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EXECUTIVE COMMITTEE OF
THE MULTILATERAL FUND FOR THE
IMPLEMENTATION OF THE MONTREAL PROTOCOL

Eighty-ninth Meeting

Montreal, 7-11 March 2022

Postponed to 16, 18 and 20 May 2022 (part I) and
16-18 June 2022 (part II)¹

Addendum

**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))**

1. This addendum, presenting a preliminary analysis of the incremental capital costs (ICCs) and incremental operating costs (IOCs) incurred in four completed HFC-related stand-alone investment projects approved pursuant to decision 78/3(g), is issued to complement the analysis provided in document UNEP/OzL.Pro/ExCom/89/10 in response to decision 84/87(a).

¹ Due to coronavirus disease (COVID-19), part I of the 89th meeting will be held online while part II will be held in person.

Background

2. At its 78th meeting, the Executive Committee decided to consider approving a limited number of HFC-related projects in the manufacturing sector only, to gain experience in the ICCs and IOCs that might be associated with phasing down HFCs in Article 5 countries (decision 78/3(g)).² The Executive Committee further agreed *inter alia* to adopt additional criteria that these projects should meet (decision 79/45) and to invite bilateral and implementing agencies to present project proposals for submission up to and including the 84th meeting, especially in sectors that were not covered by projects approved up to and including the 81st meeting (decision 81/53).

3. Subsequently, at its 84th meeting, the Executive Committee decided to continue considering proposals for HFC-related stand-alone investment projects up to the 87th meeting, in accordance with the criteria set out in decisions 78/3(g), 79/45, and 81/53, and prioritizing projects in the stationary air-conditioning (AC), commercial refrigeration, and mobile AC sectors (decision 84/53).

4. In order to provide information that could be useful to the Executive Committee as it resumes in-person discussions on the HFC cost guidelines at the 89th meeting, the Secretariat prepared the present addendum, including an overview of the projects approved, their status, and preliminary information on costs reported by the first four completed projects.

Overview and status of progress

5. Between the 80th and 87th meetings, the Executive Committee approved a total of 10 HFC-related stand-alone investment projects in the polyurethane (PU) foam, domestic refrigeration, commercial refrigeration, and commercial AC manufacturing sectors to phase out 1,111 metric tonnes (mt) of HFCs with a net climate impact of 1,628,178 CO₂-equivalent tonnes. A summary list of approved projects is presented in table 1, and further details are contained in Annex I.

Table 1. HFC-related stand-alone investment projects approved pursuant to decision 78/3(g)

| Country | Agency | Sector | Enterprise | Funds approved (US \$) | HFC phase-out (mt) | Date of completion |
|---------------------------------------|-------------|---------------------------------------|-------------------|------------------------|--------------------|--------------------|
| Final reports received | | | | | | |
| Bangladesh | UNDP | Domestic refrigeration | Walton | 3,131,610 | 230.6 | Dec-19 |
| China | UNDP | Domestic refrigeration (PU foam) | Hisense Kelon | 1,275,000 | 250.0 | Jun-21 |
| Dominican Republic | UNDP/Canada | Commercial refrigeration | Farco | 129,825 | 4.2 | Nov-20 |
| Mexico | UNDP | Domestic refrigeration | Mabe | 2,700,000 | 198.0 | Nov-20 |
| Final reports not received yet | | | | | | |
| Argentina | UNIDO | Domestic and commercial refrigeration | Several | 1,840,755 | 96.6 | Jan-22 |
| Jordan | UNIDO | Commercial AC | Petra Engineering | 1,637,610 | 118.7 | *Jun-20 |
| Lebanon | UNIDO | Domestic and commercial refrigeration | Lematic Ind. | 1,053,858 | 112.5 | Dec-20 |
| Mexico | UNIDO | Commercial refrigeration | Imbera | 1,018,123 | 76.9 | Dec-21 |

² To consider approving a limited number of HFC-related projects in the manufacturing sector only, without prejudice to different kinds of technology, no later than at the first meeting of 2019, to allow the Committee to gain experience in the ICCs and IOCs that might be associated with phasing down HFCs in Article 5 countries, on the understanding: that any Article 5 country that submitted a project should have ratified the Kigali Amendment or submitted a formal letter indicating the government's intention to ratify the Amendment; that no further funding would be available until the instrument of ratification had been received by the depositary at the Headquarters of the United Nations in New York; and that any amount of HFC reduced as a result of the project would be deducted from the starting point.

| Country | Agency | Sector | Enterprise | Funds approved (US \$) | HFC phase-out (mt) | Date of completion |
|----------|-------------|--------------------------|-------------------|------------------------|--------------------|--------------------|
| Thailand | World Bank | Commercial refrigeration | Pattana Intercool | 183,514 | 8.8 | Mar-21 |
| Zimbabwe | UNDP/France | Domestic refrigeration | Capri | 426,954 | 14.5 | Jun-22 |

* A request for extension will be submitted for the Executive Committee's consideration at the 90th meeting.

6. The Executive Committee approved these proposals *inter alia* on the understanding that the projects would be completed within 24 months of the transfer of funds to the implementing agency and that a comprehensive completion report would be submitted within six months of project completion, with detailed information on:

- (a) The eligible ICCs for all equipment and other components, including those not funded under the project;
- (b) The IOCs;
- (c) Any possible savings incurred during the conversion and relevant factors that facilitated implementation (e.g., whether any purchased and/or installed equipment or supplies had gone through a competitive quote/bidding process and the details thereof);
- (d) Changes in the energy efficiency of the products being manufactured and any related policies undertaken by the Government; and
- (e) Information on the implementation of the servicing component, where applicable.

7. As of May 2022, the Secretariat has received final reports for four projects, as shown in table 1, and an interim report on one additional project, which would require an extension to complete certain activities.³

8. Due to several factors, including the impact of the COVID-19 pandemic, the dates of completion for many of the projects approved pursuant to decision 78/3(g) have been extended by the Executive Committee, and their final reports have not yet been received.

Preliminary information on the reported costs

Overall ICCs and IOCs reported so far

9. Table 2 presents the ICCs and IOCs reported so far by the implementing agencies for projects approved pursuant to decision 78/3(g).

Table 2. ICCs and IOCs reported for HFC investment projects by sector as of May 2022

| Country / Enterprise / Component | HFC phased out (mt) | Funds approved (US \$) | Costs reported (US \$) | | | CE** (US \$ /mt) | |
|---|---------------------|------------------------|------------------------|-----------|---------------------|------------------|--------|
| | | | ICCs | IOCs | Servicing component | | Total* |
| Domestic refrigeration (PU foam) | | | | | | | |
| China / Hisense Kelon | | | | | | | |
| Foam | ***251.8 | 1,275,000 | 2,057,345 | 1,647,099 | n/a | 3,704,444 | 14.71 |

³ A request for the extension of one commercial AC project in Jordan is being presented for the Executive Committee's consideration in document UNEP/OzL.Pro/ExCom/90/9.

| Country / Enterprise / Component | HFC phased out (mt) | Funds approved (US \$) | Costs reported (US \$) | | | | CE** (US \$ /mt) |
|--|---------------------|------------------------|------------------------|-----------|---------------------|------------|------------------|
| | | | ICCs | IOCs | Servicing component | Total* | |
| Domestic refrigeration /Domestic and commercial refrigeration | | | | | | | |
| Argentina / Several | | | | | | | |
| Refrigeration | 96.6 | 1,840,755 | pending | pending | n/a | pending | pending |
| Bangladesh / Walton | | | | | | | |
| Refrigeration | 230.6 | 1,320,678 | 2,645,177 | 471,420 | 180,000 | 3,296,597 | 14.29 |
| Compressors | | 1,810,932 | 3,832,911 | n/a | n/a | 3,832,911 | n/a |
| Lebanon / Lematic | | | | | | | |
| Refrigeration | 112.5 | 1,053,858 | pending | pending | pending | pending | pending |
| Mexico / Mabe | | | | | | | |
| Refrigeration | 198.0 | 1,200,216 | ****10,969,083 | 9,073,557 | n/a | 20,042,640 | 101.23 |
| Compressors | | 1,499,784 | *****13,614,652 | n/a | n/a | 13,614,652 | n/a |
| Zimbabwe / Capri | | | | | | | |
| Refrigeration | 14.5 | 426,954 | pending | pending | n/a | pending | pending |
| Commercial refrigeration | | | | | | | |
| Dominican Republic / Farco | | | | | | | |
| Refrigeration | 4.2 | 129,825 | 653,101 | 9,885 | n/a | 662,986 | 157.85 |
| Mexico / Imbera | | | | | | | |
| Refrigeration | 76.9 | 1,018,123 | pending | pending | pending | pending | pending |
| Thailand / Pattana Int. | | | | | | | |
| Refrigeration | 8.8 | 183,514 | pending | pending | n/a | pending | pending |
| Commercial AC | | | | | | | |
| Jordan / Petra | | | | | | | |
| AC | 118.7 | 1,637,610 | 1,521,120 | 0 | n/a | pending | pending |

* Differences between the approved and reported costs were co-financed by the enterprises and other funding sources.

** Cost-effectiveness based on the actual reported costs.

*** Amount of HFC-245fa phased out (251.85 mt) was slightly higher than the 250 mt proposed in the project.

**** Includes additional costs of US \$6,549,892 not proposed in the project.

***** Includes additional costs of US \$4,838,182 not proposed in the project.

10. The Secretariat is undertaking a detailed review and analysis of costs presented in the four final reports received so far, obtaining clarifications and additional details from the relevant implementing agencies where necessary. The successful implementation and completion of the projects, as well as the clarifications and additional information provided by the implementing agencies during the review of these reports, are noted with appreciation.

11. While the Secretariat has progressed in the review of reports received so far, it should be noted that a comparative analysis of costs reported for different projects in similar applications is required to better understand the actual costs for each application, and that such an analysis can only be provided once all projects have been completed and reports received. As several projects are still ongoing, the Secretariat will only be able to complete this analysis and present its results in a consolidated manner at a future meeting. One exception is the stand-alone project at Hisense Kelon, as it was the only one approved for the PU foam sector and hence does not require comparative analysis; a summary of the analysis of the costs reported by this project is presented below.

Preliminary analysis of the stand-alone project in the PU foam (domestic refrigeration) sector

12. The project converted one domestic-refrigerator manufacturing line with a production capacity of 1,200,000 units/year and consumption of 250 mt of HFC-245fa. The project phased out 251.85 mt of HFC-245fa and the costs reported for the conversion of the manufacturing line from HFC-245fa and cyclopentane to HFO-1233zd(E) and cyclopentane are presented in table 3.

Table 3. Costs of conversion of one manufacturing line at Hisense Kelon (US \$)

| Item | As proposed* | As approved | As reported |
|---|------------------|------------------|------------------|
| ICCs | | | |
| Supply control system | 65,000 | - | 133,555 |
| Static pre-mixing machine | 250,000 | - | 319,372 |
| Foaming machine | 1,412,000 | - | 1,323,943 |
| Sealing rings | - | 10,000 | 10,188 |
| System development and product trials | - | 110,000 | 236,193 |
| Technical assistance, training, certification, verification | - | 28,000 | 34,095 |
| Contingencies | 172,700 | - | - |
| Sub-total ICCs | 1,899,700 | 148,000 | 2,057,345 |
| IOCs | 1,500,000 | 1,127,000 | 1,647,099 |
| Technical assistance | 64,000 | - | - |
| Total costs | 3,463,700 | 1,275,000 | 3,704,444 |
| HFC consumption (mt) | 250 | 250 | 251.85 |
| Cost-effectiveness (US \$/kg) | 13.85 | 5.10 | 14.71 |

* Of the total proposed cost of US \$3,463,700, UNDP requested US \$2,343,000 at US \$9.37/kg, while the difference of US \$1,121,700 was proposed to be co-financed by the enterprise.

ICCs

13. The project incurred capital costs related to the following issues:

- (a) *Higher solvency properties of HFO-1233zd(E)*: Sealing rings in different parts of the manufacturing equipment needed to be replaced due to the higher solvency of HFO-1233zd(E). This cost was considered incremental by the Secretariat and covered in the approval of the project at US \$10,000; the reported cost was US \$10,188;
- (b) *Need to change the mixing ratios of metering units for polyols and MDI*: The baseline equipment of the manufacturing line had to be retrofitted (i.e., supply control system for US \$133,555, pre-mixing machine for an estimated US \$269,372, and three foam dispensers for US \$801,000) due to the change in the mixing ratios of formulation components (polyol and MDI). These costs were covered by the enterprise. The supply control system and three foam dispensers had been in operation since 2005 and nearing the end of their useful life.⁴ In future projects, similar modifications will be assessed on a case-by-case basis, noting that they should not be required for more recent baseline equipment; and
- (c) *Need for tighter temperature control*: New temperature control devices were added to the manufacturing process: chillers in the pre-mixing area (US \$50,000), thermal-static devices in the foaming room (US \$20,000) and for the jigs and moulds of the foam machine (US \$82,000), and new cabinet pre-heating systems (US \$170,000). When the project was considered at the 82nd meeting, the Secretariat did not recommend approval of these costs based on an extensive review of available literature and expert advice indicating that there was no technical justification of the need for tighter temperature controls. UNDP explained that ensuring an accurate control of temperature was necessary due to the lower stability of HFO-1233zd(E), owing to its double bond. The Secretariat noted that, given the lower boiling point of HFC-245fa (15.3 degrees Celsius versus 19 degrees Celsius for HFO-1233zd(E)), temperature control devices would normally already be in place to be able to operate with HFC-245fa-based systems and maintain a stable temperature below

⁴ Decision 25/48(ii) indicates that for foam machines nearing the end of their useful life, the incremental cost of conversion should be based on the cost, from the same supplier, of a new machine, from which has been deducted the cost of a replacement ODS-technology machine, or a proportion thereof calculated according to Decision 18/25.

the blowing agent's boiling point. The costs associated with the new temperature-control devices were covered by the enterprise.

14. It has also been noted that the cost for system development and trials was higher than initially envisaged due to additional trials required to ensure a stable system formulation. At the 82nd meeting, the Secretariat noted that, as indicated by the blowing agent manufacturer and in TEAP reports, one of the main advantages of converting to HFO-1233zd(E) in the manufacturing of appliances was in the low ICCs it required, as the substance nears a drop-in replacement for liquid HCFCs, HFCs, and other non-fluorocarbon blowing agents. Other individual projects for the conversion from HCFC-141b to HFO-based technology in different PU foam applications previously approved under the Multilateral Fund, had ICCs between US \$2.0/kg and US \$4.0/kg in most cases. The present project had higher capital costs of US \$8.16/kg, including co-financing by the enterprise, partly due to the age of the converted baseline equipment (supply control, pre-mixer, and PU foam machines) necessitating major modifications. For instance, due to its specific size and other characteristics, the cost of retrofitting one foam dispenser including jigs and molds (US \$267,000) was higher than the cost of procuring a new high-pressure dispenser in other conversions.

15. UNDP confirmed that the capital costs incurred in the conversion were not related to either upgrades or the modernization of baseline equipment, and that all retrofits were carried out to ensure that the technical requirements of the foaming process met the standards required by Hisense Kelon. UNDP also indicated that the replacement of sealing rings and temperature control were essential in all scenarios of implementation with HFO-1233zd(E), while replacing or retrofitting baseline equipment for use with HFOs needed to be assessed on a case-by-case basis. UNDP further pointed out that the identified issues relating to temperature control and stability pertained to the application of HFO-1233zd(E), while other HFOs, such as HFO-1234ze(E), HFO-1336mzzm(Z), or HFO-1336mzzm(E) might behave differently and require other adjustments. So far, there is close to no experience under the Multilateral Fund in the conversion to the above-mentioned HFOs as availability is still limited in most Article 5 countries,

IOCs

16. At the time of project review at the 82nd meeting, based on the information provided by UNDP, the Secretariat supported the need to increase the density of cabinet foam by up to 2.075 per cent once the formulation had been optimized. The IOCs were calculated on that basis at US \$1,127,000, and UNDP was requested to include in the final report detailed information on the formulations developed and used, as well as the optimization achieved in the reduction of density (decision 82/77(c)(ii)).

17. In its final report, UNDP indicated that the IOCs incurred before optimization amounted to US \$1,647,099 (US \$6.54/kg). After the conversion, the enterprise began optimizing the foam formulation with its own resources, achieving promising results in the reduction of foam density (from 30.5-32.5 kg/m³ to 27.5-29.5 kg/m³) and reducing by 5 to 8 per cent the volume of raw materials required. The new formulation is not yet applied in the production process and trials continue, but the preliminary results provided by UNDP indicate a potential 41 per cent reduction in IOCs from the pre-optimization level, with a cost-effectiveness of around US \$4.0/kg. However, the final values can only be confirmed once the final formulation has been decided and adopted. In line with decision 82/77(c)(ii), the Secretariat looks forward to receiving detailed information on the formulations developed and used at the enterprise, as well as the optimization achieved in the reduction of density, as this could be useful for the review of other projects.

Conclusion

18. The only investment project approved to phase out HFCs in the PU foam sector was implemented at an overall cost-effectiveness level of US \$14.71/kg,⁵ which is higher than the cost-effectiveness threshold

⁵ The overall cost-effectiveness includes both costs that were considered incremental and approved, and costs that were covered by the enterprise.

set out for HCFC phase-out in the PU foam sector by decision 74/50. The reasons for this included the need to retrofit aged equipment (a cost covered by the enterprise), which may not be the case for all projects; the need to introduce temperature-control devices due to the reported instability of the blowing agent, and the increase in density of the foam produced with HFO-1233zd(E). Regarding these three main cost drivers, any future investment in equipment would need to be seen on a case-by-case basis, noting that other projects to replace HCFC-141b with HFOs had not required significant investment in equipment so far. Temperature devices would also need to be considered individually, as many enterprises using HFC-245fa are already equipped with temperature-control devices; and the increase in the density of the formulation could be optimized to achieve an actual reduction of the IOCs.

Final observation on the sectors covered by projects approved under decision 78/3(g)

19. Decision 78/3(g) allowed the submission of HFC-related investment projects to gain experience in the ICCs and IOCs that might be associated with phasing down HFCs in Article 5 countries. The Secretariat notes that most of the projects approved and implemented under decision 78/3(g) are in the domestic and stand-alone commercial refrigeration manufacturing sectors, with only one project in the PU foam and one in the commercial AC sector. All these sectors represent only a portion of HFC consumption in the manufacturing sectors. The Executive Committee subsequently prioritized projects in the stationary and mobile AC sectors by decision 84/53; however, only one such project in Sudan was submitted, and later withdrawn.

20. The Secretariat will continue to review and analyze relevant projects with completed final reports and provide further information to the Executive Committee at its 91st meeting.

Annex I

HFC investment projects approved pursuant to decision 78/3(g)

| Country | Agency | Sector | Project | Funds approved (US \$) | HFC phase-out (mt) | Net climate impact (mt CO ₂ -eq) | Date approved | Date completed |
|--|---------------|-------------------------------------|--|------------------------|--------------------|---|---------------|----------------|
| Projects for which final reports have been received | | | | | | | | |
| Bangladesh | UNDP | Domestic refrigeration | Conversion from HFC-134a to R-600a and conversion of a compressor manufacturing facility from HFC-134a- to R-600a-based compressors at Walton Hitech Industries Ltd | 3,131,610 | 230.6 | 329,455 | Nov-17 | Dec-19 |
| China | UNDP | PU foam domestic refrigeration | Conversion from HFC-245fa and cyclopentane to HFO-1233zd(E) and cyclopentane in the manufacturing of domestic refrigerators at Hisense Kelon | 1,275,000 | 250.0 | 256,750 | Dec-18 | Jun-21 |
| Dominican Republic | UNDP / Canada | Commercial refrigeration | Conversion of a commercial refrigerator manufacturing line from HFC-134a and R-404A to R-290 at FARCO | 129,825 | 4.2 | 6,317 | Jun-18 | Nov-20 |
| Mexico | UNDP | Domestic refrigeration | Conversion of a domestic refrigeration manufacturing facility from HFC-134a to R-600a and conversion of a compressor manufacturing facility from HFC-134a to R-600a at Mabe | 2,700,000 | 198.0 | 282,843 | Jun-18 | Nov-20 |
| Projects for which final reports have not been received yet | | | | | | | | |
| Argentina | UNIDO | Domestic & commercial refrigeration | Conversion from HFC-134a to R-600a/R-290-based refrigerants in the manufacturing of domestic and commercial refrigeration equipment at several enterprises | 1,840,755 | 96.6 | 137,924 | Jun-18 | Jan-22 |
| Jordan | UNIDO | Commercial AC | Conversion of a facility manufacturing large commercial unitary rooftop AC units of up to 400kW from HFC-134a, R-407c, and R-410a to R-290 as refrigerant at Petra Engineering | 1,637,610 | 118.7 | 211,317 | Jun-18 | *Jun-20 |
| Lebanon | UNIDO | Domestic & Commercial refrigeration | Conversion from HFC-134a and HFC-404A to R-600a and R-290 in domestic refrigeration at Lematic Industries | 1,053,858 | 112.5 | 245,740 | Jun-18 | Dec-20 |
| Mexico | UNIDO | Commercial refrigeration | Conversion of commercial refrigeration manufacturing in two facilities from the use of HFC-134a and R-404A to R-290 and R-600a as refrigerants at Imbera | 1,018,123 | 76.9 | 124,575 | Jun-18 | Dec-21 |
| Thailand | World Bank | Commercial refrigeration | Conversion from HFC to R-290 and R-600a in the manufacturing of commercial refrigeration appliances in Pattana Intercool Co. Ltd | 183,514 | 8.8 | 12,543 | Dec-18 | Mar-21 |
| Zimbabwe | UNDP / France | Domestic refrigeration | Conversion from HFC-134a to R-600a in the manufacturing of domestic refrigerators at Capri (SME Harare) | 426,954 | 14.5 | 20,704 | Dec-18 | Jun-22 |
| Total | | | | 13,397,249 | 1,111 | 1,628,178 | | |

*A request for extension to be submitted for the Executive Committee's consideration at the 90th meeting.