,000 m2)	11,500
Foaming product physical property testing in Saudi-Arabian Certified testing house	50,000
Technology transfer, trials and commissioning	20,000
Total	**87,500**
Contingency	8,750
Grand total	**96,250**

10. The Secretariat also noted that the 3.02 ODP tonnes of HCFC-141b associated with the project cannot be deducted as there was no remaining consumption of HCFC-141b in Saudi Arabia.

Conclusion

11. The demonstration project would increase knowledge in the application of reduced HFO formulations (a low-GWP technology) in a sector (spray foam) with a large number of SMEs where there are identified challenges in the introduction of low-GWP technologies. Optimizing reduced-HFO formulations are expected to reduce operational costs, and investigations on the use of the alternative technologies in countries with high-ambient temperatures, including on the storage of chemicals, would be of demonstration value. The Government of Saudi Arabia has adjusted the overall project cost from US $274,016 (as originally submitted) to US $96,250. Under stage I of the HPMP for Saudi Arabia, funding had already been provided to locally-owned systems houses to customize formulations, including HFO formulations, and Sham Najd is amongst the downstream customers of the systems houses; therefore, there is no more remaining consumption of HCFC-141b eligible for funding. The Secretariat notes that there are three other projects proposing demonstration of HFOs in spray foam or other applications,[5] and that two other projects have been submitted proposing demonstration of low-GWP alternatives in Saudi Arabia.

RECOMMENDATION

12. 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/76/12);

(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 $96,250, plus agency support costs of US $8,663 for UNIDO, in line with decision 72/40; and

(c) Urging the Government of Saudi Arabia and UNIDO to complete the project as planned in 16 months, and submitting a comprehensive final report soon after project completion.

[5] Colombia (UNEP/OzL.Pro/ExCom/76/26), India (UNEP/OzL.Pro/ExCom/76/35) and Thailand (UNEP/OzL.Pro/ExCom/76/50).

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, AS OF APRIL 2016)

HCFCs	1,376.63

B: COUNTRY PROGRAMME SECTORAL DATA (ODP TONNES, 2014, AS OF APRIL 2016)

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 $):	1,306,800
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

Background

13. At the 75th meeting, the World Bank submitted a demonstration project to develop windows and packaged air-conditioners using lower-global-warming-potential (GWP) refrigerant than that of HFC-410A, at the amount of US $1,306,800, plus agency support costs of US $91,476 as originally submitted[6]. This project was prepared without request of preparatory funding from the Multilateral Fund. Further to a discussion at a contact group that was established to consider all projects to demonstrate low-GWP technologies submitted to the 75th meeting, the Executive Committee decided to defer consideration of the seven demonstration projects including the air-conditioning project for Saudi Arabia, to the 76th meeting (decision 75/42).

14. On behalf of the Government of Saudi Arabia, the World Bank has re-submitted to the 76th meeting the above mentioned demonstration project at the same level of funding. The project proposal submitted is contained in Annex II to the present document.

Project objective

15. Saudi Arabia manufactures refrigeration and AC equipment. In 2011, approximately 10,000 metric tonnes (mt) (550 ODP tonnes) of HCFC-22 were used in the manufacturing the full range 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. Approximately 70 per cent of electricity consumption in the country is for the operation of AC systems.

16. Accordingly, 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. 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.

Project implementation

17. The project will be implemented with the assistance of two enterprises: Saudi Factory for Electrical Appliances Co. Ltd. (with annual capacity of 120,000 window AC units), which will develop two sizes of windows AC (18,000 Btu/h and 24,000 Btu/h) based on HFC-32 and HC-290 refrigerants; and Petra Engineering Industries (KSA) Co. Ltd.(with annual capacity of 852 packaged units), which will address the issue of flammability in packaged AC systems that combine chiller and air-handling (40 to 100 kW), using HFC-32 and HC-290 refrigerants.

18. Technical assistance will be provided to design the AC prototypes based on the alternative refrigerants considering charge size and safety measures; specify the main components (i.e., condensers, evaporators, fans and compressors) based on the required efficiency; and build the prototypes taking into consideration availability of components and suppliers in countries with high ambient temperature conditions. Tests to assess the performance of the prototypes will be carried out in Petra's laboratory in accordance with international standards. Performance, quantity of charge, and prices will be compared to those of HCFC-22-based equipment.

Project budget

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

[6] UNEP/OzL.Pro/ExCom/75/64.

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 and reciprocating compressors	2	55,000	110,000
Development for window AC (24,000 Btu/h) using rotary and reciprocating compressors	2	55,000	110,000
Petra KSA			
Design including new software for HFC-32 and HC-290		38,000	38,000
Prototypes fabrication (6 prototypes (40, 70, and 100 kW) for two alternative refrigerants)	6	70,000	420,000
Prototypes testing	6	50,000	300,000
Research and development, 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			**1,188,000**
Contingencies (10%)			118,800
Total cost			**1,306,800**

SECRETARIAT'S COMMENTS AND RECOMMENDATION

COMMENTS

20. The demonstration project re-submitted to the 76th meeting provides a more comprehensive description of the technologies selected, additional justification on the need to improve the know-how on the production of AC using HFC-32 and HC-290 operating in countries with high ambient temperature, and its potential replicability. The Secretariat noted with appreciation the submission by the World Bank of the project proposal without a request for preparatory funds from the Multilateral Fund;

21. For ease of reference, the results of the discussions between the Secretariat and the World Bank on the demonstration projects submitted to the 75th and 76th meetings are summarized below:

(a) Upon request for a clarification on potential overlaps or synergies identified with the work being done by the demonstration project to promote low-GWP alternatives for the AC industry in high-ambient countries in West Asia (PRAHA)[7], the World Bank explained that under the PRAHA project, Petra KSA only received funding for tests and shipment of split AC prototypes, with no funding available for developing prototypes. The technologies being proposed for windows and packaged AC in the demonstration project submitted to the 76th meeting were not tested under the PRAHA project; for window unit, significant development resources are required to reduce refrigerant charge size and implement safety features;

(b) The Secretariat also referred to a similar demonstration project in the AC sector in Saudi Arabia submitted by UNIDO to the 76th meeting, which entails the development, optimization and validation of window and split unit AC with the use of alternative refrigerants, including HC-290. Accordingly, there is an overlap between the projects with regard to the HC-290 technology proposed for window AC units. At the time of issuance of this document, the World Bank was still consulting with the Government of Saudi Arabia on how to resolve this overlap;

[7] Approved at the 69th meeting for implementation by UNEP and UNIDO (UNEP/OzL.Pro/ExCom/69/19).

(c) 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. 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. In addition, the enterprise participated in the PRAHA project;

(d) The project proposal indicates *inter alia* the willingness from the involved enterprises to undertake the demonstration; however, no indication on whether the enterprises would cease to use HCFCs was provided as the project does not include conversions;

(e) With regard to demonstrating the feasibility of commercial production of the prototypes being developed under the demonstration project, the World Bank explained that only after the prototypes meet performance and safety standards the enterprise could decide on commercial manufacturing. Moreover, given the competitive nature of the sector, a coordinated conversion of the sector would be the preferable option; for this reason, Saudi Arabia would need first to develop and modify standards and building codes to allow safe installations of AC based on flammable refrigerants, and technicians should also receive training and certification to work with flammable refrigerants;

(f) The Secretariat explored opportunities for rationalization the cost of the project in line with decision 74/21(c). In addressing this request, the World Bank clarified that the funds requested for "prototype fabrication" (related to packaged units) are related to material for six different prototypes, three different capacities and two types of refrigerants, outsourcing of special components, refrigerants and shipping; while the "development costs" (related to window units), include engineering work to design the prototypes, review of the refrigerant properties, optimization of the system, design of heat exchangers, software development, and laboratory testing . Based on these requirements, funding levels requested could not be rationalized; and

(g) The Secretariat expressed a concern on the need to sign new contracts with the involved enterprises, a process that has proven lengthy in the past. The World Bank indicated that a new streamlined grant project processing cycle will be used for processing a grant agreement for this project. This process would enable the project implementation to start up faster and would allow experience from this project be replicated in stage II of the HPMPs in 2018.

Conclusion

22. The Secretariat considers that this project addresses one of the priority sectors under decision 72/40 and could have a positive impact on the introduction of low-GWP technologies for AC operating in countries with high ambient temperatures, noting, however, that manufacturing of AC units with HFC-32 and HC-290 is already taking place in several countries. The Secretariat considers that the demonstration project component related to Petra KSA established in 2010 is ineligible in light with decisions 60/44 and 74/50; and that the component related to the testing of HC-290 overlaps with the demonstration project submitted by UNIDO for Saudi Arabia. Combined with the demonstration project on spray foam, there are a total of three demonstration project proposals in Saudi Arabia. In its guidance[8], the Executive Committee indicated that projects should also consider regional and geographical distribution.

[8]Paragraph 97(e) of document UNEP/OzL.Pro/ExCom/73/62.

RECOMMENDATION

23. 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 Saudi Arabia, 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/76/12); and

(b) Whether or not to approve the demonstration project at air-conditioning manufacturers to develop windows and packaged air-conditioners using lower-GWP refrigerants in Saudi Arabia.

PROJECT EVALUATION SHEET – NON-MULTI-YEAR PROJECT

Saudi Arabia

PROJECT TITLE(S)	BILATERAL/IMPLEMENTING AGENCY
(a) Demonstration project on promoting HFO-based low-GWP refrigerants for the air-conditioning sector 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 APRIL 2016)

HCFCs	1,376.63

B: COUNTRY PROGRAMME SECTORAL DATA (ODP TONNES, 2014, AS OF APRIL 2016)

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):	2,550 MT (2015)
ODS to be phased out (ODP tonnes):	0
ODS to be phased in (ODP tonnes):	0
Project duration (months):	24
Initial amount requested (US $):	1,690,000
Final project costs (US $):	
Incremental capital cost:	1,570,000*
Contingency (10 %):	n/a
Incremental operating cost:	n/a
Total project cost:	1,570,000*
Local ownership (%):	100
Export component (%):	n/a
Requested grant (US $):	1,570,000*
Cost-effectiveness (US $/kg):	n/a
Implementing agency support cost (US $):	109,900*
Total cost of project to Multilateral Fund (US $):	1,679,900*
Status of counterpart funding (Y/N):	Y
Project monitoring milestones included (Y/N):	Y

*Level of funding would be reduced by US $160,000 plus corresponding agency support costs in case the project "Promoting refrigerant alternatives for high-ambient temperature countries (PRAHA-II)" is approved

SECRETARIAT'S RECOMMENDATION	For individual consideration

PROJECT DESCRIPTION

24. On behalf of the Government of Saudi Arabia, UNIDO as the designated implementing agency has submitted to the 76th meeting a request for funding for a demonstration project on promoting HFO-based low-global warming potential (GWP) refrigerants for the air-conditioning (AC) sector in high-ambient temperatures at the amount of US $1,690,000, plus agency support costs of US $118,300, as originally submitted[9].

25. Alessa, a 100 per cent locally-owned enterprise that participated in the demonstration project to promote low-GWP alternatives for the AC industry in high-ambient countries in West Asia (PRAHA)[10], manufactures window and split-unit air conditioners, as well as some larger systems[11]. In 2015 the enterprise's consumption was approximately 2,550 metric tonnes (mt) of HCFC-22 and it produced approximately 700,000 window units with a capacity between 16 and 20 kBTU/hr (4.7–5.9 kW) and an HCFC-22 a refrigerant charge of 1.75 kg, and approximately 700,000 split units with a capacity between 19 and 22 kBTU/hr (5.6 – 6.4 kW) and a refrigerant charge of approximately 1.9 kg.

26. Through the project, Alessa will manufacture and test pilot model window and split-unit air conditioners with low-GWP HFO/HFC blends[12] as well as R-290. Units will be redesigned and optimized, including meeting energy-efficiency standards. Once the units are developed, a demonstration production run will be made to verify the procedures and workmanship required. Given limitations in the existing manufacturing line to operate with flammable refrigerants, a production line will be setup to simulate production and later converted to a full production line. The converted line will include the necessary safety measures.

<u>Project implementation</u>

27. The demonstration project will address technical challenges associated with the design of AC units with low-GWP alternatives suitable for use in high ambient temperature including:

(a) Temperature glide[13] for some of the proposed HFO blends, which are zeotropic blends[14]. These blends need to be charged accurately in the liquid phase, requiring optimization of the condenser and evaporator, and possibly the use of capillary tubes instead of expansion valves;

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[9] Funding for the preparation of this project was approved in the amount of US $30,000, plus agency support costs of US $2,100, on the understanding that its approval did not denote approval of the project or its level of funding when submitted (decision 74/33).

[10] Approved at the 69th meeting for implementation by UNEP and UNIDO (UNEP/OzL.Pro/ExCom/69/19).

[11] Alessa also manufactures refrigeration equipment, and the foam production of the enterprise was included in stage I. The enterprise converted from HCFC-141b to cyclopentane.

[12] Blends of HFO and HFCs will be tested since such blends can provide comparable volumetric cooling capacity as HCFC-22. Single-component HFOs have lower volumetric cooling capacity relative to HCFC-22, which in turn require a larger swept volume of the compressor, leading to higher costs and larger physical size of the air conditioning unit. It is expected that blends will contain HFC-32, since this increases the volumetric capacity; but may also include other components, such as HFC-152a.

[13] Temperature glide is the temperature difference between the saturated vapour and the saturated liquid temperatures at constant pressure.

[14] A refrigerant blend that exhibits temperature glide is referred to as a zeotropic blend. Single component refrigerants, such as HCFC-22, do not have temperature glide. Refrigerant blends that exhibit a small amount of temperature glide, such as HFC-410A, are referred to as near-azeotropic blends.

(b) The need for accurate charging of the refrigerant, as well as the flammability of the HFO blends, requiring vacuum testing for leak testing; and

(c) Better leak tight connections to minimize leakage during installation, requiring the redesign of the indoor and outdoor units, accommodating for a larger evaporator unit.

28. Three insulated 15-20m^2 cabins will be built to simulate a typical household placement and conduct real-life testing of the manufactured AC units. These cabins will be placed in the vicinity of Alessa for three to six months to allow for testing under the environmental conditions in Saudi Arabia, including sand accumulation on the condensers, hot days with temperatures of 50°C, and cold nights. In parallel, manufactured units will be placed in different regions of Saudi Arabia to test performance under different conditions (e.g., humidity). The cabins will also be used to train service technicians with the new refrigerants and for awareness activities.

29. After the testing phase, an assessment will be made and options selected for production purposes. The expectation is that more than one low-GWP alternative will be selected. All the equipment purchased under the project will be moved to a split-unit production line after project implementation. The project will be implemented in 24 months.

Project budget

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

Table 1. Project cost

Activity	Budget (US $)
Research and development	320,000
Pilot units testing	35,000
Testing real life	30,000
Production line	25,000
Capital investment	350,000
Capital investment – lab	250,000
Capital investment – production line	560,000
Awareness and training	30,000
Project management and technical support	90,000
Total	**1,690,000**

SECRETARIAT'S COMMENTS AND RECOMMENDATION

COMMENTS

31. In reviewing the demonstration project the Secretariat considered the information from the demonstration project on AC manufacturing in Saudi Arabia that was submitted by the World Bank, the proposal for PRAHA-II and the report from PRAHA-I[15]. While an endorsement letter was received at the time when preparation funding was requested at the 74th meeting, the Secretariat has yet to receive a letter of endorsement for the demonstration project and requested UNIDO to provide one.

32. The Secretariat noted that the demonstration project in the AC sector submitted by the World Bank also proposes to develop prototypes of window AC units using HC-290. After further discussions with UNIDO, it was noted that the overlap constituted a minor component of the UNIDO project, and the World Bank and UNIDO agreed to cooperate on this particular component if so requested.

[15] UNEP/OzL.Pro/ExCom/76/10.

33. The Secretariat clarified that after successful implementation of the demonstration project, the equipment would be integrated to convert an existing split-unit production line from HCFC-22 to the selected low-GWP alternative. Alessa agrees that no further funding will be requested to convert the selected line.

34. In light of decision 74/21(c), the Secretariat suggested that UNIDO consider possibilities to rationalize the costs of the demonstration project. Accordingly, UNIDO reduced the project costs from US $1,690,000 to US $1,570,000 as shown in Table 2, and reflected in the revised project proposal as contained in Annex III to the present document.

Table 2. Proposed project cost

Activity	Budget (US $)
Research and development	320,000*
Pilot units testing	35,000
Testing real life	30,000
Production line	25,000
Capital investment	315,000
Capital investment – lab	225,000
Capital investment – production line	500,000
Awareness and training	30,000
Project management and technical support	90,000
Total	**1,570,000***

*Level of funding would be reduced by US $160,000 plus corresponding agency support costs in case the project "Promoting refrigerant alternatives for high ambient temperature countries (PRAHA-II)" is approved

35. The Secretariat further noted the potential synergies with the PRAHA-II proposal. If PRAHA-II were approved by the Executive Committee, it could offer opportunities to further rationalize costs, particularly as it relates to research and development. UNIDO agreed that that rationalization would be possible and proposed that half of the research and development costs (reduction of US $160,000) could be rationalized if PRAHA-II were approved.

Conclusion

36. The project addresses one of the priority sectors under decision 72/40 and could have a positive impact on the introduction of low-GWP technologies for AC, particularly for operating in countries with high ambient temperatures. The project would build on the results from PRAHA-I and would complement PRAHA-II submitted to the 76th meeting if that project is approved. Alessa would use the equipment from the project to convert an existing split-unit production line from HCFC-22 to a low-GWP alternative, and agrees that no further funding will be requested to convert the selected line. The Secretariat considers that the project has a partial overlap related to the testing of HC-290 in window units with the demonstration project submitted by the World Bank for Saudi Arabia. Combined with the demonstration project on spray foam, there are a total of three demonstration project proposals in Saudi Arabia. In its guidance, the Executive Committee indicated that projects should also consider regional and geographical distribution.[16] Furthermore, at the time of the writing of this document, an endorsement letter for this demonstration project has not yet been received.

[16]Paragraph 97(e) of document UNEP/OzL.Pro/ExCom/73/62.

RECOMMENDATION

37. The Executive Committee may wish to consider:

(a) The demonstration project on promoting HFO-based low-GWP refrigerants for the air-conditioning (AC) sector 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/76/12); and

(b) Whether or not to approve the demonstration project on promoting HFO-based low-GWP refrigerants for the AC sector in high-ambient temperatures in Saudi Arabia.

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	18 months
TOTAL PROJECT COST:	
Incremental Capital Cost	US$ 87,500
Contingency	US$ 8,750
Incremental Operating Cost	US$ 107,097 (not requested for funding)
Total Project Cost	US$ 203,347
LOCAL OWNERSHIP	100%
EXPORT COMPONENT	Nil
REQUESTED GRANT	US$ 96,250
COST-EFFECTIVENESS	US$ 7,26/ kg (If IOC is calculated)
IMPLEMENTING AGENCY SUPPORT COST (9.0%)	US$ 8,663
TOTAL COST OF PROJECT TO MULTILATERAL FUND	US$ 104,913
STATUS OF COUNTERPART FUNDING	Yes
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: 24 March 2016

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 recognize 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 will be covered by the relevant component of the HPMP, 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:

A local system house will prepare the formulations with support from UNIDO Foam Sector Expert and HFO supplier.

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).

Total annual foaming operations

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)*

Sector	***HCFCs***	***HFCs***	***HCs***	***HCOs***	***HFOs***	***CO2-based***
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	Low GWP	Moderate foam	Moderate incremental capital

Formate/Methylal	Flammable although blends with polyols may not be flammable	properties - high thermal conductivity-	cost (corrosion protection recommended)

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	+	+	+

<u>IOC comparison between major alternatives</u>

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 a foaming unit for the demonstration project. After completion of the demonstration project, one of the existing foaming units (Gusmer) will be decommissioned.

6.2 Investigate impacts and possible corrective actions due to the high ambient temperature environment to pre-mixed polyol and produced rigid polyurethane spray foam as a product

- It is foreseen that the high ambient temperature environment has effects to following characteristics;
    - The maximum concentration of HFO in the polyol to be used without pressurization of polyol vessel
    - Impact to surfactants and catalysts
    - Impact of water level in the pre-blended polyol formulation to the PU-system reactivity
    - Storage time of polyol drums outdoor at the construction sites
    - Pre-mixed polyol storaging at the System House or Enuser's own storage
    - Surface of the polyurethane as a product
    - Dimensional stability of sprayed foam
    - Evaluate the correct timing for laying the protective coating for surface
    - Evaluate the performance of existing standard coating spray materials' applicability for the new product
- Prepare plan for the corrective actions such as;
    - Formulation by means of correct catalysts at the System House level
    - Formulation with optimum surfactants at the System House level
    - Maximum ambient temperature versus storing chemicals at the construction sites

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	
Overhall Spray foaming unit for testing purpose	6 000
100 meters foaming hoses	
Pneumatically operated transfer pumps	
Air compressor	
Mixing head	
General Works	
Purchase of materials for full scale field testing (3 testing each 350 m2) (1,150 m2)	11 500
High temperature ambient effects investigation at System House and certified laboratory	50 000
Technology transfer, Trials and Commissioning	20 000
Total	87 500
Contingency	8 750
Grand Total	96 250

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 for demonstration purpose, but not for funding request

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)	96,250
Incremental Operating Cost (IOC)	107,097 (not eligible for funding)
Total Cost	**96,250**

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 **US$ 96,250**. Thus, representing of Cost Effectiveness of US$3,44/kg phased out of HCFC-141b. Note that the IOC is not requested and thus the CE is not comparable for ordinary projects. If the CE includes the IOC, then it is USD 96,250 + USD 107,097 = USD 203,347. USD 203,347/28,000 kg = USD 7,26/ kg 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 spray unit overhaul / modification will be done through direct purchase from the existing equipment supplier 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

Please revise the timetable according to the new milestones below

Milestone	2015	2016				2017				2018			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Approval													
Working arrangement													
Preparation of TORs													
Purchase of items, chemicals, bidding & contract award													
Equipment Preparation													
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	Bids prepared and requested	2
3	Contracts awarded	4

Sr. #	Milestone	Months
4	Equipment preparation for testing	4
5	Field testing, commissioning and trial runs	12
6	Submission of project completion report	16

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 window 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 conditions, 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 window and packaged air-conditioning using abovementioned alternatives that are commercially available. These combinations are 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. INTRODUCTION

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 and increasing stock of air-conditioners using high-GWP refrigerant in absence of technology intervention, the Government of Saudi Arabia wishes 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 small single-split and not specifically developed for high-ambient temperature conditions.

2. PROJECT OBJECTIVE

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

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

3. 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. In 2015, Saudi Arabia’s RAC market is approximately 2.3 million units, of which window-type units accounted for 60% and split-type units for 40% of the market.

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.

The 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

4. 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.

4.1 Description of technology

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. Based on thermodynamic properties of the refrigerants, HCFC-22 has better theoretical COP than R-410A and HFC-32. However, HFC-32 refrigerant has a higher volumetric cooling capacity compared with HCFC-22 and has better heat transfer properties. 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 classified by both ISO 817-2014 and ASHRAE Standard 34-2010 to be under a new "A2L" rating for mildly flammable refrigerants with burning velocity less than 10 cm/s. 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/m^3)	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

* Sources: IPCC the fourth assessment report

4.2 Challenges for Countries with High Ambient Temperature

For all refrigerants, including HCFC-22, R-410A, HFC-32, and HC-290, efficiency degraded with increased ambient temperature. Operation of an air-conditioning system at elevated ambient temperatures results in a lower Coefficient of Performance (COP).

Both R-32 and R-290 were included in the Oak Ridge National Laboratory (ORNL) High-Ambient Temperature Evaluation Program for Low-GWP Refrigerants[1] which aims to develop an understanding of the performance of low-GWP refrigerants in small single-split air conditioners under high-ambient temperature conditions. Two small single-split air conditioners, one is designed to operate on R-22 and another on R-410A, were used as base systems to conduct testing at different environmental testing conditions. After soft-optimization, R-290 was tested with R-22 system (9.5 EER) while R-32 was tested

[1] Alternative Refrigerant Evaluation for High-Ambient-Temperature Environments: R-22 and R-410a Alternatives for Mini-Split Air Conditioners, Omar Abdelaziz, et al., Oak Ridge National Laboratory, October 2015

with R-410A system (11.5 EER). Both R-22 and R-410A units have the same cooling capacity of 5.25 kW (18,000 BTU/hr). Compared to R-22 baseline, the test results show that R-290 has 7-8% higher COP but 9-10% lower cooling capacity at hot and extreme ambient testing conditions. R-32 has both COP (5-6%) and cooling capacity (11-13%) higher than R-410A baseline at similar testing conditions.

To further improve the efficiency and capacity, the manufacturers would need to make design modifications such as heat transfer circuiting and proper compressor sizing and selection while addressing performance loss, the increase in compressor discharge temperature, and any safety concerns associated with flammable alternatives.

4.3 Increase in Current Know-how

While there are commercial production of air-conditioners using R-32 and R-290, the products are primarily single-split models and are not designed for countries with high ambient temperature.

Window AC

China and India AC manufacturers are producing small single-split AC based on R-290 with capacity ranging from 2.6 kW to 5.3 kW or between 9,000 BTU/hr and 18,000 BTU/hr. The current limitation on the cooling capacity is due to maximum charge size for flammable refrigerants. For markets in Saudi Arabia and other countries with high ambient temperature, the cooling capacity of typical window AC models range from 18,000 BTU/hr to 24,000 BTU/hr.

While R-32 air-conditioners have been introduced in many countries, all models are small split-type AC units. Based on information from Daikin, it was confirmed that they do not produce any window AC based on R-32.

Packaged AC

Large packaged AC such as those with at 40, 70, and 100 kW cooling capacity being proposed in this demonstration project contain significant amount of refrigerant. This is one of the reasons that major AC manufacturers have not commercially introduced large AC system using flammable refrigerants.

For R-32, available residential AC models have capacity up to 7 kW and light commercial AC models up to 14 kW. There is no available information that there is a commercial production of packaged AC using R-32 as refrigerant. Daikin is still working on the risk analysis of using R-32 refrigerant in VRF multi-split system.

Developing the R-290 and R-32 AC prototypes for high-ambient temperature condition will need to overcome many challenges such as efficiency drop due to elevated temperature, increased compressor discharge temperature (specifically for R-32), and minimizing charge size (specifically for R-290) in order to comply with international standards such as ISO-5149 and applicable national standards and building codes.

4.4 Link to HPMP

Stage I of the HPMP for Saudi Arabia was approved at the 68th ExCom. It focused primarily on the phase-out of HCFC-141b from the foam sector and there was no investment component for the refrigeration and air-conditioning. 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.

Based on Decision 71/42, request for project preparation funding for stage II of Saudi Arabia could be submitted in 2018, given that stage I HPMP was approved for the period 2012 to 2020 to reduce HCFC consumption by 40 per cent of the baseline. Results from this project will be used by Saudi Arabia to formulate their stage II HPMP in the refrigeration and air-conditioning sector.

4.5 Replication

Successful demonstration of low and lower-GWP alternatives will have significant replication effects. HPMP Stage I estimated there are 9 million window and 7 million small single-split units installed in Saudi

Arabia. For rooftop (packaged) and ducted split, there are approximately 0.5 million units with capacity ranging from 6 to 30 tons of refrigeration.

There are an excellent opportunities to replace these installations with low-GWP alternatives. There are also opportunities to export to other countries. For example, U.S. Environmental Protection Agency's (EPA) Significant New Alternatives Policy program recently approved, in 2015, the use of R-290 and R-32 in window AC with maximum design charge size for a 10,000 BTU/hr window AC unit up to 260g of R-290, and 3.47 kg of R-32.

However, since many of these low-GWP alternatives are classified[2] as either class 2L (mildly flammable) or class 3 (flammable) refrigerants, careful considerations must be undertaken to ensure safe installations depending on occupancy category and location of air-conditioning system. During the project implementation, the design and quantity of refrigerant in the air-conditioning system should comply with relevant international standards such as ISO-5149 in order to promote market confidence and acceptability of using flammable refrigerants.

5. 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.

5.1 Saudi Factory for Electrical Appliances Co., Ltd.

Saudi Factory for Electrical Appliances Co. Ltd. was established in 1986 and commenced its production on June 1, 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 BTU/hr and 24,000 BTU/hr) of their window AC with HFC-32 and HC-290.

5.2 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.

5.3 Technical Assistance Component

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

5.3.1 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. The design will consider measures to reduce refrigerant charge size and other safety design measures to reduce risk of using flammable refrigerants.

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[2] ISO-817 and ASHRAE-34

5.3.2 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.

5.3.3 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.

5.4 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.

6. PROJECT BUDGET

6.1 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.

6.2 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.

6.3 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 BTUH capacity) using rotary compressor and	2 sets	55,000	110,000	

ITEMS	Qty.	Unit Cost (US$)	Total (US$)	Remark
reciprocating compressor				
• Development cost for window AC (24,000 BTUH 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[3]	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	
Total			1,306,800	

6.4 Proposed Multilateral Fund Grant

The proposed grant request is US$ 1,306,800, the calculated cost based on actual situation of all participants.

7. PROJECT IMPLEMENTATION PLAN

The project will be implemented under the supervision of the Presidency of Meteorology and Environment.

[3] Average cost per unit across 40, 70, and 100 kW units

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 prototypes				X	X							
Trials/testing/analysis						X	X	X	X			
Report and review meeting.										X		
Technology dissemination workshop											X	
Completion report												X

8. PROJECT IMPACT

Not applicable.

ANNEX-1: OORG Review

REVIEW OF PROJECT PROPOSAL
DEMONSTRATION PROJECT FOR AIR-CONDITIONING MANUFACTURERS IN SAUDI ARABIA TO DEVELOP WINDOW AND PACKAGE AIR CONDITIONERS USING LOWER-GWP REFRIGERANT

INTRODUCTION

The technical objective of this project is to design, build, and optimize a vapor-compression window air conditioner (AC) and a package AC using propane (HC-290, GWP=9) and difluoromethane (HFC-32, GWP=675) by two Saudi Arabia equipment manufacturers. The overall strategic objective of the project is to demonstrate the viability of HC-290 and HFC-32 as refrigerants in the high-ambient temperature region as countries phase-out the use of R-22 (ODS) and need to implement efficient and lower-GWP fluids.

TECHNICAL ASSESSMENT

Currently, window ACs and package ACs predominantly use high–pressure refrigerants such as HCFC-22 (ODS, GWP=1810) and HFC-410A GWP=2090), which are non-flammable. Extensive studies has shown that no non-flammable, single-component fluids exist that can be used as their replacements. The available refrigerant options are limited to mixtures of existing HFCs with hydrofluoro-olefins (HFOs = unsaturated HFCs) or HC-290 and HFC-32, which are proposed in this project. Several HFC/HFO mixtures – both non-flammable and flammable – have been proposed in the literature; they are expected to be expensive due to the cost of HFOs. HC-290 and HFC-32 are readily available, and their thermophysical properties have been very well determined. HC-290 and HFC-32 are the less expensive options but their implementation faces fluid-specific challenges.

HC-290 has excellent thermophysical (thermodynamic and transport) properties. Its critical temperature is 96.7 °C, which makes it a suitable refrigerant for application in ACs even in high-ambient temperature climates. HC-290 is compatible with mineral oil and does not present unknown material compatibility issues; however, designs of compressor and heat exchangers need to be optimized to exploit the refrigerant's thermophysical properties. The significant challenge in implementing of HC-290 is its high flammability, which needs to be addressed for manufacturing, operation, and servicing based on applicable local codes and risk analysis. Because of its high flammability, HC-290 may be precluded from many applications based on the amount of HC-290 in the system, space size, and its intended occupancy.

HFC-32 has also excellent thermophysical properties. Its critical temperature is 78.1 °C. HFC-32 is a very good choice for application in ACs for moderate ambient temperatures, but its performance degrades at high-ambient temperatures faster than that of HC-290 (and HCFC-22), due to its lower critical temperature. Also, HFC-32 experiences high compressor discharge temperatures at elevated ambient temperatures, which may require special design features or appropriate lubricant. The drop in capacity can be addressed by oversizing. The lower flammability rating of HFC-32 is its advantage over HC-290; in colloquial terms HFC-32 is flammable but is rather difficult to ignite. Still, its flammability needs to be addressed for manufacturing, operation, and servicing based on applicable local codes and risk assessments.

The two candidate manufacturers proposed for this project have sufficient technical experience to pursue the use of HC-290 and HFC-32. A new paradigm of them will be flammable refrigerants. Some safety aspects of using flammable refrigerants are stated in the project description although a detailed description of the planned safety measures is not provided due to the description's format. To minimize the possibility of any accidents during execution of this project, it is a recommendation of this reviewer for the contract to implicitly obligate the candidate manufacturers to follow best safety practices. This should include handling of the flammable fluids, equipping their facilities (e.g., testing laboratory) with adequate sensors, and personal training.

The technical plan of the project stipulates the window AC manufacturer and the package unit manufacturer to develop overall designs of their new systems and heat exchangers. They will also develop specifications HC-290 and HFC-32 compressors, which will be procured. In the case of window ACs, the small size of these units should lend itself for using flammable fluids. The proposed package AC will be an indirect system – a chiller combined with an air-handling unit – which will separate the flammable refrigerants from the cooled air. The project includes testing of the built systems in an accredited laboratory in accordance with international standards. This is a workable plan which will provide a good learning path for both manufactures for further product developments.

ENVIRONMENTAL, HEALTH AND SAFETY CONSIDERATIONS

HC-290 (GWP=9, ODP=0) offers a potential of a high energetic efficiency of an air conditioner and presents no environmental concerns. It has short atmospheric life - of the order of two weeks – and its decomposition products are harmless. The safety considerations are related to the HC-290 flammability: the ASHRAE safety designation A3 indicates low toxicity and high flammability (low- toxicity is the lowest toxicity rating; lower flammability limit, LFL=0.038 $kg \cdot m^{-3}$).

HFC-32 (GWP=675, ODP=0) offers a potential of a high energetic efficiency of an air conditioner for moderate climates but suffers performance degradation at extreme high-ambient climates. Its atmospheric life is 5.2 years (short in a comparison to other currently used HFCs). Its decomposition products are well known and do not pose significant environmental risks. The safety considerations are related to its flammability: the ASHRAE safety designation A2L indicates low toxicity and mild flammability (LFL=0.307 $kg \cdot m^{-3}$).

There are no health concerns related to the project.

PROJECT COSTS

The proposed budget items are necessary and are supported.

IMPLEMENTATION TIMEFRAME AND MILESTONES

The proposed project schedule is feasible and is supported.

RECOMMENDATION

I recommend approving this project.

Piotr A. Domanski, PhD

September 21, 2015

Annex III

PROJECT COVER SHEET – DEMONSTRATION INVESTMENT PROJECTS

COUNTRY: Kingdom of Saudi Arabia

PROJECT TITLE

Demonstration Project on Promoting HFO-based Low GWP Refrigerants for Air-conditioning Sector in High Ambient Temperatures

IMPLEMENTING AGENCY

UNIDO

NATIONAL CO-ORDINATING AGENCY: PME

LATEST REPORTED CONSUMPTION DATA FOR ODS ADDRESSED IN PROJECT

A: ARTICLE-7 DATA (ODP TONNES)

HCFCS	1376.63		

CURRENT YEAR BUSINESS PLAN:		**2016**
PROJECT DURATION:	Months	24
PROJECT COSTS:		
Incremental Capital Cost	US$	1.570 000
Incremental Operating Cost	US$	0
Total Project Cost	US$	1.570,000
LOCAL OWNERSHIP:		100%
EXPORT COMPONENT:		n/a
REQUESTED GRANT:	US$	1,570,000
IMPLEMENTING AGENCY SUPPORT COST:	US $ 7%	109,900
TOTAL COST OF PROJECT TO MULTILATERAL FUND:	US $	1,679,900
STATUS OF COUNTERPART FUNDING:		**n/a**
PROJECT MONITORING MILESTONES INCLUDED:		Included

PROJECT SUMMARY

The Kingdom of Saudi Arabia is a Party to the Vienna Convention and the Montreal Protocol. It also ratified the London, Copenhagen and Montreal amendments. The country is fully committed to the phase-out of HCFCs and willing to take the lead in assessing and implementing new HCFC phase-out technologies, in the foam sector and RAC sector. KSA participated with the company Alessa to the PRAHA project and provided samples for testing. KSA and the company are very much interested seeing the initial results to pursue zero ODP and low GWP solutions.

The objective of this project is to introduce low GWP – 0 ODP refrigerants in the production of window and split unit air conditioners. Develop the technology and set the conditions for producing these air conditioners. The project will demonstrate, optimize, validate and disseminate the applicability of the technology and consequently, the reliability of the results to produce window and split unit air-conditioners with low GWP.

IMPACT OF PROJECT ON COUNTRY'S MONTREAL PROTOCOL OBLIGATIONS

This project is a demonstration project aimed to optimize low GWP refrigerants in the RAC sector and will contribute indirectly to the fulfillment of KSA Montreal Protocol obligations. If successfully validated, the optimized technology will contribute to availability of cost-effective options for Hot climate countries that are urgently needed to implement HCFC phase-out, particularly in KSA, GCC and several other countries.

Prepared by: Yuri Sorokin, Igor C. Croiset **Date:** 7 April 2016

Review: O.Nielson

PROJECT OF THE GOVERNMENT OF KINGDOM OF SAUDI ARABIA

LOW GWP AIRCONDITIONS FOR HOT CLIMATES DEMO PROJECT – DEMONSTRATION OF THE DEVELOPMENT OF THE USE OF LOW GWP REFRIGERANTS IN THE PRODUCTION OF WINDOW AND SPLIT UNT AIRCONDITIONERS - CONVERSION FROM HCFC-22 IN THE MANUFACTURE OF WINDOW AND SPLIT UNIT AIRCONDITIONERS AT ALESSA FOR REFRIGERATION AND AIR CONDITIONG CO. (ALESSA).

1.0 PROJECT OBJECTIVE

The objectives of this project are to:

- Development and validation of window and split unit air conditioners with the use of a low GWP refrigerants, e.g. L-20 (R-444B), L-41 (R447A), XL20 (R454C, previously DR-3), R290;
- Testing in laboratory and under real conditions of the different options;
- Demo production setup and validation of the procedures;
- Environmental and energy impact study (Saso requirement);
- Production of units and testing at customers;
- Training of service technicians and setting up curricula as well as documentation;
- Final reporting and workshop.

The project will therefore substantially contribute to the HCFC phase-out plan in the manufacture of window and split unit air conditioners in KSA and immediate surrounding countries of GCC, as planned under the agreement of KSA with the MLF.

2.0 BACKGROUND AND JUSTIFICATION

In the year 2007, Parties to the Montreal Protocol agreed to accelerate the phase-out of the hydrochlorofluorocarbons (HCFCs) because their increase in global consumption and taking into consideration the substantive climate benefits generated from their phase-out.

In the following years, Parties operating under the Montreal Protocol's Article 5 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).

To facilitate a smooth transition to ODS alternatives with low global warming potential (GWP), the Executive Committee in decision 72/40 agreed to consider proposals for demonstration projects for additional low-GWP alternatives and invited bilateral and implementing agencies to submit demonstration project proposals for the conversion of HCFCs to low-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.

Alessa participated in the PRAHA project and produced and shipped for testing Window and split units with the provided low GWP refrigerants. The units have been tested and the results are promising but still need optimization for future commercial purposes.

3.0 PROJECT DESCRIPTION

The use of alternative refrigerants has proven in most climatic regions and the first step was made with the PRAHA project. Alessa received compressors and refrigerants for introducing them in their existing R22 units. It was clear from the beginning that Alessa did not have the time, sufficient data of the refrigerants to optimize the refrigeration circuits and components. The plan was also to test R290 but due to time Alessa wasn’t able to implement the tests. The results of the PRAHA project however showed that this is also a candidate and Alessa wishes to have all the options open. The units which were produced were also tested in Alessa and the performance is at this stage not sufficient for commercialization, EER efficiency needs improvement. Note that R410A is not the ideal solution and therefore the gap in EER could increase further. The proposed HFO’s are zeotropic blends and need to be charged accurately in liquid phase which requires adaptation of the refrigeration circuitry. The condenser and evaporator will need to be optimized and tests been done to cope with the glide, which is not present with R22 and can be neglected with R410A. The HFO’s present a glide and the use of capillary tubes will need to be evaluated against expansion valves to improve the EER. At the moment inverter models are not commonly marketed in KSA but Alessa sees in this technology future EER improvement.

The objective of this proposal is to demonstrate alternative solutions to HCFC refrigerants with the introduction of low GWP solutions for hot climate countries.

By doing so, the roadmap will be set for the phase out of R22 in KSA and the neighboring region. Servicing capacity and knowledge build up. Standards developed

The project results will be extremely relevant for those beneficiaries to be largely covered under Stage II of HPMP, meaning those companies currently relying largely on pre-blended polyol systems.

Figure 1: production line detail

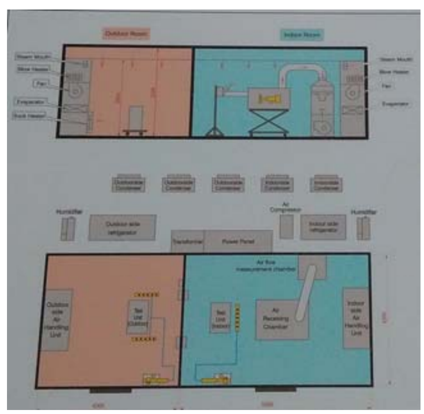

Figure 2: Lab layout

4.0 METHODOLOGY DESCRIPTION

There is therefore the need for development of the refrigeration system and e.g. with DR-3 (commercial name Opteon XL20) already thermodynamic data is available as well as R290. Nevertheless, also when the thermodynamic data is not yet available the experience gained will substantially simplify the development of the other HFO’s. The differences are not substantial between the HFOs so the first to be developed will serve the others. Several theoretical runs will be made in accordance with available commercial components.

Components research will be done and Pilot models will be manufactured and tested. In this regard the existing laboratory will need to be replaced with a calometric type instead of the psychrometric existing lab. Alessa has 3 of these labs in the laboratory and other 2 in the production. A particular item will be the condenser and evaporator in-house build by Alessa. At this stage it is clear that most probable changes in piping diameters will be required. Therefore tooling will be needed; furthermore the testing will need to be done more accurately. State of the art is nowadays vacuum chamber as the existing water bad testing is not accurate. A setup with a vacuum chamber for testing the heat exchanger is part of the equipment to be purchased.

Several work study tours are planned to meet with the refrigerant suppliers and gain more knowledge as well as with component manufacturers. A lot of effort will be needed to remodel the indoor unit as none are available on the market with HFOs. Redesign of the exterior for accommodation of the modified, larger, evaporator unit. Better leakage tight connections for the piping as major leakage occurs in this area during installation.

Efficiency testing and optimization will be a focal issue as the bureau of standards in KSA SASO and the umbrella organization for GCC countries are focused on energy efficiency improvement.

Once the units are developed a demo production run will be made for verification of all the procedures and workmanship required. At this stage still the final selection of the refrigerant of choice will not be made. The existing production is not suitable for this purpose as the quality assurance standards are not sufficient for A2L or A3 refrigerants. Furthermore, the leakage testing due to space constraints is done in a limited manner and the charging unit is not suitable for operating with flammable refrigerants. A production line will be setup to simulate a production and later on to be converted to a full production line. The line will also be suitable for setting up the safety measures regarding leakage of refrigerants and flammability issues which all have independently if they are A2L or A3. A production line transports considerable quantities of refrigerant and although experience in different countries is available it is an issue to be taken into account and measures taken.

The produced units will be exposed to intensive testing and also to a real life exposure testing. This testing will be done by construction three cabins of insulated panels of about 15-20 m2 for simulation of a typical household placement of the unit. These cabins will be placed in the area around Alessa and during a period of 3 to 6 months tested under the environmental conditions of KSA. Features as sand accumulation on the condensers, hot days of 50°C and cold nights can then be simulated. This will be done with the existing and alternative refrigerants. The output of this activity will also be to assess the testing conditions which at this moment still are according to western countries with outdoor temperature of 35°C instead of actual nearly 50°C. The PRAHA project already considered a testing condition at 46°C and showed considerable lower EER.

In parallel units will be placed in different regions of KSA to consider also hot and humid conditions. Alessa is located in Riyadh which has a fairly dry climate but for example Jeddah is hot and humid.

The opportunity of the cabins is also to train service technician with the new refrigerants as well as awareness activities.

After the testing phase an assessment will be made and options selected for production purposes. The expectation will be that there will be more than 1 option considering that Alessa also produces substantial larger models.

All the equipment purchased under the current project will be moved to the actual production lines at Alessa after project implementation.

The objective of this proposal is to demonstrate alternative solutions to HCFC refrigerants with the introduction of low GWP solutions for hot climate countries.

By doing so, the roadmap will be set for the phase out of R22 in KSA and the neighboring region. Servicing capacity and knowledge build up. Standards developed

The project results will be extremely relevant for those beneficiaries to be largely covered under Stage II of HPMP.

5.0 PROJECT COSTS

Cost forecasts for demonstration projects are problematic as these projects are by nature unpredictable.
UNIDO has a good experience in projects regarding conversion of air conditioners conversion to R290 and other refrigerants. The budget has been setup to the best knowledge.

Item	Activity	sub-activity	Budget
1	**R&D**	Analysis	$320.000,00*
		Development condensor and evaporator	
		Capillary tubes assesment	
		Components research	
		Software, inverters development	
		In-door unit modification	
		Out door unit modification	
		Performance tool introduction	
		Safety analysis production line	
		Lab modification	
		Documentation	
		*in case of PRAHA II the cost could be reduced to 160,000	
2	**Pilot units testing**	Pre-assembly and verification	$35.000,00
		production qualification model setup	
		test evaluation and feedback	
3	**Testing real life**	setup of demo sheds	$30.000,00
		setup of measurement equipment	
		testing phase monitoring and data analysis	
4	**Production line**	site preparation, civil works	$25.000,00
		installation of equipment	
		preparation workprocedures	
		personnel instruction	
		production demo units	
5	**Capital investment**	Components pilot models	$315.000,00
		Measurement equipment real life tests	

		Refrigerants	
		Tools, vac pump, gauges, leakage tester, mechanical tools, electrical tester	
6	**Capital investment - Lab**	PU housing	$225.000,00
		safety system	
		temperature control system, ducts, refrigeration unit	
		measurement equipment - calometric	
		ancillary	
7	**Capital investment - Production line**	Pressure testing equipment (not available now)	$500.000,00
		3 x vacuum pumps, vacuum test equipment, bar code reader and controls	
		charging unit for flammable and zeotropic refrigerant	
		Ultrasonic welding	
		Vulcan sealing tools	
		Leakage testing equipment	
		Electrical safety tester and power distribution cabinet	
		Performance test evaluation electronics and controls	
		Final leak test unit	
		Handheld leak test vulcan	
		Safety system, gas sensors 8x, control cabinet, sensors calibration equipment	
		Ventilation and ducting production line and refrigerant feed pumps area	
		Safety cabinet and sensors labs. Each 2 sensors	
		Refrigerant feed pump 2x	
		Refrigerant feed pump valve distribution	
		Refrigerant bottle weighing system	
		Conveyor system	
8	**Awareness and training**	Documentation, 2 x workshops Riyadh, Jeddah	$30.000,00
9	**Projekt management and technical support**	International consultants, monitoring and travels	$90.000,00
		Total	**$1.570.000,00**

6.0 PROJECT IMPLEMENTATION AND MONITORING

The project will be implemented using UNIDO's International Execution Modality. Implementation is targeted as follows **(**measured from project approval)

TASK	MONTH
(a) Project document submitted to beneficiary for commitment	0
(b) Study tours organized	1
(c) Research and Development	2
(d) Bids prepared and requested	12
(e) Contracts Awarded	14
(f) Equipment Delivered	18
(g) Training Testing and Start of trial runs	20
(h) Interim dissemination of the results	22
(i) Final report with full sets of trial data	24

7.0 PROJECT IMPACT

Direct Benefits:
It is essential to replace the R22 units for the Phase out of HCFC and avoid high GWP HFC.

The project employs commercially available and environmentally acceptable technology.

Indirect Benefits:
The project will also boost significantly Montreal Protocol's efforts for solutions for hot climate countries and meet obligations under the HCFC phase-out targets by granting the application of low-GWP latest technologies.

8.0 DISSEMINATION STRATEGY

The dissemination of the different results of the new technology will be done with different tools, in order to reach national companies, regional interested parties (PME, companies, etc.) but also MLF and other implementing agencies and NOUs.

The dissemination Strategy will include a combination of activities such as: workshop, technical brochure, technical and economic data, etc. It will also boost the servicing sector in preparation of new refrigerants.

9.0 PROJECT REPORTING

A final report can be expected 24 months after project start. Interim reporting will follow existing reporting guidelines.

10.0 ANNEXES

Annex-1: List of refrigerants
Annex-2: Details of window and split unit air conditioners
Annex-3: Environmental Assessment

ANNEX-1

LIST OF REFRIGERANTS

Name	Chemical formula	Boiling point at 1.013 bar	Molecular weight	GWP 100 yr	Typology	Classification
R22	CHCLF2	-40.8	86.5		Azeotrope	A1
410a	R32/134a (50/50%pbw)	-51.51	72.6	1900	Near azeotropic	A1
R290	CH3CH2CH3	-42	44.1	5	Azeotrope	A3
R454C (DR-3)	R32/R1234yf (21.5/78.5%)			148	zeotrope	A2L
1233zd(E)	CF3CH=CHCL	18.1	130.5	1	Azeotrope	A2L
1234yf	CF3CF=CH2	-29.4	114	1	Azeotrope	A2L
1234ze(E)	CF3CF=CHF	-19	114	1	Azeotrope	A2L
L-20 (R448b)	R-32/1234ze(E)/152a (45/35/20)		67.8	330	zeotrope	A2L
L-41 (R447A)	R-32/1234ze(E)/600 (68/29/3)		62	460	zeotrope	A2L

(grey)	No data yet available
(yellow)	No data available, Thermodynamic data available

ANNEX-2

DETAILS OF WINDOW AND SPLUT UNIT AIR CONDITIONER

Split unit

Specifications

- 18K & 24K Btu
- Cool & H/C Models
- Anti-Bacterial Filter
- US Bristol compressor
- Super Quiet Operation
- Wireless LCD Remote Control
- Twenty Four (24) Hour Programming
- Cools Even at 55˚c
- Charge 1890 grams/ 410A abt. 22 K BTU at T1 and 19 K BTU at T3

Picture: Indoor unit

Picture: Outdoor unit split unit

Window Unit

Specifications

- 24K BTU/Hr
- Cool Model Only
- Adjustable Four Ways Air Direction (Auto Air Sweep)
- Super Quiet Operation
- Three (3) Fan speed Selection
- Powerful Compressor - withstand up to 55˚C Ambient Temperature
- High Cooling Efficient Model
- SASO Certified - 3 Stars Rating
- High Energy Efficiency Ratio (HEER) -Energy Saving (Low Power Consumption)
- Reciprocating Compressor
- Bristol Compressor
- One-touch Easy to Clean - Anti-Bacterial Filter
- High Efficiency Super Slit Fin Coil
- Charge app. 1720 grams/ R22 22.5 K Btu at T1 and 20 K BTU at T3

Picture : Window unit

ANNEX-3
ENVIRONMENTAL ASSESSMENT

category	Model	Refrigerant	charge	ODP	GWP	Unit gain GWP wrt Baseline (kg charge*GWP)
Window	D024E6H5Y	R22	1720	0.055	1810	3113.2
Window	D024E6H5Y	L20	1000	0	330	-89.40%
Window	D024E6H5Y	DR3 (Opteon XL20)	920	0	148	-95.63%
Window	D024E6H5Y	R290	220	0	5	-99.96%
Split	DS24CE6HY7/DS24FE6HY7	410A	1890	0	1900	3591
Split	DS24CE6HY7/DS24FE6HY7	L41	1630	0	460	-79.12%
Split	DS24CE6HY7/DS24FE6HY7	R290	220	0	5	-99.97%

Unit replacement will provide for the window units a 0 ODP and up to 99% improved GWP. For the split units up to 99% improved GWP. The indicated refrigerants have been trial tested. EER considerations have not been made at this stage as optimization of the equipment is required. Goal is to achieve similar EER as R22 for window units and split units.

Consider that production rate of window and split units is 150 K/year and R22 consumption around 25-27 T/year and 410A 28-30T/year.