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DESK STUDY FOR THE EVALUATION OF DEMONSTRATION PROJECTS FOR LOW-GWP ALTERNATIVES TO HCFCs

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[1] Document UNEP/OzL.Pro/ExCom/90/1

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ABBREVIATIONS

AC	Air-conditioning
CFC	Chlorofluorocarbon
CO_2	Carbon dioxide
CoP	Coefficient of Performance
DME	Dimethyl ether
GWP	Global warming potential
HAT	High ambient temperature
HS	Harmonized System (for classification of goods)
HC	Hydrocarbon
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HFE	Hydrofluoroether
HFO	Hydrofluroolefin
HPMP	HCFC phase-out management plan
IA	Implementing agency
ICC	Incremental capital costs
ICR	Industrial and commercial refrigeration
IOC	Incremental operating costs
KIPs	Kigali HFC Implementation Plans
MF	Methyl formate
MP	Montreal Protocol
MLF	Multilateral Fund for the Implementation of the Montreal Protocol
mt	Metric tonnes
NH_3	Ammonia
NOU	National ozone unit
ODP	Ozone Depleting Potential
ODS	Ozone Depleting Substance
PCR	Project completion report
PU	Polyurethane foam
R&D	Research and development
RAC	Refrigeration and air-conditioning
SDG	Sustainable development goal
SMEO	Senior Monitoring and Evaluation Officer
TEAP	Technology and Economic Assessment Panel
TOR	Terms of reference
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
XPS	Extruded polystyrene foam
WB	The World Bank

EXECUTIVE SUMMARY

Background and scope of study

a. The Executive Committee of the Multilateral Fund (MLF) for the Implementation of the Montreal Protocol has funded 32 demonstration projects to use low-global-warming-potential (GWP) HCFC alternatives (decisions 55/43 and 72/40). These demonstration projects were funded to facilitate the collection of accurate data on incremental capital costs (ICC) and operating costs (IOC) or savings, as well as other data relevant to the application of HCFC alternative technologies.

b. This desk study focuses on issues related to the design and implementation of the demonstration projects, their results, and their influence/impact on the broader adoption of the tested alternative technologies in the relevant sectors. The terms of reference (TOR) defined the following aspects to be addressed in the desk-study: (a) project design; (b) technology choice, adoption and implementation of conversion project; (c) policies and regulations; (d) institutional arrangements and management; (e) monitoring, evaluation and verification; (f) technical assistance and training; (g) financial aspects; (h) communication and dissemination; and (i) sustainability and replicability.

c. The scope and coverage of the desk study is defined by the TOR approved by the Executive Committee (document UNEP/OzL.Pro/ExCom/86/12/Rev.1). The undertaking of the desk study was included as an activity to be achieved during the implementation of the Monitoring and Evaluation work programme for the year 2022 (document UNEP/OzL.Pro/ExCom/88/11/Rev.1).

Methodology

d. The desk research was developed based on a review of project documentation relating to demonstration projects and of information gathered from the implementing agencies (IAs). The study focused on key questions provided in the TOR for the desk study of the evaluation of ‘Demonstration projects for low-GWP alternatives to HCFCs’ approved at the 86th meeting of the Executive Committee. The evaluation matrix is enclosed in Annex IV.

e. The report has been prepared by an independent international consultant with relevant expertise on the technical matter, under the supervision of the Senior Monitoring and Evaluation Officer (SMEO). The MLF Secretariat and the SMEO provided all background documentation needed for the consultant to undertake an in-depth desk review and analysis of the comprehensive project-related documentation.

f. The IAs were consulted and provided additional information by filling out questionnaires and responding to ad hoc interviews when needed. They have also been given the opportunity to provide final factual comments on the advanced draft of the report; they were requested to liaise with bilateral agencies, when applicable, if having implemented on behalf of bilateral agencies. The final draft underwent an internal peer-review process within the Secretariat.

Key findings

g. The demonstration projects, in line with the objectives set out by the Executive Committee’s decision to support these demonstration projects (decisions 55/43 and 71/51(a)), aimed at assessing the use of alternative technologies to HCFCs.

Market penetration and barriers

h. These projects have contributed to identifying types of barriers that would hamper the penetration of the demonstrated low-GWP HCFC-alternative technologies, such as: lack of clarity on how to access the technology and associated costs (i.e., possible licences, royalties or technology transfer fees); technical viability of the technology for specific applications; lack of availability of the alternative substances and required components/equipment on the local market; high operating costs of some alternative technologies; and lack of standards or servicing practices (especially in handling flammable alternatives).

Impact on development of HPMP strategies

i. The desk study found that the experience gained from these demonstration projects was used by countries to develop sector plans and country strategies for HPMPs. This has led to the wider adoption of certain technologies such as methyl formate (MF), methylal and carbon dioxide (CO_2) in the polyurethane (PU) foam sector; HFC-32 in air conditioners, ammonia (NH_3)/CO_2 in commercial refrigeration, and KC-6 in the solvent sector.

Limitations in market uptake of specific tested technologies

j. A few technologies (R-290 and HFOs) face challenges related to market acceptability, a lack of relevant safety standards related to flammability, increased costs associated with addressing flammability and safety concerns and commercial availability issues. These challenges may have restricted wider adoption of these technologies, and been, in some cases, a deterrent to the adoption of the demonstrated technology.

Institutional capacity and role of the national ozone units (NOUs)

k. In some cases, weak capacity at the NOU level was identified as an important institutional barrier. There was a lack of bandwidth and technical expertise around important concerns associated with demonstration projects because these initiatives were conceived during the early days of HCFC phase-out management plan (HPMP) preparation and implementation. This finding suggests that assessment of existing capacity at NOUs for the undertaking of demonstration projects should be part of the project design to account for its implications in terms of timeframe and effectiveness of project implementation.

Technological challenges and delays

l. The desk-review analysis of project-related documentation identified the following technology-related challenges as key factors having impacted and/or delayed the projects' implementation: (a) delays in the procurement of equipment or materials; (b) performance issues observed in initial trials that necessitated additional tests for optimization; (c) a lack of proper research and development (R&D) or testing laboratories; (d) concerns about refrigerant charge size and associated safety characteristics related to the flammability of the refrigerants; and (e) lack of local technical expertise.

Project design, risk-assessment and sustainability

m. Activities included in the demonstration projects have been exhaustive and comprehensive and adequately aligned to the objectives intended by the projects. The demonstration projects have also been instrumental in identifying other non-technical issues which need further study or action for the wider adoption of successful technologies. These issues include commercial availability, required safety standards, and energy efficiency gains from the adoption of alternative technologies. The projects, however, were not intended to further explore beyond the technological viability. Additional parameters could be envisaged in future projects' design to further explore risks and sustainability related to technological uptake and market penetration. This could be facilitated by updating the design of project proposal templates to add relevant parameters that were not considered in former design of demonstration projects, including risks of failed trials, follow-up on market uptake and adoption, among others.

Timeframe period for demonstration in project design

n. Projects were expected to be concluded within 18-24 months (an average budgeted timeframe of 19 months) to provide essential insights for inclusion in HPMPs. However, almost all of the demonstration projects have been delayed (average completion time of 37 months). Limited information is available in project documentation to attribute reasons for the delays. Some of the key causes for delays mentioned in project documents include administrative and procurement-related issues. This finding suggests that project design and implementation could be further improved to anticipate potential administrative and procurement obstacles and to account for them at the design phase and the planning of project implementation.

Funding availability

o. There was adequate funding available to demonstrate the initial viability and use of the selected alternative. Co-funding for conversion projects ranged from 13.2 per cent to 86.7 per cent, which was provided by companies where conversion took place. Certain cases were identified in the desk study wherein more tests would have been required to demonstrate the feasibility of alternatives (e.g., HFOs or MF usage in the foam sector), but due to limited funds allocated for the project, these further tests were not conducted.

Gender

p. Most of the projects did not monitor or report on gender issues, and did not provide gender-disaggregated data, as they were designed before the adoption of a gender mainstreaming policy by the Executive Committee at its 84th meeting.

Way forward: Elements for the design of demonstration projects

q. The purpose and the design of demonstration projects could be reviewed and expanded to ensure that they assess not only the technical viability of using a technology but also other issues relevant to their potential adoption in the countries, including market-uptake challenges that products based on alternative technology may face. This incorporation of additional contextual parameters which potentially affect the adoption of a technology would contribute to the provision of a comprehensive techno-commercial feasibility assessment through the implementation of demonstration projects. Detailed knowledge of technology-market issues would aid countries in developing more effective HCFC and HFC reduction strategies.

r. Administrative and procurement issues could possibly be part of a detailed preliminary assessment at the design stage. Such an assessment could help identify potential bottlenecks or obstacles to be considered in defining project duration and expected date of completion. Ad hoc mechanisms for a more agile process to shorten the period between project approval date and project initiation for demonstration projects could help further their implementation and collect results within a useful period for the benefit of all stakeholders and decision-makers.

s. By their very nature, demonstration projects can encounter, during their implementation, unforeseen elements, such as initial trials failing to meet performance requirements. Conditional funding, as contingency plans under clearly defined specific conditions, for additional time and resources, when relevant, could help completing otherwise inconclusive testing. This is not the current funding practice, but it could be envisaged as a means to strengthen the usefulness of the demonstration projects. In allowing some controlled flexibility through a larger contingency budget line or agreeing on a compromise with the enterprises to cover optimization, or a combination of options, the Executive Committee could count with additional instruments to potentially increase the likelihood of results emanating from their support to demonstration projects.

t. Given the lack of technical know-how in the country/region because of limited use of alternatives, the projects should extensively engage with technical experts and competent technical institutes to provide required technical support.

u. Future demonstration projects that would support the Kigali HFC Implementation Plans (KIPs) could also include in their design specific elements to support NOUs and other relevant government agencies in acquiring and developing a technical understanding for various alternatives. These projects could also include cross-cutting issues involving energy efficiency and safety standards, which could be featured in communication and knowledge dissemination through awareness-raising programmes among key stakeholders. These contextual elements, beyond the mere technological testing, would pave the way for a stronger involvement of relevant stakeholders in developing regulatory measures and standards, or to promote market adoption of alternatives, thus increasing the sustainability of the project results beyond its completion.

v. The design of the demonstration projects did not include industry associations as stakeholders but rather individual companies. Industry associations should be included in the design of future demonstration projects as their active involvement would contribute to the adoption and the sustainability of the demonstrated technologies. They would also participate in communication and dissemination activities to foster replicability and broader adoption of those technologies.

w. The reporting tools available to learn lessons from projects’ implementation, in particular progress reports and project completion reports (PCRs), were not used to their full potential. These report templates must capture all required project attributes, including the achievement of project objectives, delays, and lessons learned, so that the insights from these projects can be passed on to future demonstration projects. IAs and NOUs should ensure that the reported information is complete and relevant. The accuracy in reporting information is instrumental to ensure the impact measurement and to inform decision-makers in the future when selecting alternative technologies. The SMEO could contribute to update the PCR templates, assessing whether specific issues should be added in the reporting process to better benefit from the learning emanating from the demonstration projects.

x. In some demonstration projects, workshops for the dissemination of the results were included. However, the project design did not include an assessment of the initial level of technical understanding of the companies’ employees. In order to measure the effectiveness of training programmes, project design should include indicators in the project’s results framework to define the baseline of technical understanding on the part of the target audience (baseline) to measure improvement after implementation. This would provide information on the extent to which new capacities have been built within the country and the specific sectors covered by the project, mostly in the servicing sector.

y. For future demonstration projects, the communication and dissemination plan should include a regular communication protocol wherein interim findings emanating from demonstration projects are shared with relevant stakeholders, during the implementation phase, without waiting to share information only when the project has concluded. This would facilitate rolling adjustments that could bring improvements in implementation and increase the likelihood of a successful demonstration.

z. The demonstration projects have not actively tracked impact on gender or any other cross-cutting issue as a part of the project results framework. Gender mainstreaming is now included in the Fund policies and as such this dimension should be tracked in project design, and included in project implementation, measured through well-defined SMART indicators, aligned to the Fund guidance to report on gender mainstreaming.

DESK STUDY FOR THE EVALUATION OF DEMONSTRATION PROJECTS FOR LOW-GWP ALTERNATIVES TO HCFCs

I. Introduction

1. The 19th Meeting of the Parties to the Montreal Protocol decided to accelerate the phase-out of HCFCs because of the increase in their global consumption and the substantive climate benefits generated from their phase-out.

2. At its 55th meeting, the Executive Committee invited bilateral and implementing agencies to prepare and submit demonstration project proposals to the Secretariat for different HCFC uses (decision 55/43). These demonstration projects were designed to facilitate the collection of accurate data on ICC and IOC or savings, as well as other data relevant to the application of the technologies.

3. At its 72nd meeting, the Executive Committee considered document UNEP/OzL.Pro/ExCom/72/40, "Overview of approved HCFC demonstration projects and options for additional projects to demonstrate climate-friendly and energy-efficient alternative technologies to HCFCs (decision 71/51(a))." To facilitate a smooth transition to ODS alternatives with low-GWP technology options, the Executive Committee, in its 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.[2]

Objectives of the desk study

4. At its 86th meeting,[3] the Executive Committee approved the TOR for the desk study of the 'Evaluation of demonstration projects for low-GWP alternatives to HCFCs.' The desk study focuses on issues related to the design and implementation of the projects, as well as their results, their influence/impact in a wider adoption of the demonstrated technologies in the relevant sectors, and their sustainability and replicability. The study assesses whether the project design and the technologies adopted in the projects, could be applied to other projects with similar applications, in activities associated to HFC phase-down.

5. Findings from the desk study have also been used to update Annexes II and III of the document "Overview of approved HCFC demonstration projects and options for additional projects to demonstrate climate-friendly and energy-efficient alternative technologies to HCFCs (decision 71/51(a))."[4] The updated information can be found in Annexes II and III of the present report.

Scope and methodology

6. The desk study was conducted between February and May 2022, including the quality assurance process for the stakeholders to review the final draft. It was developed through an in-depth review of the existing documentation. The SMEO and the Secretariat shared the project-related documentation with the independent expert consultant. He circulated a brief questionnaire to the IAs,[5] followed by telephone interviews with a few of them, to complement the desk review preliminary findings. The SMEO provided guidance and supervision to the consultant and interacted with the IAs and the Secretariat officials to verify factual information.

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[2] Only two bilateral agencies are included in the list of 32 approved demonstration projects. Implementing agencies which have implemented on their behalf were requested to liaise with bilateral agencies, when applicable, in reviewing the draft report for comments.

[3] UNEP/OzL.Pro/ExCom/86/12/Rev.1.

[4] UNEP/OzL.Pro/ExCom/72/40.

[5] UNDP, UNEP, UNIDO and the World Bank; they all responded to the questionnaire.

7. Most of the projects reviewed in this desk study concluded before 2018 (some as early as 2010).[6] Since then, many technology and market-related advancements may have occurred, resulting in the information available for the desk study not fully reflecting the current situation regarding the adoption of technologies. The consultant relied on consultations with IAs and the review of additional recent MLF documents providing a sectoral understanding of the technologies adopted (the list of documents reviewed is included in Annex V).

8. A concern identified throughout this analysis is that many PCRs for demonstration projects were incomplete. Although final project reports typically include technical and financial aspects of the project, other elements related to project design and implementation (achievement of objectives at the activity and impact levels, causes and mitigation actions taken for delays, details on co-funding modalities, etc.) that are normally included in PCRs are not available. This makes evaluating various areas of project design and implementation difficult.

9. The desk study covers the specific questions listed in the TOR for critical aspects, namely: project objectives and design; technology choice, adoption and implementation of conversion project; policies and regulations; institutional arrangements and management; monitoring and evaluation/verification; technical assistance and training; financial aspects; communication and dissemination; and sustainability and replicability. The results of the evaluation are presented below in alignment with the above-mentioned substantive areas.[7]

10. The SMEO shared the advanced draft for comments with the IAs and requested them to liaise, when applicable, with bilateral agencies on behalf of which the IAs have implemented the demonstration projects, should they have any comments to be considered. The SMEO consolidated the final draft in close interaction with the consultant and the Secretariat, providing quality assurance through internal peer-review process.

II. Results of the desk study evaluation

11. Further to the adoption of decisions 55/43 and 72/40, 32 demonstration projects were approved in the following HCFC consuming sectors: polyurethane (PU) foam (baseline technology: HCFC-141b); extruded polystyrene (XPS) foam (baseline technology: HCFC-22/HCFC-142b); air-conditioning (AC) (baseline technology: HCFC-22); industrial and commercial refrigeration (ICR) (baseline technology: HCFC-22); solvent (baseline technology: HCFC-141b); and refrigeration and air-conditioning (RAC) servicing (baseline technology: HCFC-22).

12. Out of the 32 projects approved (93.13 ODP tonnes reduction potential), 30 have been completed. Final reports for these projects were submitted to the Executive Committee. The demonstration project for 'the introduction of trans-critical CO_2 refrigeration technology for supermarkets,' initially conceptualised to include Argentina and Tunisia, was partially completed due to the cancellation of the sub-component for Tunisia.[8] One project initially approved for Kuwait was cancelled and one for the Kingdom of Saudi Arabia is still ongoing but expected to be formally completed in 2022.

13. These projects represent a variety of technology choices that have been tested in different HCFC-consuming sectors. Table 1 presents an overview of the demonstration projects that were approved, including the demonstrated technologies and the regional coverage.

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[6] See list of approved projects in Annex I.

[7] Annex IV presents the evaluation matrix in which evaluation questions have been clustered to address the different issues covered by the TOR.

[8] As reported UNEP/OzL.Pro/ExCom/82/20, para. 157, despite best efforts by the NOU and UNIDO, the identified beneficiary decided not to proceed with the project due to the required cost-share.

Table 1: Overview of approved demonstration projects by sector

	PU foam	**XPS foam**	**AC**	**ICR**	**Solvent**	**RAC servicing**	**Total**
Number of projects	13	2	8	6	1	2	32
Total cost (US \$)[9]	6,214,084	2,873,051	12,392,580	9,367,232	371,989	936,600	32,155,536
Expected ODP reduction potential (ODP tonnes)	23.28	12.3	20.19	34.30	3.06	-	93.13
Technologies demonstrated	Methyl formate Methylal Pre-blended HCs Supercritical CO_2 HFO-1233zd(E) and HFO-1336mzz(Z) with CO_2	HFO-1234ze/ DME CO_2/methyl formate	HFC-32 and R-290 HFOs	NH_3/CO_2 R-290 R-448A	Iso-paraffin and siloxane (KC-6)	R-290 HFC-32	
Regional distribution							
Africa	Egypt (2), Morocco, South Africa					Global	5
Asia and the Pacific	China (2), Saudi Arabia, Thailand	China	China (3), Saudi Arabia (2), Kuwait, Regional (2)	China (2), Maldives	China		17
Europe and Central Asia		Turkey				Regional	2
Latin America and the Caribbean	Brazil (2), Colombia (2), Mexico		Colombia	Costa Rica, Argentina			8

Source: Own elaboration based on the desk review

Demonstration projects' objectives and design

14. Countries identified demonstration projects with support from IAs and technical experts to demonstrate the use of alternative technology options to HCFCs. In cases where the project entailed the conversion of a manufacturing line or end-use equipment, there was active participation by the beneficiary organizations, including manufacturing plants, system houses, technical institutes and end-users.

15. Industry associations played a limited role in the design phase of demonstration projects, as formal industry associations did not exist in many countries at the time of project design. Also, many of the projects were planned directly with specific companies in the sector. Hence, there is little mention of the role played by industry associations in project-related documentation.

16. These projects were identified during the initial phase of HCFC phase-out (the first set of projects before HPMP stage I and others before HPMP stage II). The demonstration projects were conceived to inform sectors, countries and regions about HCFC alternative options that could be adopted to meet HCFC

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[9] Including co-funding values provided in PCRs.

phase-out goals, at a time when those alternative technologies had limited availability and usage in developing countries.

17. The desk study has identified a number of factors that would hinder the widespread adoption of the demonstrated technologies, such as: unclear grasp of their technological or commercial viability; difficult access to the technology, costs related to its adoption (i.e., possible licences, royalties, technology transfer fees or operating costs), lack of technical know-how and safety issues linked to the handling of some of the flammable alternatives.[10]

18. Demonstration projects were critical for determining the technical feasibility of low-GWP HCFC alternatives in Article 5 countries and estimating incremental capital and operating costs. Thus, it can be said that the projects achieved the expected objectives in alignment with the goals of the Executive Committee's decision in funding these demonstration projects (decisions 55/43 and 71/51(a)).

19. These projects generated the technical knowledge and confidence to work with the demonstrated alternatives. Information on technology feasibility and cost assessment also helped the governments, NOUs, IAs and sectors decide on the next stage of HCFC phase-out planning. In countries/regions where successful demonstrations were conducted and where the technologies were commercially available (methylal, MF, KC-6, and HFC-32), those alternatives were widely adopted as part of the HPMPs.

20. Broadly, two types of demonstration projects were funded, one involving changes in the production line or existing equipment to use new substances on an ongoing basis (Table 2). Another was technical assistance projects that included: testing technology by creating prototypes (e.g., air conditioners based on HFC-32 or R-290), or by conducting trials (e.g., formulations using low-GWP blowing agents in the foam sector) to assess the technology's feasibility as an HCFC alternative; or servicing sector projects. In the second category of projects, no manufacturing line redesign and installation occurred.

Table 2: Key changes carried out in manufacturing-line equipment redesign and installation

Sector	**Key changes**
PU foam	Retrofitting of foam dispenser, storage, and transportation of blowing agents, retrofitting of spray machines and safety equipment.
XPS foam	Original extrusion foaming line was retrofitted to use co-blowing systems comprising of CO_2 and MF, and production plant's ventilation and fire safety systems were updated.
AC	For R-290 and HFC-32 refrigerants, the manufacturing process required modifications in the assembly line and the installation of safety equipment like safety valves, exhaust systems, leak detection tools, alarm systems, etc. Final product design required changes in the configuration of the product components, including heat exchanger and compressor. Compressors required changes in design to minimise the vapour pressure. Additional tools were required for testing.
ICR	For NH_3/CO_2-based systems, the manufacturing process required modifications in the assembly line and installation of safety equipment. Product required changes in the configuration of the product components, including compressor, high-pressure vessels to operate with CO_2 and new cooling systems for cascade technology. Additional tools were required for testing. For R-290 and HFC-32 systems, assembly line redesign and installation of safety equipment, modifications in metal structure of condensing units. Use of R448A in the fisheries sector was a drop-in alternative and hence no retrofitting was required.
Solvent	Production-line equipment redesign and installation, including adjustment to the silicification tooling cleaning lines and process changes to the needle assembly line. Workshop modifications, including installation of safety equipment and adjustments to the production process to address the flammability of KC-6.

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[10] This desk study does not cover the current situation with regard to the continued existence of these barriers as the follow-up was not included in the concept of demo projects and thus not reported in project-related documentation.

Sector	Key changes
RAC servicing	Providing servicing equipment, leak detection, testing instruments and prototypes of equipment based on different refrigerants for testing purposes.

Source: Own elaboration based on desk review

21. In general, projects included the following activities: preparatory phase, product redesign and development, testing and analysis, installation, technical assistance and knowledge dissemination. The purpose of these projects was to assess technical feasibility along with ICC and IOC. In this regard, the desk study confirms that the project activities have adequately covered the key objectives of demonstration projects.

22. Almost all the projects witnessed delays, as against the average 19-month planned completion period, they took nearly 37 months (average) to complete (Table 3). Only 14 projects provided some information regarding the reasons for delays in the PCRs. Even in these cases, the information was too vague to consolidate a meaningful analysis on the recurrent or systemic reasons for delays. Furthermore, the project-related reporting documents did neither inform about market take-up nor on the continued use of demonstrated technologies of the converted lines, after project completion.

Table 3. Sector-wise project completion duration and delays

Sector	Planned completion time in months (average)	Actual completion time in months (average)	Average delay in project completion in months
Foam	15.0	36.5	21.5
AC	22.5	41.5	19.0
ICR	20.8	33.2	12.4
Solvent	18.0	36.0	18.0
RAC servicing	30.0	40.5	10.5

Source: Own elaboration based on desk review

23. Reasons for longer than expected time of completion cited in project documentation include administrative delays (e.g., the length of time taken between project approval and the allocation of funding for implementation of the project, delays in the signing of agreements with beneficiaries and technology providers), procurement issues and technical issues. A few projects have also reported delays due to other reasons, including a period of political uncertainty in some countries, changes in the NOU with resulting vacancies and force majeure, including hurricanes. The desk review and interviews with IAs suggest that it can take three to six months from project approval to being able to actually launch the project, due to the above-mentioned variety of reasons.

24. Procurement-related issues include delays in customs clearance of imported components and substances, longer-than-planned delivery timelines, delays in finding the right contractors and delays in confirming equipment specifications. These procurement and administrative reasons for project delays seem to indicate that there is room for improvement in project design and implementation to reduce these delays, anticipating the time needed to set-up the conditions to effectively start and implement the project.

25. The IAs informed that they provided periodic updates to countries and shared interim findings at times with the MLF Secretariat and the Executive Committee for these projects. In this way, despite delays, important lessons learned were made available to decision-makers while devising HCFC phase-out plans.

26. As part of the lessons learned from these demonstration projects, ten projects referred explicitly to energy efficiency as a relevant parameter for the selection of the demonstrated technology.[11] Other projects provided only limited information on how energy efficiency or compliance with existing local or

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[11] These projects were four AC sector projects in China, ICR sector project in Costa Rica, fisheries sector project in Maldives and two AC sector projects in Saudi Arabia, PRAHA I and II.

international energy efficiency standards were considered during the project design and implementation stages.

27. Several of the technology options (i.e., R-290, HFC-32 and methylal) are flammable or have safety issues, and their usage requires compliance with relevant safety standards. Project design included an assessment of applicable local or international standards. Key safety practices when using such technology options were evaluated during the project implementation phase and lessons learned were included in final project reports.

28. The projects were designed before the adoption of a gender policy in the MLF. Thus, the inclusion of the gender dimension was not mandatory in the project design. Therefore, gender issues were not considered formally in the demonstration projects and hence no impacts are documented.

29. With the benefit of hindsight, inclusion in demonstration projects of the following elements may also be considered:

(a) *Technical viability and sustainability*: The projects were able to demonstrate technical viability and collect the required financial information (ICCs and IOCs) during the implementation phase. However, there was also a need to do follow-up monitoring of projects over a 12- to 18-month period post-completion to assess how the final product fared in actual conditions, how market acceptability issues evolved and what transpired with regard to the commercial availability of technologies. Sustainability of achievements is an instrumental dimension which should be given attention in the design phase of the demonstration projects to factor in verification of impact beyond the completion date;

(b) *Assessment of market acceptability*: Many of the tested technologies are flammable (like R-290), even though systems based on these options are technically feasible. Such technologies are not yet sold extensively due to market acceptability issues on the part of beneficiaries. Demonstration projects could therefore also assess the market acceptability issue;

(c) *Safety issues and adoption of international standards*: Concerning the safety and environmental requirements necessary for handling flammable alternatives, adoption of these alternative technologies may require the update of national frameworks, possibly aligned to existing international standards. Demonstration projects could provide detailed information on such issues taking account of the context of each country and region; and

(d) *Commercial availability and affordability of technologies*: HFOs were tested in various sectors, including foam and AC. However, their uptake has been limited due to lack of commercial availability at acceptable cost levels. An assessment of commercial availability in the country, as well as market access entry barriers, is crucial to assess the likelihood of a technology to be adopted after its demonstration.

Technology choice, adoption and implementation of conversion projects

30. Technology options were mostly pre-decided in the project proposals based on preliminary assessments. Comparisons with other potential options were included in the project proposals which were submitted for the consideration of and approval by the Executive Committee. These options were selected based on the technical characteristics, capital and operating costs, environmental benefits (ODP and GHG reduction), ease of operations and availability considerations. Key technical criteria for technology selection during the design stage varied by sub-sector (see Table 4).

Table 4. Technical criteria for technology selection during the project design stage

Sub-sector	**Technical characteristics**
Non-insulation foam	Friability, surface adhesion, density, appearance, flammability issues, dimensional stability
Insulation foam	Thermal conductivity, compression strength, dimensional stability and friability
Residential AC	Thermo-physical properties of refrigerant, coefficient of performance (CoP), energy efficiency, compliance with safety standards to deal with flammability issues
ICR sector	Cooling performance, operating pressure of refrigerant, toxicity associated with NH_3
Solvent sector	Boiling point, volatility, chemical stability and silicification performance

Source: Own elaboration based on desk review.

31. Because the goal of these projects was to demonstrate technologies that were not widely used in the market, it can be said that the evaluation of local and international standards for health, safety and the environment, after-sales servicing requirements and conditions, energy efficiency, and market acceptability, were secondary issues that were explored during project implementation but not developed during the project design phase.

32. Broad estimates were provided regarding capital costs. However, cost effectiveness was not estimated in project proposals but rather in final project reports. The ICC and IOC for alternative technologies were estimated using actual cost information obtained during project implementation. Cost information is generally provided in the PCRs and final project reports. IOC were estimated based on the difference between the operating costs or savings for HCFC and alternative technologies.[12]

33. A review of project documentation shows that the main technology-related challenges that impacted the projects included: delays in procuring tools, equipment or material; performance issues witnessed in initial trials (e.g., in the foam sector, initial formulations did not obtain required insulation values or densities requiring further trials), which then required additional tests for optimization; lack of proper R&D or laboratories for testing (e.g., methylal as blowing agent in the manufacture of PU foams in Brazil); concerns over the refrigerant charge size and associated safety characteristics related to the flammability of the refrigerants; and lack of local technical understanding to handle new substances.

34. These challenges were mitigated by conducting additional trials/tests, bringing in experts to provide necessary technical know-how, and arranging alternate testing facilities in cases where the required R&D facilities were unavailable at the beneficiary's end. For future demonstration projects, a more detailed preliminary assessment to identify these issues would help in improving the implementation process. As demonstration projects may entail surprise elements regarding initial trials not meeting performance requirements, contingency budgeting for additional time and resources and detailed planning for conducting further tests could be envisaged under specific conditions, to allow for conclusive results.

35. IAs played an essential role in supporting organizations in conducting technology assessments, including through external technical support and validation. Technology providers also played an active part in technology validations verified by external experts. Organizations assessed performance, safety issues and manufacturing aspects using their own experts and support from external technical experts. External experts also confirmed performance parameters. Many of the companies where technology conversion took place had years of experience manufacturing or using the equipment involved in the conversion. Generally, companies used in-house expertise along with external technical experts for conversion. In some cases, specialized safety experts were also hired.

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[12] Generally, energy savings are not considered in the calculation of IOCs, as it is considered that these gains benefit end-users. Customers may prefer a more energy-efficient product even if the price is higher, but that will not reduce the cost of the equipment. It was also considered difficult to quantify the benefit of the energy efficiency gain in the IOCs calculation.

36. Apart from technology challenges, the market acceptability and financial viability of the technology were also identified as main barriers to the adoption of certain technologies on a large scale. However, it was outside of the scope of these projects to work on these non-technical challenges, given their specific technical objectives and limited resources. HPMPs are better suited to mitigate these challenges for broader adoption of alternative technologies in order to meet HCFC phase-out objectives along with climate benefits.

37. Table 5 lists key challenges and successes for alternative technologies per sector. These findings are based on the analysis of key project documentation, including PCRs and final project reports.[13] Table 5 presents the success stories resulting from demonstration projects, as per the information collected during the desk study. Further relevant information can be found in the document prepared by the Secretariat for this meeting (document UNEP/OzL.Pro/ExCom/89/10), which the consultant has also used to enrich the analysis in Table 5. The most recent data do not necessarily indicate whether alternative technologies were adopted as a result of the demonstration projects but indicate cases in which some of these technologies have been broadly adopted.

Table 5. Technology challenges and successes of demonstration projects

Sector	**Alternative technology**	**Key findings including challenges and successes**
Foam sector		
PU: Flexible and integral skin, rigid insulation foam	Methyl formate, methyl formate/CO_2	Safety issues: Safety equipment is required at systems houses handling pure MF; however, the risk is mitigated at the downstream level user level when using fully formulated MF-based systems within the content limits. Performance issues: Exhibits good performance for high-density foams; however additional optimization is needed for applications that demand lower densities than 35 kg/m^3. Many PU foam companies adopted MF or MF/CO_2 as blowing agents in Brazil, Mexico, Cameroon, Nigeria, Dominican Republic, Jamaica, Egypt, Trinidad and Tobago, India and South Africa as part of the HPMP.
PU: Non-insulation and insulation foam	Methylal	Safety issues: Flammability is an inherent safety risk that could be mitigated drastically at the downstream-user level through pre-blended systems. Performance issues: The results indicated that methylal is better suited for non-insulation foam than insulation foam. Methylal-based thermal insulation foams match HCFC-141b foams within a determined variation range of instability and density but carry a penalty in insulation value of up to 10 per cent. Methylal was adopted by companies in Mexico, Brazil and India.
PU: Rigid foam, water heaters	Cyclopentane, n-pentane	Safety issues: Need safety equipment and extensive training to handle hydrocarbon (HC). Performance issues: Pre-blended cyclopentane systems are sufficiently stable and can be commercially used. Pre-blended normal-pentane (n-pentane) systems are unstable and not recommended for commercial use, except when they are used through a direct-injected system. In general, cyclopentane systems meet most of the performance requirements. Pre-blended cyclopentane systems have been adopted in China, Ecuador, Malaysia, Cyclopentane and n-pentane in Tunisia. In the

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[13] Final reports are internal MLF documents that report on the technical assessment and viability of demonstrated technologies, which are presented to the Executive Committee after finalization of the demonstration projects.

Sector	Alternative technology	Key findings including challenges and successes
		EAP region, the World Bank discussions with industry have also resulted in HC preblended systems being exported.
PU: Spray and discontinuous panels	HFOs	Performance issues: HFO-based formulations met performance requirements during trials. However, additional trials are required to reduce HFO-1233zd(E) in PU foam formulations to address affordability/commercial viability. For discontinuous panels and other rigid foam applications, the moulds should be equipped with temperature controls to ensure good performance. There are several countries, including Argentina, Bahrain, Chile, Colombia, Ecuador, Indonesia, Jordan, Malaysia, Panama, Thailand, Uruguay and Viet Nam, where HFO-based conversion projects are mentioned in document UNEP/OzL.Pro/ExCom/89/10. However, as per inputs received from IAs for this desk study, usage of HFO is still limited due to the high cost of HFOs and commercial availability issues.
PU: Spray foam	Super-critical CO_2	The demonstration project showed that, from a technical point of view, this technology could be successfully applied in Article 5 countries. Supercritical CO_2 technology is a patented technology owned by a non-Article 5 country. Licence fees were assessed as too high by the beneficiary organization in Colombia, hence the enterprise finally decided not to implement this technology option. This licensing issue may be relevant for further adoption of this technology. No project except for the demonstration project in Colombia is mentioned in document UNEP/OzL.Pro/ExCom/89/10.
XPS foam	HFO	For XPS foam, to make such a product commercially acceptable, some optimization of density and surface (pinholes) was required. The trials showed that there is the potential to reduce flammability of the HFO-1234ze/dimethyl ether (DME, a flammable chemical) blend and to improve thermal insulation performance by reducing the amount of DME. Commercial issues: The key challenge facing wide adoption of HFOs is consistent availability and pricing. These were the main commercial issues identified by the demonstration projects which limit usage of HFOs in Article 5 countries.
XPS foam	CO_2/MF	The CO_2 and MF formulation tested can be applied to XPS foam manufacturing given that thermal conductivity, compression strength and limited oxygen index are acceptable. The solubility of MF was of concern, making it relatively difficult to transport and store. At the time of the demonstration projects, the equipment cost and the safety transformation cost for the CO_2 and MF technology were higher than the cost of HCFC technology. As the technology matures, if the cost decreases, it will be possible to use it in SMEs.
Refrigeration and air-conditioning sector		
Commercial refrigeration (supermarkets)	Trans-critical CO_2	The trans-critical CO_2 refrigeration system is technically viable for use in supermarket applications in climate conditions like Argentina, where it was piloted in a supermarket. Based on the PCR, the initial investment for a trans-critical CO_2 refrigeration system is higher than for an HFC-based system due to high pressure requiring stronger piping and better welding during installation; at prices prevailing at that time, the investment for a

Sector	Alternative technology	Key findings including challenges and successes
		similar system using R-404A was approximately 20 per cent lower than a trans-critical CO_2 system, and 10-13 per cent lower if using an HFC/glycol system. However, the electricity consumption of the trans-critical CO_2 system was estimated to be 27.64 per cent lower than the baseline HCFC-22/R-404A system based on measurements over a 11-month period prior to and after conversion in 2017 and 2018.
Industrial and commercial refrigeration, cold storage and freezing applications, commercial/cold rooms	NH_3/CO_2	Demonstration projects have validated the use of NH_3/CO_2 in commercial systems. The toxicity of NH_3 is greatly reduced in NH_3/CO_2 cascade systems when compared to the pure NH_3 refrigeration system. The new system provides lower production costs due to the reduction in electricity consumption (10-20 per cent efficiency gains), fewer maintenance interventions, no purchase of HCFC-22 for topping up the systems due to leaks during operation, and the use of lower-cost natural refrigerants. NH_3/CO_2 systems require more advanced skills and know-how for installers and technicians than HCFC-22-based systems. A wider use of this technology in smaller systems would require a review of the local technicians' capacity to handle NH_3/CO_2 and the type of regulations, standards and codes of practice that would be applicable.
Commercial and residential AC	HFC-32	HFC-32 is flammable, but it is easier to design, market and operate than HC-based systems due to lower overall flammability. It has a lower GWP (675) compared to other HFCs like R-410A (GWP 2088). In demonstration projects, HFC-32-based systems have shown energy efficiency gains compared to other alternatives. The HFC-32 heat pump/chiller cost was also/ higher than the HCFC-22-based product, mainly due to the compressor and electrical components' increased cost. It was expected that large-scale production would reduce the incremental operating expenses of HFC-32-based equipment. In the past few years, HFC-32 based equipment started to be available in countries which benefited from the demo projects either through the local manufacturers that received support from MLF or through importation by international technology providers. Countries including Bangladesh, China, Indonesia, Lebanon, Thailand and Viet Nam have seen increased usage of HFC-32-based ACs.
Residential AC	R-290	The conversion of production lines and the manufacturing of new appliances can be handled safely, despite the flammability of R-290, if appropriate measures are implemented and appropriate tools and equipment are used. Based on the tests conducted, the energy efficiency of R-290-based systems is 5-12 per cent higher than that based on HCFC-22. The main remaining barriers for the full commercialization of R-290 units are the lack of relevant standards allowing for higher charge sizes in ACs, good practices for the use of flammable substances and market acceptability factors. As per input received from the IAs, R-290 usage is currently limited owing to the reasons described above.
Residential AC	HFOs	HFO-based refrigerants provide the required cooling performance. However, consistent availability and pricing are key commercial issues, identified by the demonstration projects, that limit HFO usage in Article 5 countries.

Sector	Alternative technology	Key findings including challenges and successes
Fisheries sector	R-448A	R-448A is a drop-in alternative to HCFC-22 in the fisheries sector. However, it has a high GWP of 1,390. It can meet HCFC phase-out requirements but is not suitable for reducing GHG emissions. MIT consulting team conducted a detailed desk study to review the refrigerants R-448A as potential refrigerants for the demonstration project. However, as per the recommendation from the 80th meeting of the Executive Committee, testing of R-448A was stopped because of its high GWP value; yet there is no other alternative available in A1 category of refrigerants. Evaluations of other technologies are required to find lower-GWP alternatives.
Solvent sector		
Solvent	KC-6	KC-6 also has good environmental performance. KC-6 has a higher boiling point and greater chemical stability than HCFC-141b. This allows easier management of emission reduction and results in less consumption. The demonstration project has contributed to the sector phase-out programme as, based on the result of this demonstration, six enterprises have selected KC-6 as an alternative technology and signed contracts to phase out HCFC-141b consumption.

Source: Own elaboration based on desk review

38. Manufacturing facilities were selected as part of the project design for projects that did not entail the conversion of manufacturing processes. These facilities were used for design and technology development, prototype development and trials. These facilities conducted tests with the help of external experts.

39. Many technologies, including HFOs, supercritical CO_2, KC-6, and MF, were the leading technologies involving intellectual property (IP) rights. There was active participation by IP holders in demonstration projects. With proprietary technology involved, commercial and technical information disclosure is a complex issue. In cases where IP was paid for by MLF funds, detailed information was shared with the relevant stakeholders.

40. However, in cases where IP was paid for by the beneficiary organization, then dissemination of knowledge from such demonstration projects entailed sharing only limited information in public forums so as to preserve proprietary knowledge. In some cases, a method for sharing proprietary information with interested parties was developed, such as sharing project information only upon request, sharing sensitive information only after signing non-disclosure agreements, and enlisting the help of a technology provider for the direct sharing of required data.

Policies and regulations

41. All the conversion projects in this study included an analysis of existing policies in the country to facilitate the implementation of the demonstration projects. While these projects raised the need for changes in safety standards, the development of such standards was not a focus of the demonstration projects.

42. Project documentation mention that the main barrier to the full commercialization of HFC-32 and R-290 units is the lack of appropriate standards. These standards may include safety standards for using flammable refrigerants in household and commercial AC units; limiting the charge size of HC-based refrigerants in AC units; requirements for the transportation of room air-conditioners charged with flammable refrigerants; and technical safety codes for servicing equipment using flammable refrigerants.

Due to a lack of these standards, project-related documents mention that even after completing the conversion, manufacturers were reluctant to market their products. HFC-32-based systems have nonetheless started gaining a significant market share in some countries including China and Thailand in the past few years. However, R-290 use is still limited due to the lack of relevant standards that allow for higher charge sizes in ACs.

43. In certain projects, e.g., in the Colombia R-290 project, technical documents for updating national standards (NTC 6828), based on ISO 5149, were developed, and a support plan was prepared to focus on the end-users and the servicing sector. Similarly, in China, projects identified the need to update safety standards and revise charge-size limitations.

44. The servicing sector project 'Demonstration project on refrigerant quality, containment and introduction of low-GWP alternatives (Eastern Africa and Caribbean regions)' evaluated the impact of regulations and standards on the uptake of the technology in these countries. Stakeholders were trained in the use of refrigerant analyzers, the identification of counterfeit refrigerants and the measurement of the performance of RAC equipment using pure and counterfeit refrigerants. Project-related documents for this project also cite the need for punitive legal action to control the use of fake refrigerants.

Institutional arrangements and management

45. NOUs and IAs played leading roles in managing and coordinating the projects. In most of the projects, external technical experts were also hired. Based on the input received during discussions with IAs during this desk study, a few NOUs played an active role in coordinating various activities related to demonstration projects. At the same time, in other cases, IAs had to play a more hands-on role in coordinating the main aspects of the projects when the NOUs did not have the required capacities. Companies played a very active role in projects that entailed converting the manufacturing process or end-use equipment, in particular in cases of weak technical understanding around critical issues related to the implementation of these demonstration projects.

46. The design of the demonstration projects focused mostly on technology and less on identifying reforms and adjustments required to facilitate technology uptake. This could be better assessed in the design of demonstration projects in the future, through indicators that would assess the technical capacity for the countries to launch the projects, and what preliminary support would be required to ensure successful demonstration.

47. In most projects, industry associations were not involved during the implementation of projects. Some were actively involved during the knowledge dissemination part of the projects. In regional and global projects, coordination committees were also formed with participation from NOUs from different countries, participating organizations and technical experts. These projects also engaged institutions involved in safety standards, energy efficiency standards, testing authorities and technical institutions. However, such engagement also emanated from ongoing HPMPs.

Monitoring and evaluation/verification

48. Government officials checked project milestones with support from IAs and external experts. In the case of conversion projects, verification visits were conducted, which generally included on-the-spot investigations, verification of changes done in the manufacturing process, verification of production data and review of test results. Performance results were verified and included in the final project reports submitted to the MLF.

49. External experts verified retrofitting to ensure that the plant had converted to the selected technology and that old equipment had been discarded or destroyed. However, this was not sufficient to ensure that the technology would be actively used. There could be instances wherein, despite conversion to

a newer technology, the same was not used due to poor market acceptability or lack of technical standards permitting the placement of such products on the market (e.g., use of R-290-based AC units due to safety and market acceptability issues).

50. Project performance was addressed in different project-related documents, such as progress reports, final project reports and PCRs. The progress report template generally includes a narrative explanation of progress made by the project at the time of specific meetings of the Executive Committee. However, the progress report template is generally not filled out in detail for most of the projects, or only limited narrative explanations are provided. This limitation impacted the potential of deeper analysis for the desk study through the use of this document.

51. The PCR is conceived as a reporting format to capture all the relevant information about the project. This includes the achievement of project objectives at the activity level (section 2.1 of PCR) and at the output level (section 2.2 of PCR). However, indicators of achievement are not always well defined. A common feature witnessed during review is that for most of the projects, assessment of performance in both these sections was ‘highly satisfactory’ without a reasonable explanation for the rating. Ideally, activity-related indicators and impact-related indicators should be developed in project proposals, and those same indicators should be tracked in the PCR. Similarly, other sections of the PCR, including delays, problems, and corrective actions taken (section 3.2), lessons learned, highlights and problems (section 5) are also not always filled in with relevant information. One of the potential reasons for inadequate tracking could be lack of guidelines on developing indicators (for both activities and impacts), on how to assess progress using these indicators, and what is expected to be filled in for each section. The SMEO could consider these elements in a future update of PCR templates.

52. Wider adoption at the national or sector level was not monitored in demonstration projects, as monitoring of demonstration projects focused only on project-level milestones. Aspects of technology adoption at the national and sector level are better tracked in the HPMPs and are not related to the objectives of the demonstration projects.

53. The demonstration projects also briefly assessed whether alternative technologies had any adverse health and environmental effects. In some cases, the project documentation referred to positive impacts, including potential health benefits, and an improvement in standards, without providing enough details to be reported in this study.

Technical assistance and training

54. Technical assistance in these projects included assistance for technology transfer, plant operations, training of experts, audits of the facilities, development of product prototypes, storage and transportation, and dealing with final product usage and servicing issues.

55. For several projects, technical experts were hired to provide necessary technical guidance for the selection of alternatives, performance testing, optimization, safety considerations, manufacturing line conversion, etc. Given the limited use of the demonstrated technologies in the country/region, technical experts’ site visits and technical workshops were important to provide technical assistance.

56. In some cases, external laboratories were also used for performance testing. For instance, the application of the HFO-based spray foam in HAT conditions was evaluated by an independent laboratory in Finland and CETEC (certified laboratory for shoe testing in Mexico) was engaged for testing MF-based shoe soles performance in Mexico, Intertek lab was used for PRAHA-I prototype testing, AHRI and OTS Labs were used for PRAHA-II testing and analysis.

57. Similarly, technology providers and technical experts were also involved in certain cases to provide necessary know-how for using alternative substances. Suppliers of blowing agent (i.e., Honeywell and

Chemours) actively provided support to the formulators at system houses for using HFOs, JRAIA were used for building a risk-assessment model in PRAHA-II. ASHRAE, CHEAA, JRAIA were used for capacity building activities.

58. One of the questions for this desk study regarded requirements to obtain a licence to handle and use certain alternatives (such as flammable alternatives). Country-specific trade licences might be required to handle flammable alternatives. However, there was insufficient detailed information in project documentation to assess whether such licences were required.

Financial aspects

59. The actual funds reported as having been used by projects were very similar to the allocated funds for most projects, which leads to the conclusion that adequate funds were allocated. It may be noted that only 40 per cent of the projects provided a detailed cost breakdown in the PCRs. In the remaining projects, a comparison between approved amount and actual costs was provided without details on the type of expenditure, thus limiting the potential analysis for the desk study.

60. A few projects mentioned a lack of funding to conduct further optimization tests, such as HFO-1234ze co-blown with DME (XPS foam sector in Turkey), or MF for the PU foam sector. These projects required additional funds for further optimization or testing. However, initial funding was deemed sufficient for testing the technology's initial viability for these projects, but further work was not funded by the MLF. There could be projects wherein additional work might be required in order to gain a better understanding of technical and commercial issues. In such cases additional funding could be allocated on a case-by-case basis.

61. ICC and IOC were estimated based on final project performance in terms of the actual cost for conversion. In most conversion projects, funds allocated were close to the ICC identified by the projects, showing that funds were adequate. IOC estimation entailed an assessment of additional charges/savings for refrigerants or blowing agents compared to HCFCs.

62. For the projects that entailed manufacturing-line conversion and end-use equipment change, co-funding was obtained. In these projects, co-funding was provided by the beneficiary organization where the conversion project took place. No government co-funding is reported in the PCRs for any demonstration projects. None of the projects mention any major challenges faced in obtaining co-funding as envisaged in the project design or how these challenges were addressed.

63. Normally, counterpart funding was provided for system design, purchase of main equipment, and internal capacity-building activities. In all these cases, funding was provided to cover actual expenditures. The nature of counterpart funding (capital investments, loans, concessional finance, in-kind, etc.) is not clearly evidenced in the project documentation reviewed. In this regard, establishing a minimum required format to collate information about co-funding would be valuable for future studies.

64. Table 6 shows the co-funding value assigned to the projects (source: final project reports).

Table 6. Co-funding availed for demonstration projects

Project	MLF grant (US $)	Co-funding (US $)	Co-funding as a percentage of MLF grant (%)
Demonstration project for ammonia semi-hermetic frequency-convertible screw refrigeration compression units in the industrial and commercial refrigeration industry at Fujian Snowman Co., Ltd. (China)	1,026,815	890,454	86.7

Project	MLF grant (US $)	Co-funding (US $)	Co-funding as a percentage of MLF grant (%)
Demonstration project for conversion from HCFC-22 technology to ammonia/CO_2 technology in the manufacture of two-stage refrigeration systems for cold storage and freezing applications at Yantai Moon Group Co. Ltd. (China)	2,490,936	1,697,694	68.2
Demonstration project for conversion from HCFC-22 technology to HFC-32 technology in the manufacture of commercial air-source chillers/heat pumps at Tsinghua Tong Fang Artificial Environment Co. Ltd. (China)	733,530	96,814	13.2
Demonstration sub-project for conversion of room air-conditioning compressor manufacturing from HCFC-22 to propane at Guangdong Meizhi (China)	1,875,000	1,523,093	81.2
Demonstration sub-project for conversion from HCFC-22 to propane at Midea Room Air-conditioner Manufacturing Company (China)	4,328,495	1,679,777	38.8
Demonstration project at air-conditioning manufacturers to develop window and packaged air-conditioners using lower GWP refrigerants (Saudi Arabia)[14]	513,294	616,000	120.0
Demonstration project at foam system houses in Thailand to formulate pre-blended polyol for spray polyurethane foam applications using low-GWP blowing agents (Thailand)	274,804	45,249	16.5
Demonstration project on the technical and economic advantages of the vacuum assisted injection in discontinuous panel's plant retrofitted from HCFC-141b to pentane (South Africa)	222,200	244,000	109.8
Demonstration of R-290 (propane) as an alternative refrigerant in commercial air-conditioning manufacturing at Industrias Thermotar ltda. (Colombia)	500,000	153,831	30.8
Demonstration project to validate the use of hydrofluoroolefins for discontinuous panels in Article 5 parties through the development of cost-effective formulations (Colombia)	248,353	52,800	21.3
Demonstration of the application of an ammonia/carbon dioxide refrigeration system in replacement of HCFC-22 for the medium-sized producer and retail store at Premezclas Industriales S.A. (Costa Rica)	510,161	449,000	88.0

Source: Own elaboration based on desk review

65. As the key objective of these projects was the technical assessment of alternatives, most of the projects did not have a project component related to the development of policies and regulations needed to introduce successful HCFC alternatives in countries/regions. Only two projects mentioned the development of standards and allocated funding for that activity:

(a) Standards and market availability of quality refrigerants, implemented in six countries of the East African region: US $20,000 allocated for the assessment of national policy frameworks; and

(b) Demonstration of the application of an NH_3/CO_2 refrigeration system in replacement of

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[14] One of the components was the development of window AC prototypes at Saudi Factory for Electrical Appliances Co. Ltd., but the enterprise pulled out of the demonstration project. US $200,000 allocated for this component was returned to the MLF.

HCFC-22 for the medium-sized producer and retail store at Premezclas Industriales S.A., in Cosa Rica: Development of regulation and standards: US $15,000. The final project report does not provide information on work done under this component.

Communication and dissemination

66. All projects included communication and dissemination activities as part of project design and implementation. In general, key modes of communication and dissemination included technical workshops, study tours, product launches, technology exhibitions and booklet distribution. Furthermore, experience gained from these projects has been disseminated by IAs at various national and international conferences and workshops, including during network meetings, webinars, and international conferences. Workshops were generally conducted for technicians involved in plant operations, NOUs, technical experts, end-users, and technology providers.

67. Final project reports included information about technical indicators, the characteristics of final products, cost elements, environmental benefits and potential challenges. Fact sheets were also developed to provide essential information about projects to industry participants. These reports are available to the public through the MLF website.[15] Study tours and training workshops were conducted to facilitate knowledge transfer across organizations. IAs also disseminated successful case studies in various international forums such as network meetings of NOUs, regional conferences and technology exhibitions.

68. Countries used knowledge from demonstration projects to identify potential technologies for HCFC phase-out in their HPMPs. Countries also introduced training programmes for RAC servicing technicians to handle flammable alternatives, which contributed to spearheading the acquired knowledge among relevant stakeholders.

69. A few of the challenges identified in the project documents reviewed with regard to communicating lessons learned from the demonstration projects include: the reluctance of organizations to share competitive information about performance in wider industry forums; the overbroad nature of regional and global programs that sometimes limited the ability to reach relevant audiences given limited resources (time and budget); and the fact that many countries did not have active industry associations, which created a challenge in reaching out to broader industry participants.

70. Regarding communication and dissemination activities, the reported information covers only the modality used (e.g., workshops, study tours), the number of participants (without gender disaggregation) and total budget use. The project documentation did not report on any formal method used to assess the effectiveness and impact of these programmes. This could also be considered for additional indicators in a possible update in reporting on demonstration projects.

Sustainability and replicability

71. Most technologies selected for demonstration projects did not have any significant usage in the country/region at the time of project implementation. These projects aimed to test and demonstrate the viability of technology options in the context of application and region. For example, several projects targeted multiple RAC sector applications in HAT countries with the expectation that viable technology options could be replicated across HAT countries.

72. These projects were expected to inform countries about viable technologies, ICC and IOC, environmental benefits, and challenges related to the adoption of technologies. Communication and knowledge dissemination activities in these projects were designed to educate the industry and regulators

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[15] Available at http://www.multilateralfund.org/Our%20Work/DemonProject/default.aspx.

to promote such proven options. Countries were expected to consider these findings for broader technology adoption as part of HCFC phase-out, when developing sector plans or country strategies.

73. Funding for HPMPs can be used to replicate technologies in sectors where performance has been proven, and no significant commercial issues exist. Based on the success of these projects, methylal, MF, cyclopentane in the foam sector; KC-6 in the solvent sector, NH_3-CO_2 in the commercial sector, trans-critical CO_2 in supermarkets, and HFC-32 in the AC sector have increased in countries where demonstration projects took place, as per information available in the project documentation reviewed and based on input received from IAs.

74. MLF funds were utilised for the development of a country specific project, i.e., ‘Promotion of low-GWP refrigerants for the air-conditioning industry in Egypt.’ This project was developed based on insights and learning from PRAHA project, and it led to the approval of AC sector conversion. This is a positive example of replicability emanating from methodologies developed as part of demonstration projects.

75. The use of technologies including propane, HFOs and supercritical CO_2 were limited due to safety issues, lack of relevant standards, commercial availability, and licensing-fee-related issues, respectively, despite proving technical viability during demonstration projects. Commercial availability and costs (product costs or licensing fees) may be essential factors for other companies in the sector/region when considering whether to switch to such options.

76. The projects using flammable alternatives also highlighted the need for safety standards to handle flammable alternatives, a revision of the limit on refrigerant size (for R-290), and energy efficiency standards as a few enabling regulations which would help in replicating successfully demonstrated technologies. However, development of these standards can be complex and lengthy, and hence were taken up in HPMPs or by relevant energy efficiency authorities in the countries, as it was not in the scope of the demonstration projects to design such actions.

77. In the case of demonstration projects involving the conversion of manufacturing-line or end-use equipment, the beneficiary organizations are expected to run the plant using internal funding sources after initial ICC and IOC support from the MLF. For conversion projects, IOCs are provided after a limited period of operation, which can be considered an incentive for the sustainability of the projects. After the conversion, however, it is believed that only the enterprise’s successful operation will ensure the project’s long-term sustainability, but these factors are outside the purview of the demonstration projects.

78. Only a few projects have provided information on direct GHG reduction and other environmental impacts during the project design phase and in final project reports. It may be noted that the essential purpose of these projects was to demonstrate the viability of potential HCFC alternative options with low GWP. However, actual GHG reduction would only have taken place if the organizations ended up using these technology options after the demonstration projects. No follow-up system was designed to keep informed, after project completion, of the fate of the demonstrated technologies and their market uptake. Causality linkages between uptake of a technology and the implementation of a demo-project could not be assessed ex-post without having defined a results framework for it at the design and implementation phase of the project. This could be considered in the future, if wanting to include this post-completion assessment, as a possible element in the design of project proposals and project reporting templates.

79. Demonstration projects have also aided in the development of technical skills for beneficiaries indirectly. The development of testing facilities for product performance evaluation in the foam and RAC industries, and the development by systems houses of in-house capabilities to design formulations and optimize approaches are just a few examples. There were no unforeseen adverse effects from demonstration projects identified in any of the project-related documents reviewed.

General findings

80. *Relevance of demonstration projects*: they play an important role in developing an understanding of alternative technologies by analyzing and evaluating their performance in specific applications. They provide guidance to countries and sectors for viable technological options, thus paving the way for the adoption of alternative technologies that not only support ODS reductions but also GHG reductions.

81. *Project design factors*: The following factors in the design of demonstration projects have been identified as critical to their success:

(a) Clearly defined technical performance indicators;

(b) Involvement of all relevant stakeholders during the design phase, including industry representatives, where trials or conversions are planned;

(c) Participation of technical experts or technology providers; and

(d) A communication and dissemination plan to inform key stakeholders, at both the country and sector level, before, during and after completion of the projects.

82. Additional factors that could be included in the design of future demonstration projects are:

(a) Gender mainstreaming indicators to assess impact on women's equality and representation;

(b) Preliminary risk-assessment and contingency scenarios (including with costing options); and

(c) Improvement of project proposal and project reporting templates, including PCRs, to improve data collection and related lessons learned from demonstration projects.

83. *Technological choice*: Even if a technology is proven to be a viable option, other factors (such as market acceptability, commercial issues, lack of standards or standards prohibiting the use of certain technologies, safety considerations, etc.) may affect the active use of such technology, even after its technical validation through the demonstration project. An understanding of the issues among key stakeholders is equally important in supporting wider adoption of low-GWP technology options.

84. *Inconclusive testing*: In some demonstration projects, no conclusion was reached about the feasibility of the technology (e.g., HFO or MF in the foam sector). Further testing would have been beneficial but was not undertaken due to the limits established in the budget. Innovative approaches, such as contingency additional funding under very specific conditions, could be considered on a case-by-case basis to allow the MLF to acquire additional technical and updated cost-structure information, at only a marginal cost of an advanced validation exercise (i.e., versus funding a fully-fledged new project). Risk-assessment considerations could be added to future demo project proposals to help identify under which conditions such contingency funding would be considered.

85. *Delays in implementation*: The majority of demonstration projects experienced delays in implementation, almost doubling the planned duration for finalization of the projects. Among the reported reasons were delays in the signing of agreements with key stakeholders, hence also in fund disbursement and other administrative issues (e.g., procurement, etc.). Project design and planning could be strengthened so as to better anticipate and prevent possible delays, and identify possible contingency remedial strategies, for a more accurate estimation of the actual duration of projects and their planned completion date.

86. *Energy efficiency*: Some alternative technologies have a positive impact on improving energy efficiency; hence, the adoption of these technologies could significantly reduce GHG emissions. Gains

through energy efficiency could also help improve the commercial viability of alternative technologies, in the sectors of refrigeration, AC and PU foam when applied in thermal insulation.

87. *Lessons learned and replicability from demonstration projects*: Because the parameters of a demonstration differ from the conditions of a full-scale conversion, the estimated cost of a demonstration project is not to be considered as representative for other projects. Thus, while the results of demonstration projects are instrumental to plan for full-scale conversion, their results should not be the determining factor for final decision-making and implementation of regular investment projects. Further assessment for each specific country and technology should take place before proceeding to a full-scale strategy.

Considerations for the design of future demonstration projects

88. The purpose and the design of demonstration projects could be reviewed and expanded to ensure that their implementation will contribute to assessing not only the technical viability of alternative technologies but also other issues relevant to their potential adoption. Project design could include, among others, issues such as the market-uptake challenges that products based on alternative technology may face, affordability and competitiveness, know-how and existing capacities. Elements of continued reporting of the uptake of the technology in the country could be added in the project design so that further information continues to emanate from the implementation of demo projects and shed light on issues related to sustainability of achievements of the Montreal Protocol through the MLF's projects.

89. Through the inclusion of contextual parameters in the project design, the demonstration projects could provide a more comprehensive techno-commercial feasibility assessment as a result of their implementation. Detailed knowledge of technology-market issues would aid countries in developing more effective HCFC and HFC reduction strategies.

90. Project delays caused by administrative and procurement issues should be reduced. A detailed preliminary assessment at the design stage could help identify potential bottlenecks or obstacles to be considered in defining project duration and expected date of completion. Ad hoc mechanisms for a more agile process to shorten the period between project approval date and project initiation for demonstration projects could foster their more agile implementation and produce results within a useful time period for the benefit of all stakeholders and decision-makers.

91. By their very nature, demonstration projects can include unexpected elements such as initial trials failing to meet performance requirements; contingent budgeting for additional time and resources under specific well-defined conditions could help complete otherwise inconclusive testing, at a marginal cost.

92. In countries with weak technical know-how on the use of alternatives, the demonstration projects should extensively engage with technical experts and competent technical institutes to provide required technical support, with this component being addressed at the design stage of the project.

93. The projects have neither actively tracked impact on gender nor on any other cross-cutting issues as a part of their results framework. These issues should be integrated into project design, through the inclusion of indicators, and tracked during the implementation phase to measure the contribution to Sustainable Development Goal 5, consistently with the implementation of the gender mainstreaming policy of the Fund.

94. Future demonstration projects that would support KIPs for HFC phase-down could also include aspects in their design to support NOUs and other relevant government agencies in acquiring and developing the required technical understanding for various alternatives; they could also include cross-cutting issues involving energy efficiency and safety standards, which could be featured in communication and knowledge dissemination programmes among key stakeholders.

95. The involvement of industry associations was not enough accounted for in the project design of the demonstration projects, and not much information resulted from the demonstration projects on their potential role in adoption of the demonstrated technology. In addition, several of the project initiatives were developed in collaboration with only specific companies in the industry. Industry associations should be better accounted for in the design of future demonstration projects, as their active involvement in project implementation would expand the reach of communication and dissemination activities, as well as facilitate the adoption and sustainability of alternative technologies.

96. The reporting tools identified to enable learning from the projects, in particular progress reports and PCRs, were not used to the extent planned. These templates must capture all required project attributes, including the achievement of project objectives, delays and lessons learned, so that insights from these projects can be passed on to future demonstration projects. The projects' reporting templates could be revised and updated to include relevant areas to be reported for future demonstration projects in areas identified by the desk-study.

97. In order to measure the effectiveness of training programmes, project design should include indicators in the results framework to obtain an initial measurement of technical understanding on the part of the target audience, and a corresponding similar measurement after implementation. This would provide information on capacity building among beneficiaries.

98. For future demonstration projects, the communication and dissemination plan should include a regular communication protocol wherein interim findings emanating from demonstration projects are shared with relevant stakeholders, during the implementation phase, without waiting to share information only when the project has concluded. This would facilitate adjustments that could bring improvements in implementation and increase the likelihood of a successful demonstration.

99. Implementing agencies and NOUs should diligently and fully report the project information ensuring to fill all the different areas of the reporting tools. This would enhance the quality of the consolidated information, improve the impact assessment of the project and facilitate the informed decision-making process of relevant stakeholders.

III. Recommendation

100. The Executive Committee may wish:

(a) To take note of the desk study for the evaluation of demonstration projects for low-global-warming-potential alternatives to HCFCs contained in document UNEP/OzL.Pro/ExCom/90/6; and

(b) To invite Article 5 countries, bilateral and implementing agencies and the Secretariat to take account of, where appropriate, the findings of the desk study referred to in sub-paragraph (a) above, for the project design, implementation and reporting on future technology demonstration activities associated with HFC phase-down.

Annex I

LIST OF DEMONSTRATION PROJECTS APPROVED BY THE EXECUTIVE COMMITTEE

Sector/Project	Project code reference	Agency	Country	Alternative technology	Project completion date[1]
Polyurethane (PU) foam (Baseline technology: HCFC-141b)					
Pilot project for validation of methyl formate as a blowing agent in the manufacture of polyurethane foam	BRA/FOA/56/DEM/285	UNDP	Brazil	Methyl formate	Dec 2010
Pilot project to validate methylal as blowing agent in the manufacture of polyurethane foams (phase I)	BRA/FOA/58/DEM/292	UNDP	Brazil	Methylal	Dec 2012
Pilot project for validation of methyl formate in microcellular polyurethane applications (phase I)	MEX/FOA/56/DEM/141	UNDP	Mexico	Methyl formate	Nov 2010
Low-cost options for the use of hydrocarbons as foaming agent in the manufacturing of PU foam	EGY/FOA/58/DEM/100	UNDP	Egypt	Cyclopentane, n-pentane	Dec 2015
Super-critical CO_2 in the manufacturing of sprayed PU rigid foam	COL/FOA/60/DEM/75	Japan/ UNDP	Colombia	Super-critical CO_2	Dec 2014
Use of hydrofluoroolefins (HFOs) for discontinuous panels in Article 5 Parties through the development of cost-effective formulations	COL/FOA/76/DEM/100	UNDP	Colombia	HFO-1233zd(E) and HFO-1336mzz(Z) with CO_2	Apr 2018
Technical and economic advantages of the vacuum-assisted injection in discontinuous panels plant retrofitted from HCFC-141b to pentane	SOA/FOA/76/DEM/09	UNIDO	South Africa	Pentane (vacuum assisted injection)	Aug 2018
Foam system houses to formulate pre-blended polyol for spray PU foam applications using low-GWP blowing agents	THA/FOA/76/DEM/168	World Bank	Thailand	HFO-1233zd(E) and HFO-1336 mzz(Z) with CO_2	Dec 2018
Low-cost pentane foaming technology in PU foam at small and medium-sized enterprises	MOR/FOA/75/DEM/74	UNIDO	Morocco	Pentane	Sep 2019
Low-cost options for PU foam at very small users	EGY/FOA/76/DEM/129	UNDP	Egypt	Methyl formate, methylal	Jul 2019
Conversion demonstration from HCFC-141-b-based to cyclopentane-based pre-blended polyol in the manufacture of rigid	CPR/FOA/59/DEM/491	World Bank	China	Cyclopentane	Dec 2017

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[1] Project completion dates compiled from documents of the Multilateral Fund Secretariat available as of 29 April 2022.

Sector/Project	Project code reference	Agency	Country	Alternative technology	Project completion date[1]
polyurethane foam at Guangdong Wanhua Rongwei Polyurethane Co. Ltd.					
Conversion of the foam part of Jiangsu Huaiyin Huihuang Solar Co. Ltd. from HCFC-141b to cyclopentane	CPR/FOA/59/DEM/492	World Bank	China	Cyclopentane	Nov 2012
HFO as foam blowing agent in the spray PU	SAU/FOA/76/DEM/27	UNIDO	Saudi Arabia	HFO-1233zd(E), HFO-1336mzz(Z)	Oct 2019
Extruded polystyrene (XPS) foam (Baseline technology: HCFC-22/HCFC-142b)					
HFO-1234ze as a blowing agent in the manufacturing of XPS foam boardstock	TUR/FOA/60/DEM/96	UNDP	Turkey	HFO-1234ze/DME	Dec 2011
CO2/methyl formate co-blowing technology in the manufacturing of XPS foam	CPR/FOA/64/DEM/507	UNDP	China	CO_2/methyl formate	Dec 2014
Air-conditioning (AC) (Baseline technology: HCFC-22)					
Demonstration project for conversion from HCFC-22 technology to HFC-32 technology in the manufacture of commercial air-source chillers/heat pumps at Tsinghua Tong Fang Artificial Environment Co. Ltd.	CPR/REF/60/DEM/498	UNDP	China	HFC-32	Dec 2014
Demonstration sub-project for conversion from HCFC-22 to propane at Midea Room Air-conditioner Manufacturing Company	CPR/REF/61/DEM/503	UNIDO	China	Propane (R-290)	Dec 2014
Demonstration sub-project for conversion of room air-conditioning compressor manufacturing from HCFC-22 to propane at Guangdong Meizhi Co.	CPR/REF/61/DEM/502	UNIDO	China	R-290	Dec 2013
Promoting low-GWP refrigerants for AC sectors in high ambient temperature countries (PRAHA I)	ASP/REF/69/DEM/56	UNEP/ UNIDO	Bahrain, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates	Several	Dec 2016
Developing window and packaged air-conditioners using lower-GWP refrigerant	SAU/REF/76/DEM/29	World Bank	Saudi Arabia	HFC-32 and R-290	Nov 2018
Demonstration project on promoting HFO-based low-GWP	SAU/REF/76/DEM/28	UNIDO	Saudi Arabia	R-290[2]	Ongoing (extension

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[2] Project was initially approved to manufacture, test and optimize pilot model air conditioners with low-GWP HFO/HFC blends as well as R-290; however, during implementation, the enterprise decided to focus on R-290

Sector/Project	Project code reference	Agency	Country	Alternative technology	Project completion date[1]
refrigerants for the air-conditioning sector in high ambient temperatures					requested at 90th meeting)
Demonstration project for HCFC-free, low-GWP technology performance in air-conditioning applications	KUW/REF/76/DEM/32	UNDP	Kuwait	R-290, HFC-32	Project was cancelled
Promoting refrigerant alternatives for high ambient temperature countries (PRAHA II)	ASP/REF/76/DEM/59	UNEP/ UNIDO	Regional (West Asia)	Several	Dec 2019
Industrial and commercial refrigeration (ICR) (Baseline technology: HCFC-22)					
Demonstration project for conversion from HCFC-22 technology to ammonia/CO_2 technology in the manufacture of two-stage refrigeration systems for cold storage and freezing applications at Yantai Moon Group Co. Ltd.	CPR/REF/60/DEM/499	UNDP	China	Ammonia (NH_3)/CO_2	Dec 2014
Demonstration of the application of an ammonia/carbon dioxide refrigeration system in replacement of HCFC-22 for the medium-sized producer and retail store at Premezclas Industriales S.A.	COS/REF/76/DEM/55	UNDP	Costa Rica	NH_3/CO_2	Dec 2017
Demonstration project for HCFC-free low-GWP alternatives in refrigeration in the fisheries sector	MDV/REF/76/DEM/30	UNDP	Maldives	R-448A	Dec 2019
Demonstration project for ammonia semi-hermetic frequency-convertible screw refrigeration compression units in the industrial and commercial refrigeration industry at Fujian Snowman Co., Ltd.	CPR/REF/76/DEM/573	UNDP	China	NH_3/CO_2	Mar 2018
Demonstration of R-290 (propane) as an alternative refrigerant in commercial air-conditioning manufacturing at Industrias Thermotar ltda.	COL/REF/75/DEM/97	UNDP	Colombia	R-290	Apr 2018
Demonstration project for the introduction of trans-critical CO_2	GLO/REF/76/DEM/335	UNIDO	Argentina[3]	Trans-critical CO_2	Dec 2019

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technology based on testing by the enterprise and results from the demonstration project on promoting alternative refrigerants in air-conditioning for high ambient temperature countries (PRAHA-II).

[3] Project was initially conceptualised for two countries (Argentina and Tunisia); however, as reported in Part VI of document UNEP/OzL.Pro/ExCom/82/20, the Tunisia component of the project was not further developed and funding was returned to the Multilateral Fund (decision 84/16(c)).

Sector/Project	Project code reference	Agency	Country	Alternative technology	Project completion date[1]
refrigeration technology for supermarkets					
Solvent (Baseline technology: HCFC-141b)					
Iso-paraffin and siloxane (KC-6) technology for cleaning in the manufacturing of medical devices	CPR/SOL/64/DEM/511	UNDP/ Japan	China	Iso-paraffin and siloxane (KC-6)	Dec 2016
Refrigeration and AC servicing (Baseline technology: HCFC-22)					
Europe and Central Asia: Development of a regional centre of excellence for training and certification and demonstration of low-GWP alternative refrigerants	GLO/REF/76/DEM/333	Russian Federation	Europe and Central Asia	Several	Dec 2019
Demonstration project on refrigerant quality, containment and introduction of low-GWP refrigerants	EUR/REF/76/DEM/16	UNIDO/ UNEP	Global	Several	Jul 2019

Annex II

UPDATES ON SUMMARY OF RESULTS SO FAR ACHIEVED FROM THE APPROVED HCFC DEMONSTRATION PROJECTS

1. In line with decision 55/43 on the submission of a limited number of projects that could best demonstrate alternative technologies to the use of HCFCs, the Executive Committee approved 32 projects. The terms of reference of the present desk study request to update information provided in document UNEP/OzL.Pro/ExCom/72/40; the update is provided in Annex II and Annex III.

2. Out of the 32 approved projects (with a reduction potential of 93.13 ODP tonnes), 30 have been completed. Final reports for these projects were submitted to the Executive Committee. One project was partially completed, and one project was cancelled. The sub-project in Tunisia of the demonstration project "The introduction of trans-critical carbon dioxide (CO_2) refrigeration technology for supermarkets (Argentina and Tunisia)" was not implemented due to a lack of interest in the country.

3. Seventeen of these projects were approved after decision 72/40, and 14 of these projects involved technology conversion or technology testing. Two projects were part of RAC servicing sector and one project in Kuwait was cancelled. Considering that several of the technologies included in the demonstration projects have already been selected in various Article 5 countries for replacing HCFCs used in the foam and refrigeration and air-conditioning sectors, this annex includes a brief description of the results of the 14 demonstration projects that have been completed but were not included in Annex II of document UNEP/OzL.Pro/ExCom/72/40.

Table A. Approved demonstration projects not covered in document 72/40

Sector/Project	Project code reference	Agency	Country	Alternative technology	Final report
Polyurethane (PU) foam (Baseline technology: HCFC-141b)					
Use of hydrofluoroolefins (HFOs) for discontinuous panels in Article 5 Parties through the development of cost-effective formulations	COL/FOA/76/DEM/100	UNDP	Colombia	HFO-1233zd(E) and HFO-1336mzz(Z) with CO_2	Apr 2018
Technical and economic advantages of the vacuum-assisted injection in discontinuous panels plant retrofitted from HCFC-141b to pentane	SOA/FOA/76/DEM/09	UNIDO	South Africa	Pentane (vacuum assisted injection)	Jun 2018
Foam system houses to formulate pre-blended polyol for spray PU foam applications using low-GWP blowing agents	THA/FOA/76/DEM/168	World Bank	Thailand	HFO-1233zd(E) and HFO-1336mzz(Z) with CO_2	Apr 2019
Low-cost pentane foaming technology in PU foam at small and medium-sized enterprises	MOR/FOA/75/DEM/74	UNIDO	Morocco	Pentane	Oct 2019
Low-cost options for PU foam at very small users	EGY/FOA/76/DEM/129	UNDP	Egypt	Methyl formate, methylal	Oct 2019
HFO as foam blowing agent in the spray PU	SAU/FOA/76/DEM/27	UNIDO	Saudi Arabia	HFO-1233zd(E), HFO-1336mzz(Z)	Jul 2020
Air-conditioning (AC) (Baseline technology: HCFC-22)					
Developing window and packaged air-conditioners using lower-GWP refrigerant	SAU/REF/76/DEM/29	World Bank	Saudi Arabia	HFC-32 and R-290	Feb 2019

Sector/Project	Project code reference	Agency	Country	Alternative technology	Final report
Demonstration project on promoting HFO-based low-GWP refrigerants for the air-conditioning sector in high ambient temperatures	SAU/REF/76/DEM/28	UNIDO	Saudi Arabia	Propane (R-290)[1]	Ongoing
Promoting refrigerant alternatives for high ambient temperature countries (PRAHA-II)	ASP/REF/76/DEM/59	UNEP/ UNIDO	Regional (West Asia)	HFC-32, propane, HFO blends	Dec 2019
Industrial and commercial refrigeration (ICR) (Baseline technology: HCFC-22)					
Demonstration of the application of an ammonia/carbon dioxide refrigeration system in replacement of HCFC-22 for the medium-sized producer and retail store at Premezclas Industriales S.A.	COS/REF/76/DEM/55	UNDP	Costa Rica	Ammonia (NH_3)/ CO_2	Jun 2018
Demonstration project for HCFC-free low-GWP alternatives in refrigeration in the fisheries sector	MDV/REF/76/DEM/30	UNDP	Maldives	R-448A	Apr 2018
Demonstration project for ammonia semi-hermetic frequency-convertible screw refrigeration compression units in the industrial and commercial refrigeration industry at Fujian Snowman Co., Ltd	CPR/REF/76/DEM/573	UNDP	China	NH_3/CO_2	Dec 2018
Demonstration of R-290 (propane) as an alternative refrigerant in commercial air-conditioning manufacturing at Industrias Thermotar ltda	COL/REF/75/DEM/97	UNDP	Colombia	R-290	Apr 2018
Demonstration project for the introduction of trans-critical CO_2 refrigeration technology for supermarkets	GLO/REF/76/DEM/335	UNIDO	Argentina	Trans-critical CO_2	Jul 2020

Use of HFOs in PU foam

4. Three projects to test hydrofluoroolefins (HFOs) in the polyurethane (PU) foam sector were approved in Colombia (implementing agency (IA): UNDP), Saudi Arabia (IA: UNIDO), and Thailand (IA: The World Bank). These projects were approved at the 76th meeting of the Executive Committee.

5. In Colombia, the project was approved to validate PU formulations for discontinuous panels with reduced HFO (namely HFO-1233zd(E) and HFO 1336mzz(z)). In Saudi Arabia, use of HFO-1233zd(E) and HFO-1336mzz(Z) co-blown with water in spray PU foam applications in high ambient temperatures (HATs) was validated. In Thailand, pre-blended polyol using HFOs (namely, HFO-1233zd(E) and HFO-1336mzz(Z)) for small- and medium-sized enterprises (SMEs) in the PU spray foam sector in system houses were validated.

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[1] The project was initially approved to manufacture, test and optimize pilot model air conditioners with low-GWP HFO/HFC blends as well as R-290; however, during implementation, the enterprise decided to focus on R-290 technology based on testing by the enterprise and results from the demonstration project on promoting alternative refrigerants in air-conditioning for HAT countries (PRAHA-II).

6. In general, handling and processability of the HFO-reduced formulation at the production plant were comparable to HCFC-141b; no statistically significant difference was found between the performance of foam based on the two types of HFOs (HFO-1233zd(E) and HFO-1336mzz(Z)).

7. In discontinuous panels, compared to HCFC-141b-based formulations, the HFO-reduced formulations showed better foam flow (i.e., lower flow ratio between the free rise density and the minimum fill density); an initial foam k-factor 7 per cent higher in the laboratory (Brett injections; it was also reproduced at industrial plant level), and similar k-factor values measured one month after injected; and similar laboratory and production plant values of compressive strength, dimensional stability and adhesion to metal.

8. In the spray foam sector in HATs, the performance of HFO-1233zd(E) matched that of HCFC-141b in adhesion, thermal conductivity, dimensional stability, paintability, overall foam density and compression strength. The sprayed surface based on HFO-1233zd(E) displayed more pinholes than that based on HCFC-141b, but still met customer expectations.

9. Pre-blended HFO-based spray foam formulations in Thailand, with HFO blowing agents amounting to 10 per cent of the polyol with adjustments on the choice of polyol and the catalyst package, could yield the foam properties that were acceptable to the Thai spray foam market. While the HFO-1233zd(E) formulation demonstrated instability in the formulation, the project final report indicates that the stability issue could be solved by introducing a new catalyst package. In terms of adhesion and reactivity time, spray foams blown with HFOs exhibited adhesion performance and reactivity time that was acceptable to the market. Density of spray foam made from the reduced HFO formulations was slightly higher than the baseline HCFC-141b formulation. A slight increase in the compressive strength was also observed.

10. Based on the validation data gathered thus far, HFO technology appears to have good prospects of replacing HCFCs in PU foam applications while maintaining acceptable performance. HFOs, on the other hand, have high costs as compared to HCFC or other alternative-based formulations, according to reports. High pricing and commercial supply difficulties have been cited as major barriers to HFO adoption in the PU foam sector.

Vacuum-assisted injection in discontinuous panels plant retrofitted from HCFC-141b to pentane

11. At its 76th meeting, the Executive Committee approved the demonstration project on the technical and economic advantages of the vacuum-assisted injection (VAI) in discontinuous panels plant retrofitted from HCFC-141b to pentane in South Africa.

12. The demonstration project showed that the cyclopentane-blown foam with VAI technology has good dimensional stability; allows for a reduction in foam density of up to 5 per cent, which could result in considerable savings in terms of PU consumption; removes cyclopentane and isocyanate vapors from the work area, thereby improving worker health and safety; and achieves similar k-values (between 20.12 and 20.54 mW/mK) to HCFC-141b-blown foams (20.4 mW/mK).

13. Further, use of VAI technology results in savings due to reduced energy consumption and demolding time. Combined with the reduction in foam density, reduction in labour costs and improved worker health and safety, these savings are anticipated to cover the technology's initial investment expenditures.

Methylal and methyl formate in PU foam for very small users

14. The demonstration project on low-cost options for very small users (VSU) for PU foam applications in Egypt was approved at the 76th meeting. The project was expected to develop a foam dispensing unit for

pour-in-place (PIP) applications used by VSUs at a lower cost than dispensers available in the market; and to explore the option of pre-packaging PU foam systems for certain foam applications that would be easy to use for VSUs, with the low-cost foaming units.

15. The results of the project concluded that with very clear specifications of the minimum components of the equipment to allow foaming operations, basic foam dispensers might be available at 30-50 per cent less cost than standard dispensers therefore potentially reducing equipment costs of future foam projects funded by the MLF for small and very small foam manufacturers. Equipment requirements may need to be changed in some circumstances to allow for the usage of chemical systems with changeable ratios.

Pentene foaming technology in the PU foam sector

16. At its 75th meeting, the Executive Committee approved the demonstration project on the use of low-cost pentane foaming technology for the conversion to non-ODS technologies in PU foam at SMEs in Morocco. The objective of the project was to explore the possibility of reducing the initial capital cost by designing a simple, standardized, easy-to-handle and compact foaming machine capable of operating with flammable pentane, equipment and movable ventilation systems serving several products.

17. Pre-blended cyclopentane systems are sufficiently stable and may be commercially employed, according to the results of the demonstration project; there are no special concerns with the transportation and distribution of cyclopentane pre-blended systems in barrels. They are delivered as "hazardous chemicals," which incurs an additional expense. The foam quality generated by cyclopentane systems is comparable to that produced by HCFC-141b systems; there was no unique safety concern or difficulty in using the cyclopentane system with the provided equipment.

HFC-32- and R-290-based windows and packaged air-conditioning (AC) units in HAT countries

18. At its 76th meeting, the Executive Committee approved the demonstration project at two enterprises manufacturing AC units in Saudi Arabia: Saudi Factory for Electrical Appliances Co. Ltd (SFEA) and Petra Engineering Industries Co. Ltd. (Petra).

19. Petra designed, manufactured and tested six prototype commercial air-cooled chillers using HFC-32 and R-290 refrigerants with cooling capacities of 40 kW, 70 kW and 100 kW. The design of the equipment was in accordance with the safety requirements of ISO-514939 and IEC-60335-2-40. Testing was conducted at 35°C, 46°C and 52°C. Results were compared to R-410A, which was tested as a drop-in to HFC-32. In all cases, both HFC-32 and R-290 units showed similar or better performance (efficiency and cooling capacity) than R-410A. However, design changes necessary to mitigate the risk of using R-290 resulted in a significant increase in the cost of the equipment. The cost increase was minimal in the case of HFC-32.

20. The investigation discovered that current safety requirements would significantly limit the usage of combustible refrigerants like R-290 in most commercial applications. The cost of charging the units was 50 to 57 percent less with HFC-32 and 25 to 44 percent greater with R-290 due to the lower refrigerant charge and price compared to R-410A. The higher cost of R-290 is due to the refrigerant's high price (US $12.25/kg) as compared to R-410A (US $6.55/kg). There was a small increase in the cost of major components when transitioning from R-410A to HFC-32, resulting in an increase between 11 and 13 per cent, depending on the size of the unit. The difference in cost between HFC-32 and R-290 for most major components was minor, except for the compressor, which was approximately a factor of three more expensive, and resulted in substantial increases in the cost of a unit relative to HFC-32. A leak detector, required for R-290 but apparently not required for HFC-32, also contributed to that difference. These costs are estimates provided at the time of project implementation and may not be valid anymore.

HFO-based low-global-warming-potential (GWP) refrigerants for the AC sector in HAT countries

21. At its 76th meeting, the Executive Committee approved the project in Saudi Arabia to manufacture, test and optimize pilot model AC units with low-GWP HFO/HFC blends, as well as R-290; to undertake a demonstration production run; and to convert a production line. However, during implementation, the enterprise decided to focus on R-290 technology based on testing by the enterprise and results from the demonstration project on promoting alternative refrigerants in air-conditioning for HAT countries (PRAHA-II).

22. The Executive Committee decided to extend the completion date of the project to 15 March 2022 on an exceptional basis given the COVID-19 pandemic and the advanced progress achieved (decision 88/27). A progress report was submitted to the 90th meeting and, based on that progress report, a further extension of the date of completion was requested. Accordingly, the final report is not available in time for analysis and consideration in this desk study.

Promoting refrigerant alternatives for HAT countries (PRAHA-II)

23. PRAHA-II was approved at the 76th meeting of the Executive Committee. The project aimed to build on the progress of the PRAHA-I demonstration project to promote low-GWP alternatives for the AC industry in HAT countries in West Asia. PRAHA-II had three main elements: to build the capacity of the local industry to design and test AC equipment using low-GWP flammable refrigerants; to evaluate and optimize the prototypes built for PRAHA-I; and to build a risk assessment model for the HAT countries.

24. Results of the optimization of PRAHA-I prototypes, demonstrated that improvements in system performance can be achieved through modeling, component design and selection. Component re-design focused on the compressor, condenser and expansion valve. Tests of optimized units showed a considerable reduction in power consumption at the HAT test condition (46°C). The simulation analysis showed that refrigerant with wider saturation curves tend to result in systems with higher efficiency and less charge when no modifications to the hardware are made. The results showed, however, that by making appropriate component selection, such as compressors with larger displacement volumes and higher mass flow rate, the cooling capacities and overall performance of the other refrigerants were of the same order of magnitude.

25. The results of tests of high-glide alternatives found that refrigerant fractionation as evidenced by the leak tests does not appear to be a significant concern since less than 2 per cent change in cooling capacity was observed after the system's recharge, and changes to EE are expected to be minimal.

Ammonia (NH_3)/CO_2 usage in the industrial and commercial refrigeration (ICR) sector

26. At its 76th meeting, the Executive Committee also approved the project to demonstrate the application of an NH_3/CO_2 refrigeration system in place of HCFC-22 for the medium-sized producer and retail store at Premezclas Industriales, S.A., in Costa Rica. The project was approved to demonstrate the use of an NH_3/CO_2 two-stage refrigeration system[2] in retail stores as a viable replacement of an HCFC-22 system operating a 50-tonne refrigeration (TR) capacity cold storage system.

27. The use of NH_3/CO_2 in a cascade (with recirculated CO_2-type brine) is a novel and practical method for medium-sized industrial companies to use. The new cooling system for the completed product chamber, which uses cascade technology, saves energy (i.e., during two months of operation of the new system, the electricity costs reflect a reduction of 10 per cent). According to the estimates, the new system could save up to 20 per cent on electricity costs; the new system also saves money on production because it uses less

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[2] NH_3 is in the high-temperature system and CO_2 is in the low-temperature circuit driven by pumps, where CO_2 is used as a heat transfer fluid (brine).

electricity, requires fewer maintenance interventions, does not require the purchase of HCFC-22 to top-up the systems due to leaks during operation and uses lower-cost natural refrigerants.

28. Additional training of technical personnel may be required, in accordance with the increased experience in the operation, service and maintenance of the new cascade system; service procedures should also be developed based on the experience gained with the operation of the new system. Both CO_2 and NH_3 require more advanced skills and know-how for installers and technicians than with an HCFC-22-based system. A wider use of this technology in smaller systems would require a review of the local technicians' capacity to handle CO_2 and NH_3 and the type of regulations, standards and codes of practice that would be applicable.

29. At its 76th meeting, the Executive Committee approved the demonstration project for NH_3 semi-hermetic frequency convertible screw refrigeration compression units in the ICR industry at Fujian Snowman Co. Ltd., in China. The project proposed to establish the suitability of NH_3 semi-hermetic frequency convertible screw refrigeration compression units with CO_2 as the secondary heat transfer fluid used in small- and medium-sized ICR systems. The production line for ice makers and ice storage was modified to implement the project.

30. The demonstration concluded that the NH_3 refrigerant had a lower operating pressure than HCFC-22, requiring less refrigerant charge in the NH_3 refrigeration system. In refrigeration systems, the NH_3 compressor can replace the HCFC-22 compressor. The experiment proved that semi-hermetic NH_3 compressors may be used in cold storage. The shown semi-hermetic NH_3 compressor and refrigeration system minimised NH_3 refrigerant leakage, which is poisonous and mildly flammable, as compared to the open type NH_3 compressor, improving the refrigeration system's safety. UNDP, the implementing agency of this project, further said that the NH_3/CO_2 system now has a higher CoP as a result of better design and energy-saving features.

HCFC-free low-GWP alternatives in refrigeration in the fisheries sector

31. At its 76th meeting, the Executive Committee approved the demonstration project on HCFC-free low-GWP alternatives in refrigeration in the fisheries sector in the Maldives. The project was approved to identify low-GWP alternative technologies to HCFCs for use in refrigeration equipment with a charge of 150 kg to 200 kg of refrigerant in the fisheries sector. It included the conversion of HCFC-22-based refrigeration equipment in three fishing vessels to low-GWP technologies.

32. Based on the above criteria, and supported by a desk study undertaken, it was found that R-448A remains as the best drop-in refrigerant for replacing HCFC-22 used in the selected refrigeration systems used in fishing vessels in the Maldives. Refrigerant performance seemed suitable to retrofit the systems without affecting their performance and with limited system modification, and technical support available for the retrofitting from the refrigerant manufacture was adequate.

33. With regards to the technical assessment of R-448B (A2L refrigerant), UNDP, the implementing agency for this project, mentioned while the assessment was undertaken, the fisheries sector was reluctant to adopt the substance as it is a mildly flammable refrigerant and there are potential risks of using that refrigerant in fishing vessels.

34. R-448A is not essentially a low-GWP alternative to HCFC-22, as it has GWP of 1,386. In view of its high GWP, further explorations are required to identify low-GWP options in the fisheries sector.

R-290 usage in the commercial AC sector

35. At its 75th meeting, the Executive Committee approved the demonstration project for the use of propane (R-290) as an alternative refrigerant in commercial AC manufacturing at Industrias Thermotar

Ltda., in Colombia. The project was approved to demonstrate the safe use of R-290 as a low-GWP refrigerant in the commercial AC manufacturing sector with ranges between 3.5 kW (1 TR) and 17.5 kW (5 TR).

36. The following changes were done in-product to use R-290 as a refrigerant: reduction of the heat exchanger tube diameter (condenser), reduction of R-290 refrigerant charge, modification of the metal structure (cabinet) of condensing units, modification of the handling unit metal structure, and pump down cycle installation. Safety measures were also required for the new manufacturing line.

37. As per the demonstration project reports, the enterprise conducted comparative tests related to energy consumption between R-410A- and R-290-based equipment (5 TR). R-290-based equipment consumes 15 per cent less energy than the HCFC-22-based equipment and 13 per cent less than the R-410A-based equipment. These systems also provided required cooling performance as per local climactic conditions. At the 88th meeting, it was reported that the enterprise had been able to manufacture and sell approximately 28 R-290-based units, including several that had been exported in the region.[3]

Trans-critical CO_2 refrigeration technology for supermarkets

38. At its 76th meeting, the Executive Committee approved the demonstration project for the introduction of trans-critical CO_2 refrigeration technology for supermarkets. The demonstration project includes the introduction of a trans-critical CO_2 refrigeration system in select supermarkets in Argentina. The refrigeration capacity of the new system is 78.32 kW (68.79 KW for the medium-temperature circuit and 9.53 kW for the low-temperature circuit), which is slightly smaller than the original system of 82.14 kW (72.09 kW for the HCFC-22 positive-temperature cabinets and cold rooms and 10.05 kW for the R-404A low-temperature cabinets and cold rooms).

39. The trans-critical CO_2 refrigeration system is technically viable for use in supermarket applications in climate conditions similar to those of Argentina and where all the components used in the system are available either locally or internationally at a reasonable price. Based on industrial experience and technical literature, the initial investment of a trans-critical CO_2 refrigeration system is higher than an HFC-based system due to the high pressure requiring stronger piping and better welding during installation; at current prices, the investment of a similar system using R-404A is approximately 20 per cent lower than a trans-critical CO_2 system, and 10-13 per cent lower if using an HFC/glycol system.

40. The electricity consumption of the trans-critical CO_2 system was 27.64 per cent lower than the baseline HCFC-22/R-404A system based on measurements over an 11-month period. Based on the information in the final report, the higher cost of initial investment can be offset over a reasonable time frame by the savings from reduced electricity consumption and possible reduced refrigerant leakage during operation.

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[3] http://multilateralfund.org/88/English/1/8844.pdf

Annex III

ADDITIONAL ELEMENTS FOR POTENTIAL FRAMEWORK CONDITIONS FOR DEMONSTRATION PROJECTS

1. At its 86th meeting, the Executive Committee approved the terms of reference (TOR) for the desk study of the evaluation of "Demonstration projects for low-GWP alternatives to HCFCs." One of the tasks included in the TOR is to update Annex III of the document "Overview of approved HCFC demonstration projects and options for additional projects to demonstrate climate-friendly and energy-efficient alternative technologies to HCFC (decision 71/51(a))."[1]

2. The general criteria identified below are updated based on the findings of this desk study. These findings can provide valuable lessons to be included in future demonstration projects which may be undertaken as part of Kigali Implementation Plans (KIPs). They may contribute to improved design and usefulness of future demo projects, which would take into account lessons learned from this desk study.

General criteria for the design and implementation of demonstration projects

3. To be considered as a demonstration project in the manufacturing sector, a project proposal should offer significant improvements to the current understanding of an alternative technology (lower-GWP options) or its application.

4. Focus should be on demonstrating zero or nearly-zero GWP options to avoid any future double conversion wherein initially demonstrated technology no longer is able to meet HFC phase-down compliance goals.

5. Demonstration projects should be able to test conditions under which tested technology can be adopted in countries/regions within approximately three to five years from the time of approval, with the potential to be used in several activities.

6. These conditions could include, inter-alia, technical feasibility, commercial availability, compliance with safety standards, potential energy efficiency gains, market acceptability and other important aspects such as post-installation servicing requirements. A comprehensive assessment of all these factors is important to be covered for countries to make a well-informed decision on technology selection.

7. Given that a short time for implementation is essential for the projects, an eligible enterprise should have been identified. This enterprise should commit to the conversion of their manufacturing process to the new technology and to cease using the high-GWP substance. Criteria should also include a strong assurance of timely reporting of results and findings, for these to be useful for real-time decision-making.

8. Further, the time for project implementation should be limited to three years, except where agreed otherwise at the time of project approval. However, additional time could be allocated if initial test results suggest a need for further trials for proving technical feasibility or optimization of technology to reduce costs or improve market acceptability.

9. For future demonstration projects, the communication and dissemination plan should include a regular communication protocol wherein interim findings emanating from demonstration projects are shared with relevant stakeholders without waiting to share information only when project has concluded.

10. In line with the new gender mainstreaming policy of the Multilateral Fund (decision 84/92(d)), all projects should also address the gender dimension in all phases, from design, to implementation and

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[1] Document UNEP/OzL.Pro/ExCom/72/40.

reporting. This would ensure that gender equality is mainstreamed in the project design and ultimately the implementation has a positive impact on women's equality and empowerment in the countries and sectors where the projects are executed.

Annex IV

EVALUATION MATRIX

Criteria and key evaluation questions	Sub-questions (based on document UNEP/OzL.Pro/ExCom/86/12/Rev.1)	Indicators	Data collection tools/methods, key informants/constraints
Relevance of the project			
How consistent were the project's objectives with the Executive Committee's decision? What has been the overall value of the demonstration projects to the implementation of the HCFC phase-out and upcoming HFC phase-down?	How did the project design envisage outputs from the demonstration that could inform similar projects under the HPMP? How did the project contribute to the country's overall compliance with the Montreal Protocol and the sustainable replacement of HCFC-based technology by low-GWP alternative technology? What was the need for this project? How was it identified? What were the local, regional and international conditions in the sector that implied that such a project could be implemented successfully and serve as an effective demonstration of the technology for other enterprises? What are the main lessons and challenges faced by the choice of technology and its transition?	• Project outputs • Existing situation of technology usage at the time of project design • Criteria to select technologies and to evaluate their performance • GWP and ODP impact of selected technologies	• Desk review of project documentation including project proposals, project evaluations, progress reports, project completion reports (PCRs), fact sheets and final reports • Multilateral Fund (MLF) documents including decision 55/43 and documents 55/47, 72/40, 73/8, 74/9, 75/9, 80/10, 82/11, 82/12, 84/11, 88/10, and 89/10 • Status reports and reports on projects with specific reporting requirements (ExCom meeting documents 62/09, 63/15, 65/12, 66/17, 67/06, 72/11, 73/17, 76/10, 81/10, 83/11, 84/22, 85/09) • Questionnaires and, when required for complementing the information, remote interviews with implementing agencies (IAs)
How adequate was the project design to achieve the intended goals in demonstrating technologies?	Were the set of activities selected during the project design conducive to complete the demonstration in a successful manner? What activities were unnecessary, and which necessary activities were not included? Which were the institutions in charge with the management and coordination of the project? Were there changes in the management (i.e., structure and composition) during the project's life and how did this affect its implementation? What was the role of the national ozone unit? In retrospect, what additional elements would need to be taken into consideration, when designing low-GWP technology demonstration projects in the future, to ensure their success and influence in the wider adoption of the selected technology?		
Effectiveness of demonstration projects			
Have the demonstration projects effectively achieved	To what extent did the project influence the strategy determined and the technology selection in the HPMP?	• Inclusion of successful technologies in HPMPs	Desk review of MLF documentation (for all projects):

Criteria and key evaluation questions	**Sub-questions (based on document UNEP/OzL.Pro/ExCom/86/12/Rev.1)**	**Indicators**	**Data collection tools/methods, key informants/constraints**
the objectives for which they were conceived?	Were there positive and/or negative results from the demonstration not envisaged during project design? Did the project have effects on broader policies and other enterprises to use the new low-GWP alternatives?	• Level of adoption of technologies in the sector/region • Inclusion of technology performance details in project documents	• Progress report, final report, fact sheets and PCRs • Country-specific HPMPs • Input from IAs through questionnaires and/or remote interviews
	Which are the promising technologies that had positive outcomes in demonstration? Which are the technologies that did not meet performance requirements for specific applications? What manufacturing line equipment redesign and installation, if any, were required for this project? If there were intellectual property (IP) rights aspects involved, what were they and how were they resolved? What actions were taken to ensure that the results of the project were widely available, considering IP concerns if applicable?	• Technology performance in different applications • ICC and IOC of technology adoption • Technical characteristics of technologies for specific applications	
Were projects finished within the specified duration?	Was the time schedule allocated during project design sufficient to complete all the activities related to the demonstration? If not, how could the implementation schedule have been determined better?	• Planned vs. actual project duration	Desk review of PCRs
How well did the project include the institutional support in the design and use it during the implementation phase?	What were the mechanisms implemented to coordinate with key stakeholders related to the project (e.g., industry associations, civil society, technical and standards authorities), and how was this achieved? If there were specialized new institutions that needed to be involved in the project, how were the outreach and coordination mechanisms established with these institutions (e.g., safety standards authorities, energy efficiency standards and testing authorities)? How were the professional associations (e.g., foam, refrigeration and air-conditioning manufacturer associations) consulted in the project design phase and how were their inputs incorporated? What were the main institutional challenges faced in ensuring timely and effective completion of the demonstration project, if any? How were these challenges addressed?	• Planned vs. actual project duration • Stakeholders' involvement • Challenges and success factors	Desk review of project proposals, evaluation sheets by the MLF Secretariat, final project reports, and inputs from IAs in questionnaires and/or remote interviews

Criteria and key evaluation questions	Sub-questions (based on document UNEP/OzL.Pro/ExCom/86/12/Rev.1)	Indicators	Data collection tools/methods, key informants/constraints
Efficiency of funding			
Are these projects financially efficient?	Were the incremental capital and operating costs well estimated in the project design? Were there funding problems encountered during project implementation? Was funding for the demonstration project adequate? If not, what were the reasons for inadequate funding and the variances? If there were differences between the planned and needed funding, what were the reasons for these differences? If none, describe how funding was determined to be sufficient. Were there components that were not adequately funded, and if so, explain why? In cases where policies and regulations were needed in the country to introduce the demonstrated technology, did the project budget allocate funds for this activity? What were the co-financing modalities considered, including details of specific components that were co-financed? What were the sources of co-financing along with the proportion of co-funded components (e.g., funding from non-MLF sources, internal resources at the enterprise)? If there was co-financing, what specific forms did it take (e.g., loans, concessional finance)? What challenges were encountered in obtaining co-funding? How were these challenges addressed? What were the financial incentives obtained from the Government for implementing the project, if any?	• Projected ICC and IOC • Project budget and actual funding use • Co-financing details (sources and value)	Desk review: Project design document, progress report and final project reports Constraints: Many projects did not include detailed information in final project reports for co-financing
Impact of the projects			
Were the demonstration projects able to influence policy development conducive for wider adoption of technologies?	What were the changes needed, in the existing policies and regulation framework, to implement the project, if any? How long did it take to implement these changes? Have standards been introduced to facilitate the uptake of this technology, such as safety, energy efficiency or other? What were the main policy and regulatory challenges faced in ensuring timely and effective completion of the demonstration project, if any? How were these challenges addressed?	• Policies and regulations required for technology adoption • Energy efficiency and safety standards	Desk review of project final and completion reports

Criteria and key evaluation questions	Sub-questions (based on document UNEP/OzL.Pro/ExCom/86/12/Rev.1)	Indicators	Data collection tools/methods, key informants/constraints
	What legal actions were planned/designed to ensure sustainability when replicating the demonstrated technology?		
Are the demonstration projects able to influence policy development conducive for wider adoption of technologies?	What were the estimated impacts on direct greenhouse gas emission reductions and other environmental impacts identified during project design and how were these addressed during implementation? What were the benefits achieved through this project, in addition to the demonstration of the low-GWP technology (e.g., benefits to health sector, improvement in standards relating to a specific technology)? What is the expected ODP reduction from demonstration projects?	• ODP reduction potential in project proposal and factsheets • GHG reduction potential in project proposal and factsheets • Reporting on other aspects including energy efficiency, health, standards, and environmental issues	Desk review: Project design documents, PCRs, factsheets, final project reports and questionnaires to IAs
Were projects able to provide required technical assistance for operating new technologies?	What were the technical assistance needs during implementation and how were they met (e.g., training of technical personnel, training of national experts, environmental and safety audits of the facilities)? How were the training workshops planned and conducted? Where did the training take place? What indicators were used to measure success of the training conducted?	• Training activities reported by IAs • No specific indicator was defined apart from the reference to the trainings held included in the reports	Desk review: Project design documents, PCRs, factsheets, final project reports and questionnaires and interviews to IAs
Sustainability and replicability of achievements			
Were these projects designed and implemented to sustain long-term project results (i.e., achieving HCFC phase-out with the use of low-GWP HCFC alternatives)?	Were the results obtained by the project aligned with the objectives? How was the sustainability of the demonstration project (i.e., adoption of the technology) and its achievements in the country/region taken into account in the project design? What are the factors related to design and implementation of the project technology/processes that would result in replicability? Which aspects of the project that were expected to be replicated could not be replicated and why? Were there solutions explored to use the enterprise's internal funding to ensure sustainability? Are there examples of replicability based on	• Activities included in the project proposal for sustainability and replication • Monitoring framework to assess technology demonstration • Linkages between demonstration projects and HPMPs	Desk review: Project design documents, PCRs, factsheets, final project reports, country HPMPs, and "Desk study on the evaluation of the sustainability of the Montreal Protocol achievements," document UNEP/OzL.Pro/ExCom/84/12 Constraints: No systematic follow-up included in the design of the project to assess sustainability of achievements

Criteria and key evaluation questions	**Sub-questions (based on document UNEP/OzL.Pro/ExCom/86/12/Rev.1)**	**Indicators**	**Data collection tools/methods, key informants/constraints**
	project results? Were there follow-up mechanisms or incentives to track the sustainability of these projects? If so, how was it achieved? Upon completion of the demonstration project, what were the main challenges faced to achieve a broader adoption of the selected low-GWP technology beyond the demonstration project? To what extent have those challenges been addressed through the HPMPs, and the technology adopted in the country? Could any of these challenges have been addressed through a different demonstration project design, or are these challenges beyond the scope of the demonstration project? Once the technology was adopted by the beneficiary, how were the different aspects of the technology assessed (i.e., performance, safety, environmental impact, level of difficulty of application at manufacturing, usability at the end-user level)? Did the project include independent assessments and follow industry standard methodologies for these assessments?		after project completion; no consistent information available for projects to infer findings on sustainability as a whole
How were the communication plans associated with these projects to disseminate knowledge about the outcomes?	What communication tools and platforms were used for disseminating the results of the project (e.g., information on availability and specific use characteristics of the new alternative; engineering design of product and manufacturing process; product development and testing; consumer adoption of product and performance feedback; product release conferences including involvement of industry associations at national and regional level; environment impact of product adoption) to stakeholders at national and regional levels? In cases where more than one enterprise was involved in the project (e.g., in the servicing sector), how were the project design and project implementation plan communicated to different stakeholders to secure their collaboration and ensure a smooth implementation? What were the challenges encountered in communicating lessons learned from this experience? Were the results of the communication efforts useful to influence policy making and to encourage adoption of demonstrated technologies and methodologies nationally, regionally and globally?	• Knowledge dissemination programmes and activities (designed and implemented) • Budget and resource allocation • Final output of communication activities • Challenges highlighted in the project documents	Desk review: Project design documents, PCRs, factsheets, final project reports and questionnaires to IAs

Criteria and key evaluation questions	Sub-questions (based on document UNEP/OzL.Pro/ExCom/86/12/Rev.1)	Indicators	Data collection tools/methods, key informants/constraints
Were projects able to provide required technical assistance for operating new technologies?	What were the technical assistance needs during implementation and how were they met (e.g., training of technical personnel, training of national experts, environmental and safety audits of the facilities)? How were the training workshops planned and conducted? Where did the training take place? What indicators were used to measure success of the training conducted?	• Training activities reported by IAs • No specific indicator was defined apart from the reference to the trainings held included in the reports	Desk review: Project design documents, PCRs, factsheets, final project reports and questionnaires and interviews to IAs
How were these projects replicated in sector/region based on successful outcome of demonstration?	How wide is adoption of these technologies after successful demonstration was achieved? What are the typical issues impacting wider use of these technologies? Did operators and technicians in the converted manufacturing plants, or in charge of servicing equipment using the new technology, require a specific licence or certification? How was it provided?	• Actual up-take of successful technologies in the sector/region	
Gender mainstreaming			
Gender mainstreaming in project design and implementation	How did the project design take into consideration gender mainstreaming elements? What indicators were identified to measure the integration of the gender policy? What impact did the project have on gender mainstreaming parameters and sustainability of gender mainstreaming in the sector/industry?	• Inclusion (non) of gender elements in project design • Monitoring framework to reporting on gender issues • Consideration of gender dimension during implementation	Desk review: Project design documents, PCRs, factsheets, final project reports and questionnaires and interviews to IAs Constraint: Demonstration projects were approved prior to the MLF’s gender mainstreaming policy. Limited information available.

Annex V

LIST OF DOCUMENTS REVIEWED

Document number/Source	Title/Description
Executive Committee documents	
UNEP/OzL.Pro/ExCom/55/47	Revised analysis of relevant cost considerations surrounding the financing of HCFC phase-out (decisions 53/37(i) and 54/40)
UNEP/OzL.Pro/ExCom/72/40	Overview of approved HCFC demonstration projects and options for additional projects to demonstrate climate-friendly and energy-efficient alternative technologies to HCFC (decision 71/51(a))
UNEP/OzL.Pro/ExCom/73/8	Desk study on the evaluation of HCFC phase-out projects in the foam sector
UNEP/OzL.Pro/ExCom/62/9 UNEP/OzL.Pro/ExCom/63/15 UNEP/OzL.Pro/ExCom/65/12 UNEP/OzL.Pro/ExCom/66/17 UNEP/OzL.Pro/ExCom/67/06 UNEP/OzL.Pro/ExCom/72/11 UNEP/OzL.Pro/ExCom/73/17 UNEP/OzL.Pro/ExCom/76/10 UNEP/OzL.Pro/ExCom/81/10 UNEP/OzL.Pro/ExCom/83/11 UNEP/OzL.Pro/ExCom/84/22 UNEP/OzL.Pro/ExCom/85/9	Status reports and reports on projects with specific reporting requirements
UNEP/OzL.Pro/ExCom/75/9	Desk study on the evaluation of HCFC phase-out projects in the refrigeration and air-conditioning manufacturing sector
UNEP/OzL.Pro/ExCom/82/11	Final report of the evaluation of the refrigeration servicing sector
UNEP/OzL.Pro/ExCom/84/12	Desk study on the evaluation of the sustainability of the Montreal Protocol achievements
UNEP/OzL.Pro/ExCom/89/10	Analysis of the incremental capital costs and incremental operating costs and their duration, and the cost-effectiveness of all approved investment projects in the relevant manufacturing sectors and sub-sectors (decision 84/87(a))
Project-specific internal documents of the Multilateral Fund Secretariat	For each demonstration project: Project submission by agencies, project proposal and evaluation sheet submitted to the Executive Committee, progress report, project completion report, factsheet, final project report, comments from the MLFS on final project report, status reports and reports on projects with specific reporting requirements
Written responses to questionnaires	Implementing agencies filled the questionnaires prepared for this desk study and also had follow-up discussions with the consultant when needed
Technology and Economic Assessment Panel reports	
Report of the Technology and Economic Assessment Panel, May 2021	Volume 4: Decision XXXI/7 - Continued provision of information on energy-efficient and low-global-warming-potential technologies
RTOC 2018	Report of the Refrigeration, Air Conditioning and Heat Pumps. 2018, Technical Options Committee. https://ozone.unep.org/sites/default/files/2019-04/RTOC-assessment-report-2018_0.pdf