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EXECUTIVE COMMITTEE OF
THE MULTILATERAL FUND FOR THE
IMPLEMENTATION OF THE MONTREAL PROTOCOL
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Montreal, 27-31 May 2024
Item 10 of the provisional agenda[1]

PAPER ON THE ISSUE OF ALTERNATIVES IN POLYURETHANE FOAM MANUFACTURING

(paragraph 127 of document UNEP/OzL.Pro/ExCom/93/105)

Background

1. At the 93rd Executive Committee meeting, under agenda item "Overview of issues identified during project review," the Secretariat presented the issue of HFCs contained in imported pre-blended polyols in the polyurethane (PU) foam sector in stage I of the Kigali HFC implementation plans (KIPs). During the ensuing discussion, two members emphasized the difficulties faced by some countries in sourcing low-global-warming-potential (GWP) alternatives to HCFCs in the PU foam sector, including pre-blended polyols, leading to project implementation delays, with one of them stating that hydrofluoroolefins (HFOs) were not a sustainable alternative because of their rapid decomposition, a consideration that should be reflected in a Secretariat's note on the issue. Members agreed that the issue of alternatives in PU foam manufacturing should be discussed at the 94th meeting, and that the Secretariat should prepare a separate paper for consideration at that meeting, presenting related experiences, best practices, and information gathered so far.

2. In response to this request, the Secretariat has undertaken a review of available data on PU foam sector projects implemented within ongoing HCFC phase-out management plans (HPMPs), consulted with bilateral and implementing agencies during the Inter-Agency Coordination Meeting in March 2024, solicited written input from UNDP, UNIDO, and the World Bank on relevant projects, and consulted the reports of the Open-ended Working Group (OEWG), the Meeting of the Parties (MOP) to the Montreal Protocol, and the 2022 Foam Technical Options Committee (FTOC) assessment report. The present document has been prepared taking into account information obtained from the above sources.

[1] UNEP/OzL.Pro/ExCom/94/1

3. One Executive Committee member, the government of Argentina also sent input to the Secretariat on the status in the Latin America region. Information on prices and delivery times is included as technical information in this document and its annex.

HCFC phase-out projects in the polyurethane foam manufacturing sector assisted by the Multilateral Fund

4. As of April 2024, the Executive Committee has approved, as part of 48 HPMPs, individual projects for the conversion of PU foam enterprises manufacturing various types of foam products[2] to hydrocarbons (HCs) (cyclopentane, n-pentane, isopentane and pre-blended polyols containing HCs), methyl formate, methylal, water-based technology, HFOs (i.e., HFO-1233zd(E), HFO-1336mzz(Z)) and in two cases during stage I, HFC-245fa.

5. Of those, the HPMPs of several countries[3] have also included projects for the adaptation of locally owned systems houses to the manufacturing of non-HCFC-141b pre-blended polyol systems and, through them, conversion of numerous downstream foam enterprises.

6. The total HCFC consumption associated with these projects amounted to 8,792 ODP tonnes or 79,932 metric tonnes (mt) of HCFC-141b and 27 ODP tonnes (485 mt) of HCFC-22.

7. In addition, the Executive Committee approved 13 projects to demonstrate low-GWP technologies as alternatives to HCFCs in the PU foam manufacturing sector, including HCs pure and pre-blended in polyols, methyl formate, methylal, supercritical CO_2, and HFOs (HFO-1233zd(E), HFO-1336mzz(Z)).

8. In the HFC phase-down context, at the 82nd meeting, the Executive Committee approved a stand-alone investment project for conversion from cyclopentane blended with HFC-245fa (250 mt or 257,500 CO_2-eq tonnes) to cyclopentane blended with HFO-1233zd(E) in the manufacturing of foam panels for domestic refrigerators at one enterprise in China (pursuant to decision 78/3(g)); and at the 93rd meeting, as part of the KIP for Mexico, the Committee approved the PU foam sector plan for the total phase-out of HFCs (596 mt or 545,791 CO_2- eq tonnes) with HFOs as the selected alternative.

Experience in the implementation of projects, best practices, and information on alternatives with low global-warming potential in the polyurethane foam sector

9. Bilateral and implementing agencies have shared insights of their involvement in assisting Article 5 countries in the PU foam sector, including experience gained, main challenges encountered, and the best practices followed by the assisted governments and enterprises to ensure the sustained adoption of the low-GWP technologies.

10. In addition to ensuring the engagement, and in some cases co-financing, of the beneficiary enterprises to convert to the selected technologies, the assistance provided to Article 5 countries in adopting low-GWP alternatives in the PU foam sector involved technical assistance and capacity building on the use of the selected alternative, technology transfer, and demonstration at other enterprises locally or abroad.

11. A crucial factor enabling the transition of numerous small and medium-sized enterprises (SMEs) in Article 5 countries has been the support provided to local systems houses to develop formulations based on low-GWP technologies. These supported systems houses have played a central role in offering technical guidance to SMEs in the adoption of such technologies.

[2] E.g., insulation foam for refrigeration appliances, panels, insulation for water heaters, block, and integral skin.
[3] Argentina, Brazil, Chile, Colombia, Egypt, Indonesia, the Islamic Republic of Iran, Mexico, Nigeria, Saudi Arabia, and South Africa.

12. An effective practice to ensure the sustainability of HCFC phase-out in the sector continues to be the promulgation of regulatory measures to support the conversions of local enterprises to low-GWP alternatives, generally in the form of bans on the import and/or use of controlled substances in the PU foam application or sector. In several cases, these measures have been delayed if appropriate low-GWP alternatives were not available for specific applications (i.e., non-flammable substances with acceptable insulation properties in spray foam applications). In some countries, such as China and Thailand, measures covering specific applications have been promulgated, leaving others for later; in others, the ban on HCFC-141b in pure form has preceded the ban on HCFC-141b contained in imported pre-blended polyols to allow additional time for the adoption of alternatives, especially by the SMEs.

13. The selection of alternatives has depended on the performance requirements of the specific application (e.g., insulation performance), the infrastructure and capacity of the enterprises to adopt low-GWP technologies, the operational costs of the technology, the location of the enterprise, and local policies related to occupational health and safety. A brief overview of the agencies' experience regarding the adoption of different low-GWP technologies is presented below.

Hydrocarbon-based technology

14. Technology based on HCs remains the preferred option for larger enterprises, driven by factors such as product quality and operating costs. Conversion to HC-based technology entails relatively large incremental capital costs for the adaptations needed to operate with flammable foam-blowing agents. In some instances, enterprises needed to provide co-financing. Despite generally smooth project implementation, delays have occurred primarily linked to completion of safety-related plant adaptations and the obtention of permits for operating with flammable substances in specific locations.

15. It is also reported that this technology remains largely inaccessible to small enterprises lacking the necessary technical expertise and resources. HCs and pre-blended polyols based on HCs, still highly flammable, are not suitable for spray foam due to safety. Although pre-blended polyols based on HCs may represent a potential alternative for some enterprises in some applications, their sales can be limited due to stringent safety requirements.

Methyl formate and methylal

16. Implementing agencies have shared their experiences with methyl formate and methylal with positive results in some applications, although with technical challenges reported in certain formulations and concerns about performance in terms of thermal behavior and other parameters. Corrosion issues associated with methyl formate have been addressed through changes in materials. Both blowing agents are flammable and both have been used in formulations combined with other blowing agents to reduce the cost of PU foam systems. However, their adoption has been generally limited.

Water-based technology

17. Water-based technology has been widely used by SMEs in applications where insulation performance is of lesser importance or where costs associated with safety measures are prohibitive. However, water-blown systems present inferior thermal performance and challenges associated with adhesion and significant shrinkage after the foam has cooled, leading to various complications in foam processing and catalyst usage. To compensate for the suboptimal foam properties, greater quantities of MDI[4] are required, rendering water-based systems more expensive compared to HCFC-141b. Despite these challenges, there have been reports of improvements in water-based systems over time, and the technology

[4] Methylene diphenyl diisocyanate (MDI), chemical agent used in the manufacturing of a variety of PU products.

continues to be adopted in various applications, albeit with acknowledged performance limitations. Water has also been used as a co-blowing agent alongside methyl formate, methylal, or HFOs.

Hydrofluoroolefins

18. The agencies reported that transitioning from HCFC-141b to HFO-based systems was relatively straightforward, with operational processes closely mirroring those of HCFC-based systems. Demonstration projects funded by the Multilateral Fund in various countries, such as Colombia, Saudi Arabia and Thailand, have produced positive outcomes in the use of HFOs, whether pure or blended with water in specific proportions.[5] An identified challenge when using HFO-1233zd(E) is its low boiling point, which requires careful temperature control during the transfer of the polyol blend from the drum to the foaming machine's work tank, a challenge also observed in spray foam applications. Concerns have also been raised regarding the shorter shelf life of systems based on HFOs containing chlorine, which may pose logistical challenges. Nevertheless, the primary issue identified in adopting HFO-based technology remains the availability and pricing of the blowing agent, as described below.

19. During the IACM, one implementing agency made the point that discussions on the impacts of per- and polyfluoroalkyl substances (PFAS) might have caused concerns in some countries regarding the long-term viability on the adoption of HFOs as PU foam alternatives. On this matter, at the 45th OEWG meeting, one representative expressed concern over the increasing use of PFAS, many of them as substitutes for substances controlled under the Montreal Protocol and urged parties to consider the potential consequences for the climate and environment when assessing the use of alternatives to controlled substances.[6] In its 2023 progress report presentation to the meeting, the Technology and Economic Assessment Panel (TEAP) noted that PFAS have been defined differently by national and sub-national jurisdictions.[7] At the 35th MOP (October 2023), the TEAP indicated that the proposed broad PFAS regulations could limit the use of HFOs, potentially affecting HFC phase-down.[8]

Blowing agent prices and availability

20. The implementing agencies reported that several Article 5 countries had designed their PU foam sector plans with the goal of adopting HFO-based technologies, based on the expectation that HFOs would be fully commercially available by 2015, as initially indicated by suppliers. However, the availability of those substances has proven inconsistent, with prices varying greatly among regions and from country to country, from US $18/kg in the United Arab Emirates up to US $25/kg in Pakistan in Asia, and from US $17/kg to US $35/kg in Latin America, with availability depending on the country.

21. The 2022 FTOC Assessment Report[9] noted shortages of low-GWP foam blowing agents in both Article 5 and non-Article 5 parties, though less severe than previously reported. Supply issues arose in 2020 due to logistics, raw material shortages, manufacturing issues, weather, and increasing demand. Undisclosed manufacturing issues from at least one HFO/HCFO supplier led to *force majeure* declarations, according to several foam manufacturers. Shortages of HCs of sufficient purity for foam use, such as cyclopentane, had also been reported. Consequently, some Article 5 parties increasingly use HFC365mfc/HFC-227ea or HFC-365mfc/HFC-245fa blends, while non-Article 5 parties revert to HFC-365mfc blends and HFC-245fa due to their availability. The report also indicated information that at least one HFC foam blowing agent

[5] HFOs blended with water could help reduce production costs, but there is a limit to the proportion of water that can be introduced in the formulation without affecting foam properties.
[6] Report of the forty-fifth meeting of the OEWG of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer, paragraph 57.
[7] Examples of how different organisations and jurisdictions are addressing the issue of PFAS can be found in the report of the forty-fifth meeting of the OEWG of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer, Annex II, page 67.
[8] Report of the Thirty-Fifth Meeting of the Parties to the Montreal Protocol, paragraph 75.
[9] Flexible and Rigid Foams Technical Options Committee 2022 Assessment Report

manufacturing facility will close in 2024 and additional production capacity for HFOs/HCFOs has come online.

22. At the 44th OEWG meeting (July 2022), in its 2022 Progress Report, the TEAP informed of challenges with production and chemical supply of low-GWP HCFO and HFO foam blowing agents related to several factors, including production constraints, restrictive patents, high prices relative to HCFC-141b and HFC blowing agents, and regional shortages of CTC used as raw material in the process to manufacture HCFO/HFOs. New production capacity for HCFO/HFOs was expected to be available in 2023.[10]

23. At the 34th MOP, the TEAP reported that there were remaining challenges, especially for SMEs and field-applied systems, including the higher prices of HFOs/HCFOs, the potentially cost-prohibitive capital investment of HCs to address safety challenges for smaller companies, and safety considerations for field-applied foams, which limit alternatives. The insufficient supply of HFO/HCFO foam blowing agents had resulted in delayed conversions in some parties or reversion to HFCs for some companies.[11]

24. At the 45th OEWG meeting (July 2023) the FTOC had reported that for alternatives, including HFOs and HCs, specifically cyclopentane, supply was insufficient to meet demand, based on reports from several companies. However, additional capacity had come online in recent years, and the same companies now reported that the situation had eased somewhat, and supply had increased.[12]

Additional identified challenges

25. In addition to the extensively reported impact of the COVID-19 pandemic on all consuming sectors in recent years, a significant challenge reported in implementing PU foam sector plans, notably in Latin America, has been the continued availability of low-priced HFCs (i.e., HFC-365mfc and the HFC-365mfc/HFC-227ea blend) combined with the lack of availability of HFOs and their high prices when available. As a result, many foam manufacturers, especially SME downstream users supplied by systems houses, have been reluctant to commit to never using HFCs, as long as those are available on the market. This situation has caused difficulties in engaging enterprises to replace HCFC-141b with low-GWP alternatives and delays in the implementation of projects, as observed in previous HPMP tranche submission requests submitted by Brazil.[13]

26. Some systems houses supplying HFO-pre-blended polyols also offer systems based on HFC-245fa and HFC-365mfc at a significantly lower cost than HFO systems. Therefore, it is challenging to monitor the consistent use of HFO-based pre-blended polyols in converted plants. Local systems houses continue to explore alternative options, with technical assistance provided to their downstream users to facilitate transition to other low-GWP alternatives, where feasible.

27. The closure of HFC-365 production may alleviate this issue, though it remains uncertain whether HFC-245fa will replace HFC-365mfc.

Feedback per region

28. The subsections below provide information on the status of implementation and adoption of alternatives of PU foam projects in stages II of the HPMPs for several countries. This information has been obtained form different sources, including inputs provided by UNIDO and the World Bank, information on

[10] 2022 Progress Report, TEAP, available at https://ozone.unep.org/system/files/documents/TEAP%20Progress%20Report%2044th%20OEWG.pdf

[11] Report of the Thirty-Fourth Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer, Annex I, paragraphs 22, 25

[12] Report of the forty-fifth meeting of the OEWG of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer, paragraph 47

[13] UNEP/OzL.Pro/ExCom/88/39

progress reports available in the Secretariat for all regions as well as additional input for Latin America from the government of Argentina. Information presented in these subsections and in the annex to the present document does not include all countries with projects in the PU foam sector.

Asia and the Pacific

29. A PU foam component has been included in stages II of the HPMP of several countries, *inter alia*:

(a) In China, larger PU foam enterprises have been converting to cyclopentane and water-based technology, while systems houses were assisting spray foam enterprises in transitioning to HFO-1233zd(E); HFO-1336mzzd was only used in niche applications and more expensive;

(b) In the Islamic Republic of Iran, larger PU foam enterprises converted to cyclopentane, while SMEs were converting to pre-blended HC systems or water-based technology. The number of enterprises assisted was reduced over time due to issues related to eligibility, cessation of production or self-funded conversions. Fifteen SMEs requested a change of technology from water-based to pre-blended HC due to performance-related issues;[14]

(c) In India, 158 PU foam enterprises were assisted in converting to a variety of low-GWP alternatives. As of the 91st meeting, 92 of them had become fully operational with the new technology selected, while the remaining 66 enterprises were completing trials and certification;

(d) Jordan received assistance for 3l large PU foam enterprises to convert to cyclopentane and for 43 SMEs and six spray foam enterprises to convert to HFOs. Between the 83rd and 87th meetings,[15] six enterprises changed technology from the initially selected HFO to cyclopentane, and five additional ones changed to water-based, as HFO-based technology was not available from the regional systems houses;

(e) Malaysia received assistance for the conversion of 10 large PU foam enterprises and 57 SMEs to low-GWP alternatives (HCs, pre-blended HCs and HFOs). Larger and many of the medium-sized enterprises converted to HC but some SMEs struggled to find an alternative due to large investment associated with HCs, price and availability of HFOs, or performance below expectations of methyl formate and methylal. Fifteen of the SMEs withdrew from the project to convert to HFC in pre-blended polyols (primarily based on HFC-365mfc), an additional 11 withdrew from the project due to financial difficulties and converted to pre-blended HFCs. All active PU foam enterprises completed their conversions to HCs, pre-blended HCs, methylal (2) and water-based systems, and none to methyl formate given the limited supply chain for that blowing agent and concerns about the royalties held for pre-blended methyl formate systems. An additional concern expressed by the PU foam industry in Malaysia related to potential emissions and controls of PFAS being discussed in various fora;

(f) In Vietnam, most enterprises stopped using HCFCs on their own due to a market shift, a ban on bulk HCFC-141b, and a construction sector policy on insulated roofing. Enterprises converted to lower-cost water-blown technology that is the most popular alternative, especially for roofing panels;

(g) In Thailand, most PU foam enterprises that could afford high capital investment converted to cyclopentane. Smaller enterprises have been using HFC-245fa for products requiring a

[14] Decision 84/74(b)(i)
[15] Decision 83/24(b), 86/25(b) and 87/12(b)

high insulation property and water-based technology for products where the insulation property is not critical. For spray foam applications, a large part of the market has shifted towards PU foam insulated roofing panels. Some PU foam enterprises that were not eligible for funding and those deciding not to participate in the Fund-supported activities have opted for HFC-365mfc/HFC-227ea due to its higher boiling point. While HFOs are available, their prices are substantially higher than those for other blowing agents. With the phase-out of HFC-365mfc production, several enterprises reverted to the use of HFC-245fa.

Africa

30. Several countries in the African region included PU foam projects in stage II of their HPMPs (i.e., Egypt, Nigeria, Sudan, and Tunisia). The implementing agencies provided information on Tunisia, where two PU foam enterprises changed technology from cyclopentane to HFO, given the large initial investment required by the enterprises to adopt a flammable blowing agent and the availability of HFO-based polyol systems supplied by a local systems house.

31. In the case of Nigeria, where one enterprise, 37 SMEs and four commercial refrigeration enterprises are being assisted to convert to cyclopentane, methyl formate, HFOs or water depending on the enterprise and application, no specific issues have been reported. The four commercial refrigeration enterprises converted to HFO-based chemicals to produce insulation foam for cold rooms, while the other conversions are still ongoing.[16]

Latin America

32. Several HPMPs in the Latin American region with HCFC consumption in the foam sector have proposed HCFC reductions beyond the Montreal Protocol limits, with activities that included PU foam components converting from HCFC-141b to HFOs. These proposals were based on the expected prices and availability communicated by the blowing agent suppliers at the moment of project preparation and included bans on the import and use of HCFC-141b pure or contained in pre-blended polyols to be imposed between 2018 and 2022, based on the expected time of implementation of the PU foam sector plans.

33. Most of these projects are presently facing issues related to HFO supply and prices, which has delayed implementation and in some cases led the Governments to postpone the planned bans[17]. Conversions at SMEs and enterprises working on applications such as PU spray foam have been affected by the lack of availability, long provisioning times and high prices of HFOs pure or contained in pre-blended polyols. Specific details on some of the countries are summarized below:

(a) Argentina was set to totally phase out HCFC-141b before 1 January 2022, when the ban on HCFC-141b was planned. However, due to the lack of availability and higher than expected prices of HFOs, the project suffered delays, and the ban had to be postponed.[18] At its 92nd meeting, the Executive Committee when considering the HPMP (stage II, third tranche) for the country, acknowledged the considerable challenges that Argentina and other countries in the region faced owing to the lack of availability of low-GWP alternatives in the foam sector and agreed that it would be useful to explore some of the issues raised in the document in the margins of the present meeting.[19] At the 93rd and 94th meetings, Argentina has submitted reports on the status of availability of HFOs indicating no major changes in the situation. Based on information received by the government, the enterprise Arkema declared a reduction of their prices, but it has not yet started supplying Argentina. Chemours reported that its products were still not available locally as it was not possible to

[16] UNEP/OzL.Pro/ExCom/93/77
[17] See annex to the present document on information on the dates of the planned bans.
[18] UNEP/OzL.Pro/ExCom/92/21 paragraph 11
[19] UNEP/OzL.Pro/ExCom/92/56, paragraph 137

forecast the demand with its product sold at US $32/kg. Honeywell has faced supply shortages but indicated that it has an "early adopters" programme, whereby HFOs can be offered to selected systems houses at a price of around US $15/kg. The enterprise has not promoted this programme in the Latin American region;

(b) In Brazil, in 2022, one enterprise and one systems house withdrew from the project due to unavailability of HFOs in the domestic market, coupled with the availability of the blend HFC-365mfc/HFC-227ea at competitive prices. In addition, three systems houses that had already converted to low-GWP alternatives requested the authorization of the Government of Brazil to temporarily supply some of their clients with the HFC-365mfc/HFC-227ea blend.[20] They subsequently reported that they had stopped using the HFC blend, while UNDP reported difficulties in engaging SMEs in the project as they preferred not to commit to never using HFCs, owing to concerns about the imbalance in the supply of HFOs. One additional systems house that temporarily used HFCs due to the high price of gaseous HFO for a specialized application recently withdrew from the project;

(c) In the case of Uruguay, as described in a progress report submitted to the present meeting,[21] the high prices and unavailability of commercial quantities of HFOs in the country have prompted one enterprise to shift to cyclopentane at an additional cost, and other enterprises to test water-based technology. As the tests were unsuccessful, they decided to withdraw from the project. In total out of 21 enterprises included in the plan, one converted to cyclopentane, three converted to HFO and 17 did not complete their conversions due to the lack of availability of the HFO-based systems and are returning the unused funds; and

(d) Other Latin American countries that have experienced delays in the completion of their projects due to similar issues include Chile, Colombia, and Costa Rica.

Changes of technology, temporary use of alternatives with high global-warming potential, and extension of the duration of HCFC phase-out management plans

34. At various Executive Committee meetings, Article 5 countries have expressed concern about the lack of availability of HFO alternatives and have requested changes of technology for some of the assisted enterprises, extensions to the duration of their HPMPs, or permission to temporarily use high-GWP alternatives until the low-GWP alternative selected for the project could be properly adopted. The Executive Committee considered these cases on a case-by-case basis, applying flexibility in line with existing policies and terms of the HPMP Agreements, to allow for these adjustments and extensions and ensure the proper completion of those projects.[22]

35. Particularly in the cases of temporary use of high-GWP alternatives, the Executive Committee requests the relevant implementing agencies to continue assisting the Governments in securing the supply of low-GWP alternative technologies, on the understanding that any incremental operating costs related to the conversions (where applicable) would not be paid until the technology originally selected or another low-GWP technology had been fully introduced, and to provide, at each meeting until the technology originally selected or another low-GWP technology had been fully introduced, a report on the status of temporary use of high-GWP alternatives, along with an update from the suppliers on the progress made towards ensuring that the selected technologies, including the associated components, were available on a commercial basis in the country.

[20] UNEP/OzL.Pro/ExCom/91/18 and decision 91/26(a)(iii) and (c)
[21] UNEP/OzL.Pro/ExCom/94/9
[22] Countries that requested change of technology, project duration extension or temporary use of high-GWP alternatives in the PU foam sector include *inter alia* Argentina, Brazil, Chile, Egypt, Jordan, Lebanon, Malaysia and Uruguay.

RECOMMENDATION

36. The Executive Committee may wish to note document UNEP/OzL.Pro/ExCom/94/58 on the issue of alternatives in the polyurethane (PU) foam manufacturing sector and consider the information contained therein while discussing the issue of alternatives in the PU foam sector.

Annex I

Details on the implementation of polyurethane foam projects and availability of alternatives in several Article 5 countries

Country	Local blowing agent prices (US $/kg)	Comments on availability of alternatives	Comments on delays experienced due to lack of alternatives
Argentina	HFO: 20-35 (delivery time 90-120 days)	Chemours has not yet forecasted a purchase of HFO in that volume. Honeywell is not selling directly to Argentina.	Almost all system houses performed tests and trials with clients; producers unable to supply quantities needed for full conversion; forecasts cannot be made with prices above US $25/kg. Project is not yet completed (relevant HCFC ban date: 2022 but postponed).
Bahrain	HFO: n/a	Available from UAE from Honeywell. Supplied by Huntsman as a preblended polyol.	Project ongoing with no delays.
Brazil	HFO: 18 (delivery time 90 days)	Alternatives available.	Supply shortages caused delays in projects implementation. Several enterprises withdrew participation in the project. Country expects that with the normalization of the supply, HFC controls and the closure of the HFC-365mfc production, enterprises will want to participate in the project (relevant HCFC ban date: 2020).
Chile	HFO: 20 (delivery time 45 days)	After some delays, alternative (HFO) is now available from systems houses in Spain or Panamá.	Over 2021-2023, suppliers did not have the substance; and one supplier's price was twice the price of the other. The lack of affordable catalysts affected foam quality. Two enterprises refused to participate in conversions due to the high prices and poor availability of HFOs (relevant HCFC ban date: 2020).
China	C-pentane: 1.54 HFO-1233zd(E): 12-18 HFO-1336mzz(Z): 18-35 Water-blown: 1.95-2.00	Alternatives available at commercial scale.	Project ongoing with no delays.
Colombia	HFO: 17-19 (delivery time 15-45 days)	After some delays, alternative (HFO) is now alternatives available, but prices of blowing agent, catalysts and additives are still a concern.	Delays in umbrella projects up to 2020 due to lack of HFOs; currently high prices of HFOs, catalysts and other additives are problematic (relevant HCFC ban date: 2017).
Costa Rica	HFO: 17 (delivery time 45-60 days)	Alternative available.	The conversion was planned for 2022 and HFO was not available at that time. Conversion completed in 2023.
Egypt	C-pentane: 2.50	Alternative available.	There was no delay in implementation as a result to the lack of C-pentane.
Ecuador	Water-based polyol: 5.80 HFO-based polyol: 8.82 (delivery time 180 days)	Available: Can be obtained only from one chemical distributor.	Due to the lack of alternatives especially HFO, the test was delayed. The tests with water-based and HFO systems resulted in some deficiencies for a final formulation that could be improved for density, reaction time, and adhesion enhancements but will require further research, development, and testing. Enterprises have converted from HCFC to HFC due to the lack of alternatives.
Indonesia	HFO-1336mzz(Z): 38.00	Available at commercial scale but not popular due to cost.	Delays during the COVID-19 period and supply-chain problems.
Islamic Republic of Iran	C-Pentane: 3.00 N-Pentane: 1.50	HFOs not available.	Delays for SMEs due to the hazards associated with on-site blending and absence of other alternative solutions. SMEs awaiting supply from a system house, which is not yet completely operational and unable to meet consumer

Country	Local blowing agent prices (US $/kg)	Comments on availability of alternatives	Comments on delays experienced due to lack of alternatives
			demand. Inflation and exchange rate affects imports of raw materials. (relevant HCFC ban date: 2023 but postponed one year).
Jordan	n/a	HFO is implemented in the spray foam sector.	
Morocco	C-pentane: 4.00	HFO not available as bulk.	Project ongoing with no delays.
Pakistan	n/a	HFOs available as a pre-blended polyol from Thailand.	The thermoware sector faces delays due to unsuitable foam formulations tested with water blown, then with HFO and Methyl Formate (MF). HFO/water co-blown systems as well as MF/water-blown systems are nearing quality requirements. Other sectors are fully completed.
Sudan	C-pentane: 4.00		Project has suffered delays due to internal conflict.
Thailand	HFO-1233zd: 24.00+ HFO1336mzz(Z): 45.00+	HFOs commercially available for larger users; smaller spray foam users are supplied by a local systems house, with commercial availability of HFO-1233zd expected by May 2024.	Systems house experienced delays due to the unavailability of catalyst for HFO-1233zd; spray foam enterprises completed conversions but await the formulation from systems house.
Uruguay	HFO: 20-21	Pre-blended polyols for rigid foams and heaters available. Technology for spray foam not available yet.	Most funds would have to be returned because of the lack of interest of enterprises Most small enterprises were left unconverted, many are no longer in the market or shifted from partial production to importing products with included insulation (relevant HCFC ban date: 2024).
Viet Nam	HFO-1233zd: 25-35	Not available at commercial scale.	No delays reported. SMEs will likely switch to water- or c-pentane based polyol until normalization of cost differential with HFOs.
Tunisia	C-pentane: 2.10 HFO: n/a	HCs are available. HFOs expected to be available from BASF. There have been delays in ensuring availability of bulk HFO supply. Based on Europe prices available, a price around US $20/kg is forecasted.	Enterprise Le Panneau's mother company SNCI is operating continuous sandwich panel production lines utilizing n-pentane in the foaming process.