

**MONTREAL PROTOCOL ON SUBSTANCES THAT
DEplete THE OZONE LAYER**

**REPORT OF THE TECHNOLOGY AND ECONOMIC ASSESSMENT
PANEL**

MAY 2026

VOLUME 1: PROGRESS REPORT



Montreal Protocol on Substances that Deplete the Ozone Layer
United Nations Environment Programme (UNEP)
Report of the Technology and Economic Assessment Panel

May 2026

VOLUME 1: PROGRESS REPORT

The text of this report is composed in Times New Roman.

Co-ordination: Technology and Economic Assessment Panel

Composition of the report: Bella Maranion, Marta Pizano, Ashley Woodcock

Layout and formatting: Marta Pizano, Bella Maranion, Ashley Woodcock

Date: May 2026

Under certain conditions, printed copies of this report are available from:

UNITED NATIONS ENVIRONMENT PROGRAMME

Ozone Secretariat

P.O. Box 30552

Nairobi, Kenya

This document is also available in portable document format from the UNEP Ozone Secretariat's website:

<https://ozone.unep.org/science/assessment/teap>

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ISBN: 978-9914-733-70-9

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Acknowledgements

The TEAP and its Technical Options Committees and members acknowledges with thanks the outstanding contributions from all of the individuals and organizations that provided support to the Panel, Committees and members. The opinions expressed are those of the Panel and the Committees and do not necessarily reflect the reviews of any sponsoring or supporting organization.

Foreword

The 2026 TEAP Report

The 2026 TEAP Report consists of 4 volumes:

Volume 1: TEAP 2026 Progress Report covering the following:

- Decisions IV/13 and XI/17: Sector updates
- Decision XXXI/8: TEAP procedures, organizational matters and matrix
- Decision XXXV/20: Options for the organization of the TEAP and its technical options committees
- Decision XXXVI/2: Life-cycle refrigerant management
- Decision XXXVI/6: Developments in metered dose inhalers with low-global warming potential propellants
- Decision XXXVII/4: Halon availability and global distribution of halon banks

Volume 2: TEAP May 2026: Assessment of the Funding Requirement for the Replenishment of the Multilateral Fund for the Period 2027-2029

Volume 3: TEAP September 2026: Response to Decision XXXVII/2: Emissions of HFC-23

Volume 4: TEAP September 2026: Supplement to the May 2026 TEAP Replenishment Task Force Report

This is Volume 1

The UNEP Technology and Economic Assessment Panel (TEAP):

Bella Maranion, co-chair	US	Marco Gonzalez	CR
Marta Pizano, co-chair	COL	Roberto Peixoto	BRA
Ashley Woodcock, co-chair	UK	Fabio Polonara	IT
Omar Abdelaziz	EGY	Ian Porter	AUS
Paulo Altoe	BRA	Rajan Rajendran	US
Suely Machado Carvalho	BRA	Helen Tope	AUS
Adam Chattaway	UK	Dan Verdonik	US
Sukumar Devotta	IN	Helen Walter-Terrinoni	US
Bassam Elassaad	LEB	Shiqiu Zhang	PRC
Takeshi Eriguchi	JP	Jianjun Zhang	PRC
Ray Gluckman	UK		

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1 Executive summary

This is volume 1 of 4 of the 2026 Technology and Economic Assessment Panel (TEAP) Report and contains Progress Reports from the five Technical Options Committees (TOCs) that compose the TEAP: Fire Suppression TOC (FSTOC), Flexible and Rigid Foams TOC (FTOC), Methyl Bromide TOC (MBTOC), Medical and Chemicals TOC (MCTOC) and Refrigeration, Air Conditioning and Heat Pumps TOC (RTOC).

The following decisions are also addressed in the corresponding chapters and/or sections of this report:

- Decisions IV/13 and XI/17: Sector updates
- Decision XXXI/8: TEAP procedures, organizational matters and matrix
- Decision XXXV/20: Options for the organization of the TEAP and its technical options committees
- Decision XXXVI/2: Life-cycle refrigerant management
- Decision XXXVI/6: Developments in metered dose inhalers with low-global warming potential propellants
- Decision XXXVII/4: Halon availability and global distribution of halon banks

This report also contains the TEAP and TOC membership lists, as of 30 April 2026, including each member and their term of appointment, in annexes at the end of this document. A matrix of needed expertise for the TEAP and its TOCs is included in an additional annex.

TEAP would like to express its sincere gratitude for the voluntary service and contributions of members of its TOCs. TEAP held a hybrid meeting, 20-24 April, in Brussels. We want to express our sincere appreciation to the European Commission (EC) for hosting our meeting and the Ozone Secretariat for its continuing support and assistance with the organization of TEAP meetings.

1.1 Key messages from Technical Options Committees

Key messages arising from TOC progress reports are presented in this section.

1.1.1 *FSTOC*

The FSTOC progress report is contained in Chapter 3 of this report and includes the following updates:

- In response to “Decision XXXVII/4: Halon availability and global distribution of halon banks”, the FSTOC has worked with the International Civil Aviation Organization (ICAO) and has refined the halon 1301 run-out date. This is now estimated to be in the 2035 +/- 4 years timeframe, based on the latest available data from civil aviation, oil and gas, and nuclear power plants, together with the amounts being recovered from shipbreaking activities.
- Parties may wish to consider determining what, if any, changes may be needed to the Essential Use Nomination (EUN) and Evaluation Processes, given that every individual party will be unable to determine their civil aviation needs, i.e., production and consumption, on an annual basis.
- The FSTOC model continues to compare well with emissions derived from atmospheric measurements of halon 1301, now through 2024.
- The FSTOC is not aware of any new fire protection/extinguishant agents under development.

- The European Chemicals Agency (ECHA) Socio-Economic Analysis Committee (SEAC) draft opinion, released on March 26, 2026, on the European Union (EU) per- and polyfluoroalkyl substances (PFAS) restriction proposal would lead to bans on the use of critical halon alternatives following the entry into force of any regulation, unless a derogation allows a grace period. The SEAC draft opinion on the EU PFAS restriction proposal recommends a 12-year derogation for 2-bromo-3,3,3-trifluoropropene (2-BTP) in hand-held extinguishers on aircraft. No derogation is being proposed for the potential future use of the 2-BTP/carbon dioxide (CO₂) blend to replace halon 1301 in cargo compartments.

1.1.2 FTOC

The FTOC progress report is contained in Chapter 2 of this report and includes the following updates:

- Parties are successfully transitioning the foam industry from hydrochlorofluorocarbons (HCFCs) in Article 5 (A5) parties and high global warming potential (high-GWP) hydrofluorocarbons (HFCs) in non-Article 5 (non-A5) parties and some A5 parties, with emphasis on avoiding adoption of high-GWP HFCs where possible. Regulation and supply phase-down are driving transitions.
- As available global HCFC-141b inventories are diminished, parties may wish to consider completing transitions from HCFC-141b. In 2026, the China Ministry of Ecology and Environment (MEE)¹ did not allocate quota for HCFC-141b production, and supply of HCFC-141b will cease. Manufacturers of hydrofluoro-olefins/hydrochlorofluoro-olefins (HFO/HCFOs) have increased capacity to meet the demand for lower GWP blowing agents that is expected to result from the implementation of lower GWP regulations. There have been significant improvements in the development and availability of additives, co-blowing agents, equipment and formulations enabling the successful commercialisation of foams containing lower GWP blowing agents.
- Foam manufacturers continue to work to reduce costs and optimise the characteristics of foams with new foam blowing agents (FBAs), co-blowing agents and additives in both A5 and non-A5 parties. New FBA co-blowing agents and additives have different toxicity and thermal properties that can result in safety challenges in handling, and lower thermal performance of insulation.
- Generally, costs have increased in 2025-26 due to additional taxes, anti-dumping duties, and geopolitical impacts to energy cost and availability. Some parties may be more impacted by these issues. These economic impacts may affect construction and demand for equipment and foams.

1.1.3 MBTOC

The MBTOC progress report is contained in Chapter 4 of this report and includes the following updates:

- Phase out of methyl bromide (MB) for controlled non-quarantine and pre-shipment (non-QPS) uses was completed with the last critical use nomination (CUN) received in 2025. Together with the MB phase out achieved prior to the CUN process, this has led to about

¹ [Announcement of the Issuance of ODS and HFCs Production Quotas in 2026](#)

62,000 tonnes of MB being phased out globally over 30 years. No new CUNs were received in 2026.

- Reported global production of MB for QPS in 2024 was 8,935 tonnes. Reported QPS consumption in 2024 was approximately 8,000 tonnes of MB (about 900 tonnes less than the reported production). There is evidence of widespread uptake of alternatives to MB for QPS uses in some parties over the past several years. Still, some clear areas of concern remain, i.e., atmospheric concentrations of MB have stopped declining as QPS uses continue. Over recent years, MB reporting by some parties has been difficult to understand and has required follow up by MBTOC and the Ozone Secretariat to review potential errors. The accuracy of reported data is essential for TEAP to be able to compare bottom-up and top-down estimates of MB emissions.
- Recent surveys have shown unreported uses of MB in sectors where MB has neither been approved as a controlled use nor exempted as a QPS use. Publications from China have raised concerns about unexplained MB emissions and there is no further clarification on the source (~4,000-9,000 tonnes per year) (Hu *et al.*, 2024).
- MB is highly toxic to humans, and increasingly subject to control during occupational exposure. Several parties which use MB for QPS applications already have or are planning to introduce stringent reductions in permitted workspace concentrations for MB. This will have a major impact on MB use with the requirement for large buffer zones.
- MB use for QPS uses is exempted from controls under the MP. The use of MB for specific quarantine pests (“Q”) may likely be required in the long-term in many jurisdictions. However, for pre-shipment uses (“PS”), several alternatives (e.g., hot and cold temperatures, irradiation, phosphine, ethyl formate, hydrogen cyanide, ethane dinitrile) are at least as effective as MB, and safer both for humans, the environment and the products being treated. Confusion over classification between Q and PS is still problematic for many parties.
- Parties may wish to consider how to more strongly focus on how to prevent emissions from QPS uses, limit MB exemptions for PS uses, and prevent the misuse of non-QPS MB by clarifying and focusing solely on quarantine (Q) uses. This could prevent the emissions which are of a similar magnitude to those that were reduced due to the phase-out of MB under the CUN process.

1.1.4 MCTOC

The MCTOC progress report is contained in Chapter 5 of this report and includes:

- Updated information on the production and use of controlled substances for chemical feedstock;
- An evaluation of and recommendation for a destruction technology submitted by Canada for TEAP review and consideration by parties to be recognised as an approved destruction technology under the Montreal Protocol; and
- Developments regarding metered-dose inhalers (MDIs) with low-GWP propellants in response to Decision XXXVI/6.

MCTOC has not identified compelling new information to report to parties in this progress report on developments in process agent uses, n-propyl bromide, and laboratory and analytical uses.

Feedstocks

- Data reported by parties to the Ozone Secretariat on production and import of controlled substances used as feedstock for the years up to and including 2024 was provided to the MCTOC.
- In 2024, total production and import reported for feedstock uses of ozone-depleting substances (ODS) (including process agents) was 1,947,949 tonnes, a slight decrease to the quantity in 2023 (1,965,768 tonnes). HCFC-22 is, by a considerable margin, the largest feedstock used, with 990,395 tonnes reported in 2024, an increase from the revised quantity reported for 2023 (978,084 tonnes).
- The reported amounts of HFCs produced for feedstock use was 183,539 tonnes in 2023 and 211,326 tonnes in 2024. The increase in production of HFC for feedstock use in 2024 is mainly due to HFC-152a, with reported HFC-236ea also increasing into the 1,000–10,000 tonnes band in 2024.

Evaluation and recommendation of a destruction technology submitted by Canada

- Parties have taken several decisions to approve destruction technologies for the purposes of the Montreal Protocol's definition of production and production data reporting requirements. The current list of approved destruction technologies is contained in Annex II of the report of the Thirtieth Meeting of the Parties (MOP-30), as modified by the MOP-35 in Decision XXXV/5.
- Under decision XXXV/5, parties are invited to submit information to the Ozone Secretariat relevant to a review of destruction technologies. Under decision IV/11, TEAP is requested to evaluate technology submissions and prepare recommendations for consideration by the parties to the Montreal Protocol at their annual meeting.
- According to the preamble to decision XXX/6, TEAP evaluates destruction technologies for their destruction and removal efficiency and makes recommendations to parties for potential approval for the list of approved technologies. TEAP also provides technical advice about emissions of other pollutants and the technical capability of destruction technologies as part of its assessment for consideration by parties.
- Canada submitted confidential and non-confidential information to the Ozone Secretariat regarding a patented plasma arc technology utilising steam for evaluation by TEAP. During its evaluation, MCTOC requested clarifications of Canada about information provided in the submission.
- Based on MCTOC's review of submitted performance data provided by Canada, the technology demonstrated that the DREs achieved for the destruction of chlorofluorocarbon (CFC)-12, CFC-11, HCFC-22 and HFC-134a are greater than 99.99%, meeting the destruction and removal efficiency (DRE) performance criteria² for these controlled substances for the purposes of destruction under the Montreal Protocol.

² Although the submission states that the destruction technology was tested on more than 60 compounds, including perchlorinated and brominated compounds, no supporting data were provided for these compound classes. Therefore, beyond the controlled substance categories where data were presented, no data-based assessment could be made on these other substances.

- TEAP recommends that the technology, under a new generic category Steam Plasma Arc, be approved for destruction of concentrated sources of Annex A Group 1, Annex C Group 1, Annex F Group 1 controlled substances for the purposes of the Montreal Protocol.

Response to Decision XXXVI/6 on developments regarding metered-dose inhalers

- Decision XXXVI/6 requests the TEAP “*to continue to provide in its annual progress reports updated information on low-global-warming-potential metered-dose inhaler propellants and to complement its 2026 quadrennial assessment report with timely information, including on the availability, technical feasibility, economic viability, safety and market penetration of those propellants in parties operating under paragraph 1 of Article 5 of the Montreal Protocol on Substances that Deplete the Ozone Layer and in parties not so doing.*”
- The transition from high- to lower GWP propellants in pressurised metered-dose inhalers (pMDIs) presents many challenges, including: the context of global environmental legislation; the continuity and stability of supply of pharmaceutical grade HFCs; the continued availability and affordability of alternative devices; regulatory approval and launch of lower GWP pMDIs; and patient acceptability.
- Small- and medium-sized manufacturers in low and middle-income countries (LMICs) are particularly vulnerable; without access to technology licences, investment for scale-up, or regulatory expertise, many may struggle to transition to lower GWP formulations, further widening global inequalities. In practice, consolidation or partnerships with larger contract manufacturing organisations may be the only viable way for these smaller producers to continue supplying their markets while keeping essential inhalers accessible and affordable.
- At least ten companies globally appear to be developing pMDIs containing pharmaceutical-grade lower GWP propellants, HFC-152a and/or HFO-1234ze(E), including three companies in India and one in Bangladesh. Several generics manufacturers in Latin America are also developing lower GWP pMDIs. Two companies in China have initiated development of bulk propellant HFO-1234ze(E).
- After a major effort over several years, the first launch of a pMDI containing a lower GWP propellant has occurred in the United Kingdom (UK). A second company has also filed for approval in the UK. Two companies have announced the successful completion of clinical studies with the intention to obtain marketing authorisation.

1.1.5 RTOC

The RTOC progress report is contained in Chapter 6 of this report and includes the following updates:

- The growing global demand for refrigeration, air conditioning, and heat pump (RACHP) systems creates a dual climate challenge from both direct refrigerant leakage and indirect electricity consumption, requiring comprehensive lifecycle assessments.
- Reducing cooling and heating loads through passive measures such as insulation and shading is the most critical first step, capable of cutting cooling demand and energy consumption by approximately 30%.
- There is no single "ideal" refrigerant; selection requires balancing legal, safety, environmental, suitability, cost, efficiency, and usability factors, with increasing attention on lifetime risk assessment.

- Implementing Lifecycle Refrigerant Management could halve the projected 2050 emissions but face a growing skills gap and urgent need for capacity building and trained technicians capable of handling lower GWP and flammable refrigerants.
- Strengthening national systems for collecting RACHP-related data is essential to improve modelling accuracy on RACHP banks, consumption and emissions and enable evidence-based mitigation strategies.
- In commercial refrigeration, there is a significant shift away from R-404A toward R-744 (CO₂) as the leading sustainable solution, particularly in lower ambient temperature countries like those in Europe. In other regions, lower GWP A2L refrigerants are being adopted along with R-744 and R-290 in small charge systems.
- In industrial refrigeration, R-717 (ammonia) and R-744 (CO₂) are the preferred lower GWP refrigerants and are expected to increase in use, while transport refrigeration faces slower transition due to safety, infrastructure, and long equipment lifecycles.
- Reducing energy consumption remains key in comfort cooling, with a global trend toward inverter-type compressors (to achieve variable capacity), though this technology remains under-represented in many A5 parties and some non-A5 parties.
- Integrated systems for combined heating and cooling can improve overall energy efficiency by 30-50% and significantly reduce CO_{2e} emissions by replacing fossil fuel heating.
- Except for absorption and adsorption, non-vapour compression (not-in-kind) technologies are currently not capable of replacing mechanical vapour compression for comfort cooling, with most remaining at emerging or research and development stages.

1.2 Per- and polyfluoroalkyl substances

In Chapter 7 of this report, TEAP provides an update to important information for the parties related to PFAS and considerations of the potential implications for sector transitions to alternatives from substances controlled under the Montreal Protocol. TEAP has brought these emerging technical and economic policy-relevant issues to the attention of parties in its 2022 Assessment² and 2023-2025 Progress Reports.^{3, 4, 5}

ECHA's Risk Assessment Committee (RAC) adopted its final opinion on March 2, 2026, evaluating risks of PFAS to human health and the environment. The SEAC finalized its draft opinion on the universal restriction proposal on all PFAS, with a public comment period open until May 26, 2026. The draft opinion recommends restricting the manufacture and use of PFAS in the EU. After the comment period, adoption of the reports will conclude the ECHA committees' scientific evaluation of the proposed restriction. The opinions will be formally submitted to the EC who could propose a restriction for discussion and vote in the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Committee, which is comprised of EU Member States.

The potential implications for the Montreal Protocol of a broad PFAS regulation include the following:

- Some ODS and HFCs, controlled by the Montreal Protocol, and some of their alternatives (e.g., HFOs and HCFOs) and their atmospheric decomposition products could be included in PFAS definitions and bans.

- Some fluoropolymers used in all sectors of interest to the Montreal Protocol (e.g., as components in compressors, valves, heat exchangers, flexible seals and coatings) could be included in PFAS definitions and bans.

The risk of possible bans of Montreal Protocol controlled chemicals and their alternatives, are creating uncertainty for the transition from ODS and HFCs, resulting in delays to transitions or reduced availability of optimised solutions in many sectors. Some manufacturers and end-users and other stakeholders have reported that they are delaying investments, due to concerns over potential bans. In the context of these ongoing national and subnational actions which may or may not restrict products using chemicals controlled under the Montreal Protocol, TEAP is providing additional information related to current considerations with some exemplar sectors of use.

Under “Decision XXXV/3: Potential areas of focus for the 2026 quadrennial reports of the Environmental Effects Assessment Panel (EEAP), the Scientific Assessment Panel (SAP) and the [TEAP]”, parties requested the panels to include in their assessment information on controlled substances and their alternatives and breakdown products, in particular PFAS. TEAP is coordinating with EEAP and SAP on the scope of information on this topic to be covered by each panel’s assessment for 2026.

1.3 TEAP organisational matters and follow-up on Decision XXXV/20 on organisational options for TEAP and its TOCs.

“Decision XXXV/20: Options for the organization of the [TEAP] and its [TOCs]” requested TEAP to provide options on the organization of the panel and its TOCs, considering the panel’s terms of reference (TOR) and informed by consultation with the TOCs co-chairs and members. TEAP conducted the relevant analysis and presented its conclusions at the 47th Open-ended Working Group Meeting (OEWG-47). At an informal group meeting held during the MOP-37 in Nairobi, parties requested TEAP to further elaborate on possible options for future reorganisation of the TEAP and its TOCs in its 2026 Progress Report.

Overall, the current composition and structure is working well, allowing TOCs to conduct their tasks successfully. TEAP presents some further analysis for the consideration of the parties, particularly on the options preferred by each TOC to address their future workload from 2027 onwards. The preferred options presented for the TOCs reflect the current practicalities of managing near-term anticipated changes within the committees over the next few years (i.e., normal attrition, lack of support for participation, recruitment of new members) as well as gaining more experience, for at least the largest two TOCs, with working through subcommittees structures. These options can be revisited in the future as the needs of parties evolve.

TEAP has also updated its matrix of needed expertise to indicate those areas where gaps have been identified. Nominations from parties to meet the gaps in expertise identified in the matrix would be very helpful to TEAP.

TEAP identifies the continuing challenges to its work including attrition and annual workload. The recruitment of experts to serve on TEAP and its TOCs requires a pool of experts who have the capacity, support, and time to understand the work and TOR. Recruitment of new experts as well as continued participation of all experts is becoming critical to maintaining an independent and consensus-based process for TEAP’s development of its reports. To address these challenges to the long-term viability of TEAP and its TOCs, the panel will need the support of the parties to find sustainable solutions.

2 Flexible and Rigid Foams TOC (FTOC) Progress Report

2.1 Introduction

This report of the FTOC provides an update to information on the use of controlled substances as FBAs for insulating and non-insulating foams. FTOC met on 17-18 April 2026, in Brussels, Belgium. The meeting was attended in person by eight members, primarily from A5 parties and virtually by seven members primarily from non-A5 parties. The FTOC generally meets virtually biweekly to complete its work on the quadrennial assessment but will revert to monthly virtual meetings once it is complete.

As noted in the TEAP's Matrix of Needed Expertise (Annex 5), FTOC seeks expertise in the following areas: extruded polystyrene (XPS) production in India and China; polyurethane system house technical experts – particularly from Southern Africa, South Korea, the Middle East, Latin American parties, especially experts within small- and medium-sized enterprises (SMEs); FBA chemistry and foam interaction; FBA production, fluorine chemistry, and supply chains.

2.2 Emerging trends in the transition to non-ozone-depleting foam blowing agents

2.2.1 Use of controlled substances and alternatives

Parties are successfully transitioning the foam industry from HCFCs in A5 parties and high-GWP HFCs in non-A5 parties and some A5 parties, with emphasis on avoiding adoption of high-GWP HFCs where possible. Regulation and supply phase-down are driving transitions.

As available global HCFC-141b inventories are diminished, parties may wish to consider completing transitions from HCFC-141b. In 2026, the China MEE³ did not allocate quota for HCFC-141b production, including export for supply for other parties and supply of HCFC-141b should cease this year.

Manufacturers of HFO/HCFOs have increased capacity to meet the demand for lower GWP blowing agents that is expected to result from the implementation of lower GWP regulations. There have been significant improvements in the development and availability of additives, co-blowing agents, equipment and formulations enabling the successful commercialisation of foams containing lower GWP blowing agents.

Although HFOs/HCFOs supplies have normalized, raw material availability and costs have increased in 2025-26 due to additional taxes, anti-dumping duties, and geopolitical impacts to energy cost and availability. Some parties may be more impacted by these issues. Foam manufacturers continue to work to reduce costs with new FBAs and co-blowing agents in both A5 and non-A5 parties. These economic impacts may affect construction and demand for equipment, foams, and FBAs.

Foam manufacturers continue to reduce loading of fluorocarbon (FC) FBAs by adding water or other blend components to reduce cost. Significant resources are spent by foam manufacturers in optimising the characteristics and costs of new FBAs and foam systems through optimising blends with new additives. Some new non-FC FBA additives or co-blowing agents have different toxicity and thermal properties, resulting in handling challenges and lower thermal performance of insulation, which is especially challenging where thermal performance is mandated for foams and energy efficiency (EE)

³ [2026 ODS and HFCs production quota issuance announcement](#)

standards are set for equipment. It has been estimated that approximately 80% of HCFC-141b in A5 parties have been replaced with non-FC alternatives.

There is continued consolidation within the foam supply chain in non-A5 parties. There could be also supply chain consolidation in A5 parties (e.g., to rationalize capacity).⁴

2.2.2 Issues influencing the foam blowing agent market for A5 parties

Some A5 parties have completed both HCFC and HFC transitions in foams, while others plan to finalize their HFC transitions within five years in foams and have pending HFC bans (e.g., Türkiye ban of HFC-134a for use in foams in 2027 and all uses in 2029).

According to the China MEE⁵, no quota was allocated for HCFC-141b production in 2026. As available inventories are diminished, parties may need to align completion of transitions from HCFC-141b. Some parties have already banned HCFC-141b import (e.g., some parties in Latin America in 2026), with limited allowance in polyol blends. National HCFC Phaseout Management Plan (HPMP) projects are nearly complete.

Use of HCFC-141b in foams is also controlled in China according to the China MEE Announcement No. 28 of 2025⁶, “Announcement on Prohibiting the Production of Polyurethane Products Using HCFC-141b as a Blowing Agent”⁷ under the Phase One Ban. Effective January 1, 2026, the production of polyol blends and polyurethane products using HCFC-141b as a blowing agent is prohibited (spray-applied polyurethane foam products are exempted at this stage). Inventory of spray foam polyol blends containing HCFC-141b must be used through 30 June 2026.

According to the Multilateral Fund (MLF) Executive Committee (ExCom) Decision 96/52, which approved Kigali Implementation Plans (KIPs), some A5 parties (e.g., Mexico, Ecuador, Guatemala, Bolivia, Honduras) plan to eliminate HFCs contained in imported preblended polyols used in the polyurethane (PU) foam sector. For these projects, an average HFC consumption during the period 2022-2024 will be considered for local SMEs established before 1 January 2020. Local environmental authorities for each party will implement the KIPs and decide total phase out each year from 2028 to 2030.

Domestic and commercial refrigeration and continuous panel sectors have largely converted to hydrocarbons (HCs). In some parties (e.g., China, Mexico, Brazil) mandatory national performance-based, EE standards for refrigeration appliances and construction materials continue to strongly influence blowing-agent selection, limiting the applicability of water-blown or CO₂-based systems in higher-performance insulation products. Blended FBAs, including FCs, are used to improve EE. For example, in Southeast Asia, where there are more stringent EE requirements for water heaters and commercial refrigeration, HFC-245fa is still in use.

⁴ There may be some extra capacity that will be resolved at this time especially where local demand has changed due to building codes or other changes in construction design and overall demand.

⁵ [2026 ODS and HFCs production quota issuance announcement](#)

⁶ [2026 ODS and HFCs production quota issuance announcement](#)

⁷ https://www.mee.gov.cn/xxgk/2018/xxgk/xxgk01/202511/t20251124_1134725.html

There is a growing trend for medium-sized enterprises consuming 1000 tonnes or more to self-formulate blends for their own systems especially in Asia and Latin America (e.g., for discontinuous panels).

A growing number of parties have banned imports of ODS (e.g., CFC-11, HCFC-141b) for use in foams including imports blended in polyols. New standards have emerged to test polyol blends and foams to confirm which FBA is present, like QB/T 5114-2017 from China and JIS A 1485:2006 from Japan. Parties are collaborating to create a global International Organization for Standardization (ISO) standard for testing FBA type in foams and in polyol blends. Table 2.1 lists current test procedures to identify FBAs.

Table 2.1 Test procedures to identify FBAs

Analysis methods for blowing agents in polyol blends and foams

Standards	HJ1058-2019	DB32/T1718—2011	QB/T 5114-2017
Purpose & method	Headspace method for blended polyols	Determination of retained blowing agent in rigid polyurethane foam – Squash the foam and extract	Determination of retained blowing agent in rigid polyurethane foam - Freeze and squash the foam, and extract
Qualitative & Quantitative	GC-MASS	GC-MASS	GC-MASS
Blowing agents	CFC-12, HCFC-22, CFC-11, 141b	CFC-11, 141b, CP, MF, 245, 365mfc	Method A: CP, IP, MF Method B: CFC-11, 141b, CFC-22, 245, 365, 227ea, 134a
Issue date	Oct 31 2019	June 20 2011	Oct 1 2017

2.2.3 Issues influencing the foam blowing agent market for non-A5 parties

In the EU, the 2024 fluorinated gas (F-gas) Regulation⁸ incorporated HFOs/HCFOs, with another review required in 2030 and a potential ban in 2033 unless required for safety. F-gas regulations have limited HFCs with GWP greater than 150 in foam manufacturing from 2023⁹. In 2026, no fluorinated FBA can be used to manufacture foams for domestic and commercial refrigeration equipment. Some companies are exploring vacuum insulated panels (VIPs) and specialized polyols to maintain energy performance, which is more challenging without fluorocarbons.

Local environmental regulation of HFOs and HCFOs varies between EU parties. In some parties, unsaturated HCFCs and HFCs are defined as volatile organic compounds (VOC) and require environmental permits for use. Other EU parties exempt them from VOC regulations based on their

⁸ 2024 European Union F-gas regulations at https://climate.ec.europa.eu/eu-action/fluorinated-greenhouse-gases/f-gas-legislation_en

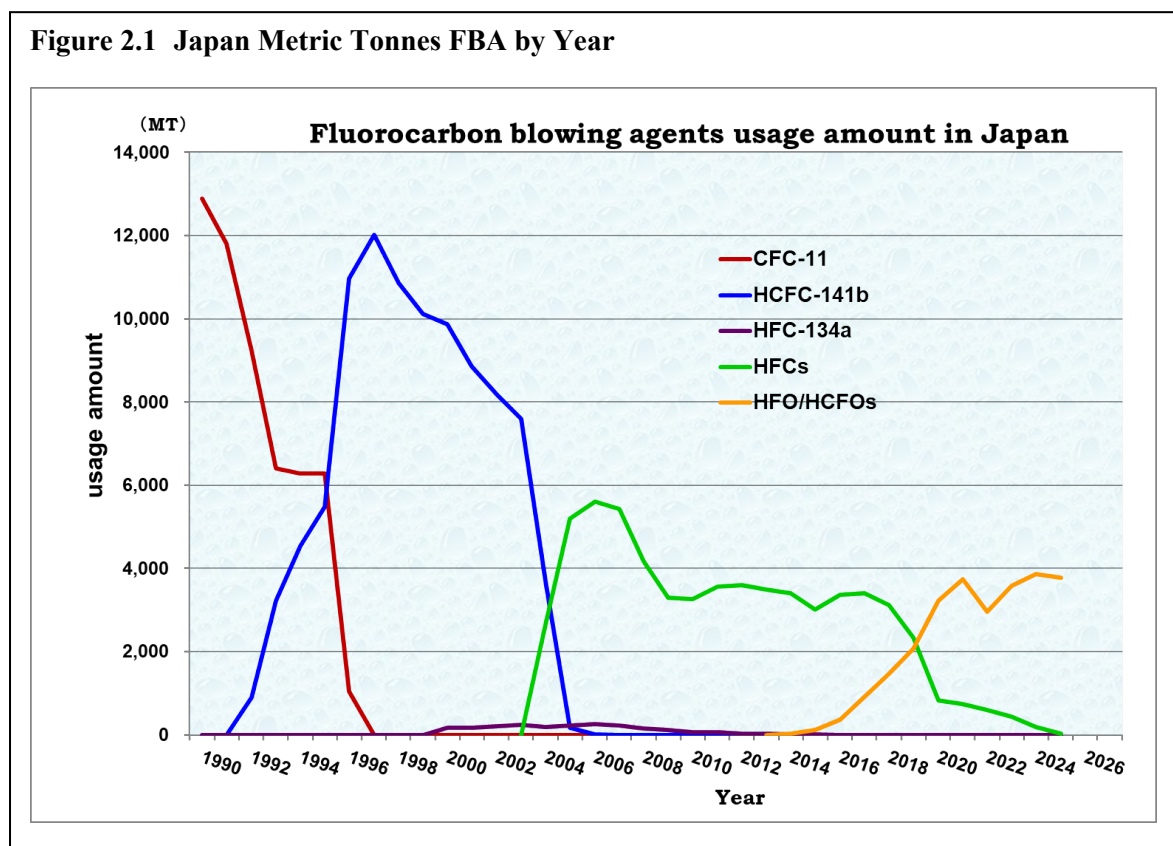
⁹ There are now some commercially available appliances using new technologies (e.g., vacuum panels) for insulation without foams.

Maximum Incremental Reactivity (MIR) in comparison to ethane. Denmark, which previously regulated unsaturated HCFCs and HFCs by the same laws as high-GWP HFCs, has lifted the restriction when the GWP value is below 5 through a dedicated ordinance. In Switzerland, under the Swiss ODS Ordinance, HCFO-1233zd which has an ODP of 0.00034 is considered an ODS, because of its chlorine content. However, the law provides a mechanism for obtaining exemption based on the lower GWP value and its EE.

In Japan, “The Act on Rational Use and Proper Management of Fluorocarbon”, was amended effective April 1, 2020, to require companies and industry associations to submit a voluntary action plan for the HFC phase down/phase out. In 2020, the average GWP of blowing agents used by the residential spray foam industry was limited to less than 100, with a target HFC consumption of less than 620 metric tonnes (MT) in 2020 and 450 MT by 2024. The average GWP of the system houses that met the goal by 2020 was 17.3 with the remainder achieving the goal by September 2021. There were challenges with the cold chain transition and the total HFC consumption was more than the action plan due to a lack of available supply of HFOs/HCFOs.

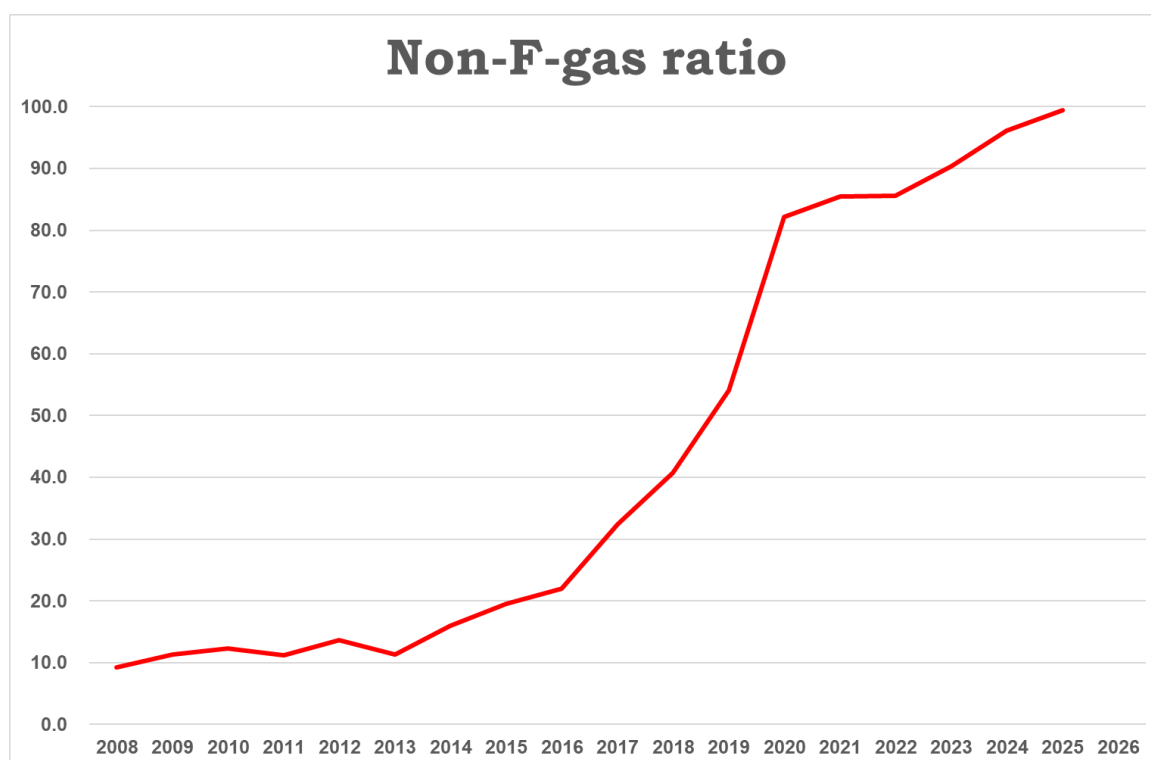
In 2025, HFCs consumption dropped to only 22MT, achieved the action plan submitted to the Government (450MT in 2024). Non-HFCs ratio for PUR blowing agent reached up to 99.5% and HFOs/HCFOs volume recovered to 3800 MT, as noted in Figure 2.1 in describing the near complete transition from HFCs.

Figure 2.1 Japan Metric Tonnes FBA by Year



According to the Japan’s Home Appliance Recycling Law, HFC and HCFC refrigerant and FBA in air conditioners, refrigerators, freezers, washing machines and dryers must be collected and destroyed, and results must be submitted to the Government. About 3 million refrigerators and freezers are recycled a year and collected HFC/HCFC decreases year by year. In 2024, 164 MTs of HFC/HCFC were collected from PUR and EPS and destroyed. This is a 15% decrease compared to 2023, as noted in Figure 2.2.

Figure 2.2 Japan percentage of non-fluorinated FBA



In the United States, a 150 GWP limit was set for most, if not all, FBAs effective January 2025 and January 2028 under the American Innovation and Manufacturing (AIM) Act 2023 Technology Transition Rule.¹⁰

2.3 Foam blowing agent selection

Manufacturers of HFO/HCFOs have increased capacity of some of the HFOs/HCFOs to meet the demand for lower GWP blowing agents that is expected to result from the implementation of lower GWP regulations. There have been significant improvements in the development and availability of additives, co-blowing agents, equipment and formulations enabling the successful commercialisation of foams containing lower GWP blowing agents.

There has been an increase in the use of non-FC FBAs. Hydrocarbons (HCs, specifically pentanes), methylal, methyl formate and small quantities of trans-dichloroethylene (t-DCE) and methylene chloride¹¹ are blended with fluorocarbons to reduce cost. There are some limits to availability and allowance of use because of safety (flammability) and health (human exposure) concerns.

¹⁰ [The American Innovation and Manufacturing \(AIM\) Act Technology Transition Rule.](#)

¹¹ Methylene chloride is a controlled substance in some parties due to its use in processing cocaine.

Carbon Dioxide

The use of CO₂ is gaining market share as an FBA, by adding minimal quantities of water to manage physical properties (e.g., adhesion and cell size). Water reacts with the foam system to create CO₂. Innovative case studies are emerging that document production of high-quality foams, especially with new additives.

Additional water reduces FBA cost but can impede adhesion and increase friability. The polyurethane formulation is optimised commonly through changing the polyol choice (such as the addition of low functionality polyol), catalyst package, and the use of plasticizer or flame retardant to reduce friability and improve adhesive properties. Additional chemicals (e.g., maleate) may be added to optimise blends containing large quantities of water.).

Supercritical CO₂ is used in flexible foam and occasionally used in field-applied systems (e.g., spray foam), but there are challenges around thermal performance. Supercritical CO₂ is less likely to be used in equipment or building applications where the degree of thermal performance has higher thermal requirements.¹²

Water blown foam is not used in domestic or commercial refrigeration systems with stringent EE requirements for insulation. They are used in the EU and some other parties in commercial refrigeration for equipment without strict EE requirements¹³ Water blown foams are not generally used in domestic refrigeration because they cannot meet the EE requirements.

FBA blends with varying levels of water are used to manufacture both open- and closed-cell foams in sandwich panels in roofs, milk tanks and foam applications where thermal performance is not critical. This progress has helped independent systems houses provide cost-competitive foams with lower HFO/HCFO loading in systems. In many cases, friability and foam structural concerns have been addressed for construction foams.

It is expected that CO₂-based systems will play a significant role in the phase-out of HCFCs in China, particularly for medium- to large-scale enterprises, alongside the continued use of other lower GWP alternatives depending on application and regulatory requirements.

Flammable Foam Blowing Agents

HCs are largely selected to reduce cost. Foam manufacturers should follow best practices and appropriate precautions in handling flammable FBAs and blends including eliminating competent ignition sources (e.g., electrical sparks) in foam injection machinery and the surrounding workplace. If the blowing agent can be released during production or in storage, precautionary measures (e.g., ventilation, cooling) should be taken to prevent reaching blowing agent concentrations that are flammable or explosive. Safety data sheets (SDSs) should be provided, and drums should be labelled to communicate associated hazards.

UN Implementing Agencies (IAs) projects for A5 parties have included requirements to upgrade facilities for the use of HCs. Projects that are not funded by UN IAs do not necessarily follow the UN IAs safety guidance. FTOC is not certain that all local safety measures have been universally implemented in compliance with local fire codes and transportation requirements, where these exist. In Asia, there are anecdotal reports of pre-blended polyols containing HCs used in spray foams without

¹² Now, Supercritical CO₂ blown foams are manufactured at lower temperatures with less frothing with a finer cell structure and more efficient foam and making less polyurea, which has improved foam structure and performance.

¹³ Heated moulds improve foam adhesion and flow.

clarity around safety measures, as HC's at flammable levels are not in widespread use of spray foam. However, larger enterprises and projects implemented under MLF or United Nations Development Programme (UNDP) supervision generally demonstrate higher compliance with safety requirements.

The use of HCs and other flammable FBA (methyl formate and methylal) pre-blended in formulations continues to be of concern, as their use requires safety measures and plant modifications for blending facilities, including in SMEs. SDSs should indicate the flashpoints of pre-blended polyols based on the characteristics of the FBA and the load of the FBA and based on its separation in the vapor space. Flashpoints are used in determining local safe operating and handling requirements. The flashpoint and volatility are used to determine compliance with local safety regulations such as storage and transportation limits under the Global Harmonized System.

To control cost, foams are also manufactured with oxygenated HC (i.e., methylal and methyl formate) in small quantities unblended or in co-blown in blends. Safety precautions should be taken based on flammability of oxygenated HCs. Methylal and methyl formate (both flammable) are used as a foam co-blowing agent in rigid foam applications and integral skin foam applications. Methyl formate continues to be used as an FBA by some companies and as a solvent.

Most HFC-134a use in XPS has transitioned to lower cost alternatives (e.g., HFC-152a, carbon dioxide, dimethyl ether or DME, HCs, ethanol or blends or even methanol). Precautionary safety measures are needed for these flammable alternatives. The preparation for conversion to flammable¹⁴ blowing agents requires approximately 18 to 36 months for capital investment and product qualification based on the specific end-use (e.g., walls, roofs, structural support, transportation, cold storage). FBA use is also affected by local and regional air quality regulations on VOCs. FBAs have not been identified for XPS foams requiring high thermal performance that are non-fluorinated or with even lower GWP FBAs.

Other foam blowing agents

1,2- trans-dichloroethylene (DCE) continues to be used as a co-blowing agent worldwide, for use with HFCs, HFOs/HCFOs. DCE use may have increased in use as a co-blowing agent to reduce FBA cost.

Other blowing agents and co-blowing agents continue to be used in small quantities. Isopropyl chloride (2-Chloropropane) is blended with isopentane generally for phenolic foam. Other fluorinated additives continue to be used as additives for nucleation.

2.4 Production- based model for emissions and banks

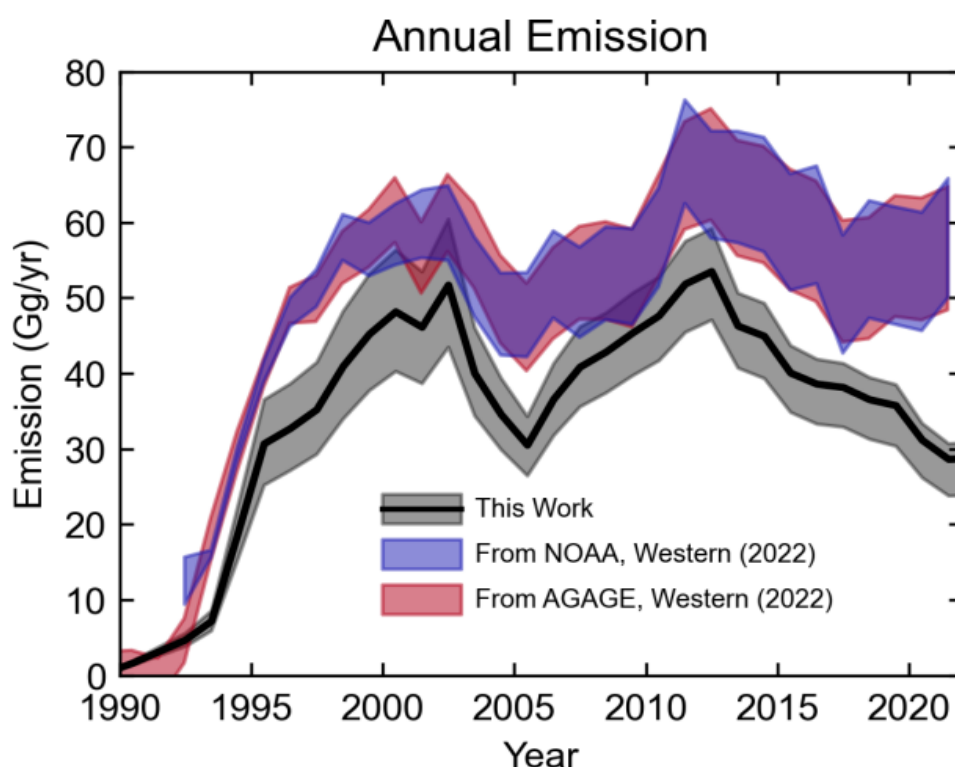
A newly verified bottom-up model incorporates release (leak) rate testing and research, existing use and life-cycle information to calculate emissions and banks and uncertainties into a third-party peer-reviewed paper.¹⁵ To demonstrate the model, it was applied to globally reported 1,1-dichloro-1-fluoroethane (HCFC-141b), whose production is currently being phased out. The calculated global emission trends are qualitatively similar to those derived from atmospheric measurements from 1990 to 2017, without reverse engineering emissions rates, foam lifetimes or other assumptions.

¹⁴ A new paper on flammability hazards of HFO-1234ze during processing. *Comprehensive Evaluation of the Flammability and Ignitability of HFO-1234ze*; R.J. Bellair, L.S. Hood, Process Safety and Environmental Protection, In Press (2019). <https://www.sciencedirect.com/user/error/ATP-2?pii=S0957582019313734>

¹⁵ A new production-based model for estimating emissions and banks of ODSs: application to HCFC-141b Walter-Terrinoni et al Atmospheric Chemistry and Physics January 26 2026 <https://acp.copernicus.org/articles/26/1193/2026/>

The bottom-up model is not constrained to atmospheric observations, and thus represents a completely independent calculation of emissions and banks over time, unlike many other approaches that are constrained to observations in some manner (e.g., Lickley et al., 2022; Western et al., 2022; WMO, 2011, 2014, 2018, 2022; Velders and Daniel, 2014). The approach allows for including changing fundamental emission parameters as demonstrated for recovering banked HCFC-141b in refrigerator foams in Europe from 2002 onward. As shown in Figure 2.3, the comparison of calculated emissions with emissions estimated from global atmospheric measurement networks is quite good in terms of the temporal shape from the beginning through the late 2010s, although modelled emissions are generally somewhat lower. The most straightforward parameter change that would bring the calculated emissions higher across all years is to increase the emissions associated with production or to increase the fraction that has been used as a solvent. Importantly, however, these are not the only ways to improve agreement.

Figure 2.3 Japan percentage of non-fluorinated FBA



Total calculated global emissions compared with top-down estimates made with a 12-box model using atmospheric measurement networks, as given in Western et al. (2022). All shaded regions represent the 68 % confidence range. Note that the overlap of the top-down observations appears purple.

After 2017, the calculated emissions no longer track the observationally based trends through the end of the comparison in 2021, which could have relevance to the question of compliance with the Montreal Protocol. The discrepancy suggests either a growing additional source of emissions that is inconsistent with reported production or a model deficiency that was not apparent before 2017.

Historical total bank calculations compare well to those of Lickley et al. (2022). Future total bank estimates begin in good agreement with those of the World Meteorological Organization (WMO) (2022), but the size of our bank estimates drops off more slowly over time, which is unsurprising, given the differing approaches to projecting future banks. Furthermore, the analysis shows that by

2040, the majority of the HCFC-141b in banks will be found in spray foams and discontinuous panels, both used in buildings, and thus likely more expensive to extract before building demolition than capturing an ODS from, for example, refrigeration units.

3 Fire Suppression TOC (FSTOC) Progress Report

3.1 Introduction

The FSTOC met in person in Marrakesh, Morocco, from 2-6 February 2026. The meeting was attended in person by 15 members from the following parties: Australia, Brazil, China, Denmark, Egypt, India, Italy, Japan, Kuwait, Morocco, the UK, and the United States, and virtually by two members, one each from Sweden and the United States.

3.2 Alternatives to Controlled Substances in the Fire Suppression Sector

3.2.1 *New Agents*

The FSTOC is not aware of any new alternatives to halons, HCFCs or high-GWP HFCs under development since the last progress report. Two additional, not-in-kind, solid aerosols are under regulatory review under the U.S. Environmental Protection Agency Significant New Alternatives Policy (SNAP) program. Also under the SNAP program, a 50-50% blend of 2-BTP and CO₂ being proposed as a possible replacement for halon 1301 in civil aviation cargo compartments, has been proposed as acceptable but not yet approved. No airframe manufacturer has approved this blend, and no civil aviation authority has approved it for use in that application. As the FSTOC has previously stated, the timescale for research, development, and regulatory approval is long. Therefore, the FSTOC does not anticipate any other new agents being commercially available in the near to mid-term (i.e., 10 years or longer).

In the 2018 Assessment Report, the FSTOC believed that the initial 10% reduction in HFC production would not have a significant impact on the fire suppression sector. In the 2022 Assessment Report, the FSTOC noted that HFC phasedown regulations in non-A5 parties had a bigger impact on the cost and availability of HFC fire suppressants than initially anticipated. What the FSTOC is now seeing, is a significant impact on the cost of HFCs. The FSTOC believes this is for the following reasons:

- HFCs used for fire extinguishing are high-GWP,
- allocation mechanisms (Kigali Amendment obligations) tend to be GWP-weighted,
- market factors mean that producers and importers have to decide which HFCs to manufacture or import, based on their GWP and future market needs, and
- the lower the GWP, the more agent can be produced or imported under a given allocation or obligation.

Although the Kigali Amendment for A5 parties is currently in the freeze phase with the initial 10% reduction due in 2029, the FSTOC is aware that parties that have established HFC quotas are already incorporating reductions in high-GWP fire suppressants, thereby reducing the use of high-GWP HFCs faster than originally anticipated in the fire suppression sector.

In the fire suppressant sector, agents are typically high-GWP HFCs and manufacturers appear to choose to produce and sell lower GWP refrigerants to maximize their allocation. Combined with the observed rising cost of HFC fire suppressants means that the HFC phasedown worldwide is having a big impact on the production and consumption of HFC fire suppressants.

As more parties act on their obligations under the Kigali Amendment, some parties, e.g., EU and its member states, are regulating additional phase-down than required. The recent amendment to the EU F-Gas Regulation (2024/573) illustrates this with a ban in place for HFCs for new fire protection systems, “except when required to meet safety requirements at the site of operation”.

The EU F-gas Regulation also includes more onerous restrictions on placing fire suppressant agents on the market, for HFCs in general, than the dates in the Kigali Amendment. Whereas the Kigali Amendment requires a 70% reduction by 2029, 80% by 2034 and 85% by 2036 and no further reduction beyond 2036, the EU Regulations now require more than an 87% reduction by 2029, over 94% by 2032, over 95% by 2035, and further gradual reductions to reach a 100% reduction by 2050.

While the above noted factors are affecting the installation of new systems, the FSTOC is aware of the associated increasing cost to maintain (hydrostatic, test, refill, etc.) existing HFC systems.

3.3 Availability of alternatives to HFCs

3.3.1 Inert Gases

The highest-pressure inert gas (IG) systems (300 bar) help offset (to some degree) one of the drawbacks of IG systems, which is that of a greater number of cylinders and the resulting increased system footprint. A simplified example would show that half the number of 300 bar cylinders are needed as compared with 150 bar systems. While a 300-bar system will still be typically greater than the footprint for the halocarbon systems, it does represent a useful saving as compared with a 150-bar system.

300-bar IG systems are now becoming more popular with some parties, for the reason of reduced footprint, compared with 150- or 200-bar systems. In many other parties, the availability for filling/refilling at 300 bar is limited, with some parties having a limit of 200 bar and even only 150 bar. As an example, in the Middle East, 300 bar systems are often limited to only two parties, with many others not equipped to facilitate 300 bar refilling, e.g., Egypt's refilling capability is generally limited to 150 bar.

The limitations in the Middle East occur in other parties. In Asia, pressurization to 200 bar or even 150 bar is also the limit. In-country support for filling IG cylinders is sporadic in Africa. It is also important to note that the filling of fire suppression cylinders is different to the filling of industrial gas cylinders. Fire suppression IG systems use valves with high discharge rates versus slow discharge rate valves often used for some other industrial applications. For IG blends, e.g., IG-541 and IG-55, it is necessary to ensure more precise filling than for industrial use. In many A5 parties, the inert gas fillers are not equipped to handle such systems. Furthermore, the Inert Gas blends require not only more precise filling to ensure a mix of the component gases in accordance with system approvals, but then also post filling analysis, such as gas chromatography and moisture check being undertaken on every cylinder, to demonstrate that the exact blends are within strict tolerances in accordance with standards, such as ISO 14520.

3.3.2 FK-5-1-12

Some A5 parties (and many non-A5 parties) are expressing concern over potential future PFAS regulations on FK-5-1-12. Although many parties do not yet have national PFAS regulations as they relate to gaseous fire suppressants, they are monitoring the global PFAS situation, especially that of the EU and individual states in the United States. This will affect the future global supply of gaseous firefighting agents.

3.4 Agent Lifecycle Management (ALM)

Shortages in the future global supply of gaseous firefighting agents will make Agent Lifecycle Management (ALM) even more critical, especially in parties that do not have any ALM in place.

3.4.1 *Verra Methodology on HFC destruction*

In December 2025, the Verra carbon registry and crediting program in the United States released a new version of the methodology ‘VM0016 Destruction of Ozone-Depleting Substances and Hydrofluorocarbons, v2.0’ in the Verified Carbon Standard (VCS) program. The methodology is a first for addressing the destruction of HFCs from specific sources in addition to ODS, including halons. The methodology quantifies the greenhouse gas (GHG) emission reductions from project activities that recover and/or collect ODS or HFCs from products and subsequently destroy them, including the fire suppression agents halons, HFC-227ea, HFC-236fa, HFC-125, etc. The methodology outlines the eligibility conditions of projects and is applicable in all parties both A5 and non-A5 parties. The FSTOC is concerned that this methodology could lead to the destruction of HFCs which otherwise could be reclaimed for fire-suppression purposes.

3.5 The global halon 1301 bank

3.5.1 *Oil & Gas*

The 2022 estimate included a portion of the bank assigned to the oil and gas sector of 1,500 tonnes is now 1,850 tonnes, including dedicated reserves of 33%.

3.5.2 *Shipbreaking*

Recent data from Bangladesh and India have been obtained by the FSTOC which suggests that a few ships still contain halon 1301. A total of 22 tonnes was reported over the last three years. Recalling that ICF (ICF, 2015) estimated that approximately 200 to 300 tonnes of halon 1301 could be available per year, the 22 tonnes from Bangladesh and India seem very low.

In the 2022 Assessment Report it was hypothesized that halon is being removed and recycled prior to the ships being broken, or that the amounts of halon being recovered may also be lower for other reasons, for example the supplies of halon may be becoming exhausted sooner than anticipated.

The FSTOC has now confirmed that there are many instances of the halon cylinders being removed prior to the ships arriving at the breaking yards. Three possible reasons were cited for this:

- **Prior Harvesting:** Because halon 1301 is so valuable, shipowners often "harvest" the cylinders while the ship is still in service or at a lay-up port to use as spares for their remaining active fleet.
- **In-Transit Theft:** In high-risk transit zones or during long layups before reaching the breaking yard, portable and even fixed cylinders are frequently stolen for their high resale value.
- **Port-State Disposal:** Some vessels are required to remove ODS in their home ports (under local EU or US regulations) before departing on their final voyage to the ship breaking yards.

The FSTOC will continue to monitor shipbreaking as a source of halon 1301, since its supply is one of the factors that might affect the runout date for halon 1301.

3.5.3 *Updates to Global Bank Estimates*

This is included at the end of this Chapter “Response to Decision XXXVII/4” (section 3.8).

3.6 Civil Aviation

3.6.1 Status of Alternatives

The status of halon alternatives in civil aviation is unchanged. Both engines and cargo compartments are still reliant on halon 1301.

One development is that the U.S. SNAP program has listed the blend of 2-bromo-3,3,3-trifluoropropene/carbon dioxide (2-BTP/CO₂), as acceptable, subject to use conditions, as a total flooding agent for use in normally unoccupied spaces onboard aircraft (including engine nacelles, auxiliary power units, and cargo bays) (EPA, 2026).

3.6.2 Recap of 42nd ICAO General Assembly

As noted in the 2025 Progress Report, the long-term supply of halon 1301 is a concern to the FSTOC and is now also a concern to the ICAO secretariat.

The FSTOC model has previously predicted that the halon 1301 run out date lies in the range 2030-2049 (FSTOC, 2022). This will impact the civil aviation sector and has resulted in a working paper: A42-WP/74, “THE CHALLENGE OF HALON REPLACEMENT: BALANCING FIRE SAFETY, ENVIRONMENTAL GOALS, AND INDUSTRY READINESS”. This paper was presented by the International Coordinating Council of Aerospace Industries Associations (ICCAIA), the International Federation of Air Line Pilots’ Associations (IFALPA), and the International Business Aviation Council (IBAC) to the ICAO 42nd General Assembly in September 2025 in Montreal, Canada.

In addition to A42-WP/74, the informational paper, A42-WP/395: “AIRCRAFT FIRE SUPPRESSION – HALON REPLACEMENT” was presented by the International Coordinating Council of Aerospace Industries Associations (ICCAIA) to the ICAO 42nd General Assembly providing complementary details.

A42-WP/395 outlines the complexities involved in identifying suitable halon replacements for aircraft cargo compartments and highlights the implications of upcoming regulations restricting PFAS use and in conclusion urges ICAO to initiate a process to establish a sustainable revised deadline for halon replacement in cargo compartment fire suppression systems. It noted that, assuming global reserves of halon are limited according to the FSTOC 2022 Assessment Report, halon reserves are expected to be depleted soon; therefore, in the absence of acceptable alternatives, the presented paper states it is crucial to explore means to secure halon supply via an EUN under the Montreal Protocol until an acceptable halon replacement is available for use in aircraft cargo compartments.

Following the ICAO 42nd General Assembly, Provisional Edition of the Resolutions Adopted by the Assembly was published in October 2025 and presents the Resolution A42-11: Halon replacement, which introduces two new items, 6 and 7, as follows:

6. Encourages States, with the assistance of ICAO, to liaise with the United Nations Environment Programme (UNEP) Ozone Secretariat and the Montreal Protocol advisory body, the Technology and Economic Assessment Panel and its Fire Suppression Technical Options Committee, to assess global halon reserves and support the sustainable management of existing halon banks, including an essential use nomination for halon in aircraft cargo compartment applications under the Montreal Protocol to maintain aviation safety;

7. Directs the Council, in coordination with industry and considering the assessment of availability of the global halon reserves, to develop a proposal for a revised sustainable effective cut-off date for Halon replacement in Annex 8 — Airworthiness of Aircraft for new aircraft type certificate applications. This proposal shall be based on comprehensive data including Halon availability, progress in alternative solution development and take account of safety considerations.

The most recent Decisions adopted by the Thirty-Seventh Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer is Decision XXXVII/4. The full text of the Decision is included in Section 3.8. The operational text is reproduced below:

1. To request that the Ozone Secretariat liaise with the secretariat of the International Civil Aviation Organization on the matter of fire suppression agents controlled under the Montreal Protocol on Substances that Deplete the Ozone Layer and facilitate the exchange of information between the Technology and Economic Assessment Panel, through its Fire Suppression Technical Options Committee, and the relevant International Civil Aviation Organization technical committees and working groups in order to allow the Panel to:

(a) Better assess the future use of and need for halons in civil aviation, making use of, among other things, available data on the locations of the maintenance, repair and overhaul operations authorized to service halons, data on future fleet evolution and estimates regarding aircraft in operation with different types of halon fire protection systems;

(b) Submit a report on halon availability and the global distribution of halon banks, based on the above-mentioned activities, to the parties in advance of the forty-eighth meeting of the Open-ended Working Group of the Parties to the Montreal Protocol;

2. To encourage parties to liaise, through their national ozone officers, with their national civil aviation authorities to gain an understanding of how halons and their alternatives are being used and supplied to air carriers to meet ongoing civil aviation needs;

3. To also encourage parties to reassess any national import and export restrictions other than licensing or quota requirements with a view to facilitating the import and export of recovered, recycled or reclaimed halons and other controlled substances used for fire suppression, with the aim of facilitating the meeting of remaining needs of the parties, taking into account the requirements of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, where applicable;

4. To invite parties to submit, on a voluntary basis, to the Ozone Secretariat, by 31 March 2026, available information regarding the development of alternatives suitable for use as substitutes in fire suppression, and to request the Ozone Secretariat to forward the information received to the Technology and Economic Assessment Panel for its consideration and for inclusion, at the latest, in its 2027 progress report.

Both the ICAO Resolution A42-11 and Montreal Protocol Decision XXXVII/4 call for liaison between ICAO and FSTOC to assess global Halon reserves and aviation needs. In response, ICAO and Ozone Secretariats were approached regarding feasibility of a Joint Signatory Letter signed by equivalent high-level officials from both ICAO (Secretary General level) and the UNEP (Ozone Secretariat) to request data from Parties aiming to better assess the future use of and need for halons in civil aviation.

The ICAO Secretariat has requested the formation of a formal expert group via the ICAO Airworthiness Panel, including but not limited to original equipment manufacturers (OEMs); maintenance, repair and overhaul entities (MROs); suppliers; recyclers; non-governmental organizations (NGOs); TEAP/ FSTOC and other relevant stakeholders. This action is ongoing and will help with exchanging information.

To address the Decision and the Resolution, the Cargo Compartment Halon Replacement Advisory Group (CCHRAG) under the ICCAIA is coordinating efforts to gather data to assess future demand of halon 1301 necessary to sustain current in-service aircraft fleet and the forecast new aircraft deliveries. These actions will help determine the need for a future EUN request or otherwise. For further information see Section 3.8.

3.7 Training

All FSTOC A5 members are concerned that the current level of training in the fire suppression sector requires major improvement. The FSTOC is emphasizing the need for the development and organized implementation of a structured training program to drive awareness of new and evolving hazards resulting in part from the implementation of the Montreal Protocol. Examples where training is needed include addressing high pressure and very high-pressure cylinders, flammable refrigerants, difference in toxicity versus asphyxiation, etc.

3.8 Response to decision XXXVII/4: Halon availability and global distribution of halon banks

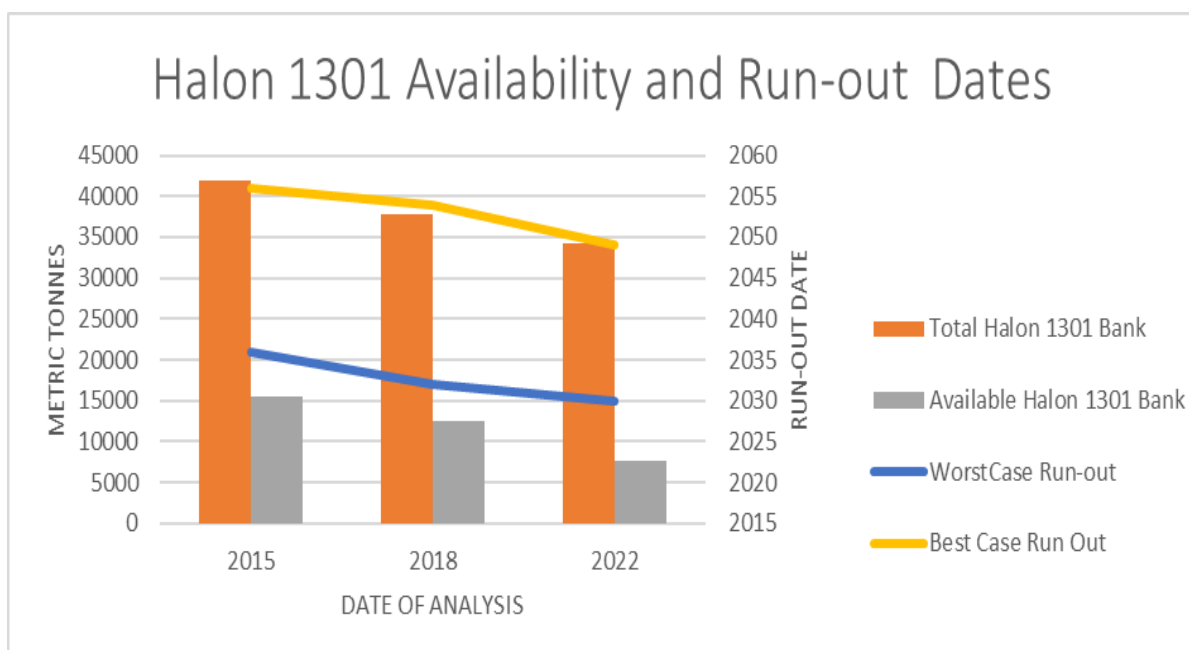
3.8.1 Introduction

The FSTOC has responded to three decisions of the parties regarding future availability of halon 1301. A summary of its findings is included in the table and figure below, TEAP (2023).

Table 3.1 Halon 1301 availability and run-out dates

Decision	Date of Analysis	Total Halon 1301 Bank (Metric tonnes)	Available Halon 1301 Bank (Metric tonnes)	Worst case Run-out date	Best case Run-out date
XXVI-7	2015	42,000	15,500	2036	2056
XXIX-8	2018	37,750	12,500	2032	2054
XXX-7	2022	34,310	7,620	2030	2049

Figure 3.1 Halon 1301 availability and run-out dates



It is important to understand that the available bank is depleting faster than the unavailable bank. This is because the unavailable bank is “tied up” in enduring uses. If a system employed in an enduring use is discharged, due to a fire, false alarm, or it leaks, then the system likely is refilled, from the available bank. Thus, the available bank is depleted while the unavailable bank is largely static. This would appear to explain why every time the FSTOC has performed this analysis in the past, the run-out dates always move to the left, i.e., occur sooner.

3.8.2 *Decision XXXVII/4*

Decision XXXVII/4 is reproduced below:

Decision XXXVII/4: Halon 1301 and its continuing use in the aviation industry, and management of other controlled substances used for fire suppression

The Thirty-Seventh Meeting of the Parties,

Taking note of the 2025 progress report of the Technology and Economic Assessment Panel¹ and its update on the potential long-term use of halon 1301 in the aviation sector,

Noting that some controlled substances, including halons and HCFC-123, continue to have a meaningful role in fire suppression,

Noting with concern that the long-term supply of halon 1301 is uncertain because of its continuing use in key sectors, difficulties in transboundary shipment of recovered, recycled or reclaimed halon 1301, the deliberate destruction of halon 1301 for carbon credits and the switch to halon 1301 by some users of halon 2402,

Taking note of resolution A42-11¹⁶ of the Assembly of the International Civil Aviation Organization, in which the Assembly, among other things, directed its Council to develop a proposal for a sustainable, effective revised cut-off date for halon replacements for new aircraft type certificate applications, considering the assessment of availability of global halon reserves, and to base the proposal on comprehensive data, including halon availability, and progress on alternative solution development and take account of safety considerations,

Noting that, in the resolution, the Assembly encouraged States, with the assistance of the International Civil Aviation Organization, to liaise with the Ozone Secretariat, the Technology and Economic Assessment Panel and its Fire Suppression Technical Options Committee, to assess global halon reserves and support the sustainable management of existing halon banks, and encouraged the International Civil Aviation Organization to continue collaboration with the Ozone Secretariat through the Fire Suppression Technical Options Committee on the topic of halon alternatives for civil aviation,

Noting also that considerable work has been carried out on evaluating alternatives to halon 1301 in cargo compartments for new aircraft designs, and that at least one alternative candidate might soon be available,

¹ United Nations Environment Programme, *Report of the Technology and Economic Assessment Panel: Volume 1 – Progress Report*, May 2025 (Nairobi, 2025).

¹⁶ Available at https://www.icao.int/sites/default/files/Meetings/a42/Documents/Resolutions/a42_res_prov_en.pdf (provisional edition).

Recalling the ongoing communication between the International Civil Aviation Organization and the Fire Suppression Technical Options Committee of the Technology and Economic Assessment Panel,

Recalling also the long-standing decisions XXI/7, XXII/11, XXVI/7, XXIX/8 and XXX/7 and, most recently, decision XXXVI/7 on measures to support the sustainable management of recovered, recycled or reclaimed halons,

Decides:

1. To request that the Ozone Secretariat liaise with the secretariat of the International Civil Aviation Organization on the matter of fire suppression agents controlled under the Montreal Protocol on Substances that Deplete the Ozone Layer and facilitate the exchange of information between the Technology and Economic Assessment Panel, through its Fire Suppression Technical Options Committee, and the relevant International Civil Aviation Organization technical committees and working groups in order to allow the Panel to:
 - (a) **Better assess the future use of and need for halons in civil aviation, making use of, among other things, available data on the locations of the maintenance, repair and overhaul operations authorized to service halons, data on future fleet evolution and estimates regarding aircraft in operation with different types of halon fire protection systems;**
 - (b) **Submit a report on halon availability and the global distribution of halon banks, based on the above-mentioned activities, to the parties in advance of the forty-eighth meeting of the Open-ended Working Group of the Parties to the Montreal Protocol;**
2. To encourage parties to liaise, through their national ozone officers, with their national civil aviation authorities to gain an understanding of how halons and their alternatives are being used and supplied to air carriers to meet ongoing civil aviation needs;
3. To also encourage parties to reassess any national import and export restrictions other than licensing or quota requirements with a view to facilitating the import and export of recovered, recycled or reclaimed halons and other controlled substances used for fire suppression,¹⁷ with the aim of facilitating the meeting of remaining needs of the parties, taking into account the requirements of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, where applicable;
4. To invite parties to submit, on a voluntary basis, to the Ozone Secretariat, by 31 March 2026, available information regarding the development of alternatives suitable for use as substitutes in fire suppression, and to request the Ozone Secretariat to forward the information received to the Technology and Economic Assessment Panel **for its consideration and for inclusion, at the latest, in its 2027 progress report.**

3.9 ICAO Resolution A42-11

Resolution A42-11, including the new paragraphs (6 and 7) is reproduced below:

Recognizing the importance of aircraft fire extinguishing systems to the safety of flight;

Recognizing that halogenated hydrocarbons (halon) have been the main fire extinguishing agent used in civil aircraft fire extinguishing systems for over fifty years;

¹⁷ Covered in the 2022 assessment report of the Technology and Economic Assessment Panel.

Whereas halons are no longer being produced by international agreement because their release contributes to ozone depletion and climate change;

Recognizing that more needs to be done because the available halon supplies are decreasing and unsure and that the environmental community continues to be concerned that halon alternatives have not been developed for all fire extinguishing systems in civil aircraft;

Recognizing that the Minimum Performance Standard for each application of halon has been developed already by the International Aircraft Systems Fire Protection Working Group with participation by industry and regulatory authorities;

Recognizing that there are stringent aircraft-specific requirements for each application of halon that must be met before a replacement can be implemented;

Recognizing that the aircraft manufacturing industry has established mechanisms for stakeholder engagement in the development of common solutions for halon replacement in a realistic timeframe for cargo compartment applications;

Recognizing that the production is prohibited by international agreement, halon is now exclusively obtained from recovery, reclaiming and recycling. Therefore, recycling of halon gas needs to be rigorously controlled to prevent the possibility of contaminated halon being supplied to the civil aviation industry; and

Recognizing that any strategy must depend on alternatives that do not pose an unacceptable environmental or health risk as compared to the halons they are replacing;

The Assembly:

1. *Urges* States and their aviation industries to intensify development and implementation of acceptable halon alternatives for fire extinguishing and suppression systems in aircraft cargo compartments;
2. *Urges* States to determine and monitor their halon reserve and quality of halon;
3. *Encourages* ICAO to continue collaboration with the International Aircraft Systems Fire Protection Working Group and the United Nations Environment Programme's Ozone Secretariat through its Technology and Economic Assessment Panel's Halons Technical Options Committee on the topic of halon alternatives for civil aviation;
4. *Encourages* States to collaborate with the Industry Consortium for engine/APU applications and the Cargo Compartment Halon Replacement Working Group established by the International Coordinating Council of Aerospace Industries Associations;
5. *Encourages* States to support measures to minimize unnecessary halon emissions that occur when there is an absence of any safety threatening fire event and to ensure the better management and preservation of existing halon reserves;
6. *Encourages* States, with the assistance of ICAO, to liaise with the United Nations Environment Programme (UNEP) Ozone Secretariat and the Montreal Protocol advisory body, the Technology and Economic Assessment Panel and its Fire Suppression Technical Options Committee, to assess global halon reserves and support the sustainable management of existing halon banks, including an essential use nomination for halon in aircraft cargo compartment applications under the Montreal Protocol to maintain aviation safety;

7. *Directs* the Council, in coordination with industry and considering the assessment of availability of the global halon reserves, to develop a proposal for a revised sustainable effective cut-off date for Halon replacement in Annex 8 — Airworthiness of Aircraft for new aircraft type certificate applications. This proposal shall be based on comprehensive data including Halon availability, progress in alternative solution development and take account of safety considerations.

8. *Directs* the Council to mandate the replacement of halon in cargo compartment fire suppression systems used in aircraft for which application for type certification will be submitted after a specified date in the 2024 timeframe; and

9. *Declares* that this resolution supersedes Resolution A39-13.

3.10 Actions taken

The FSTOC and the Cargo Compartment Halon Replacement Advisory Group (CCHRAG) under the International Coordinating Council of Aerospace Industry Associations (ICCAIA), for ICAO, have proposed that the Ozone Secretariat and the ICAO Secretariat consider developing a “Joint State Letter” to be sent to all parties to the Montreal Protocol and ICAO Member States requesting increased collaboration on halon issues raised in ICAO Resolution 42-11 and the Decision XXXVII/4 . It is making progress within ICAO.

To address the ICAO Resolution 42-11 and the Decision XXXVII/4, the CCHRAG put together a small working group including the FSTOC member who also is on the CCHRAG, to coordinate efforts to gather data to assess both the future demand of halon 1301 necessary to sustain current in-service aircraft fleet, and to also forecast halon 1301 needed for new aircraft deliveries and their sustainment.

3.11 Status

3.11.1 Aviation Fleet and Halon Usage Estimates

In response to Resolution A42-11 and Decision XXXVII/4, ICCAIA’s CCHRAG assessed the amount of halon currently installed in the actual in-service fleet. This analysis allows for the prediction of future for new aircraft as well needs to replenish halon emissions due to discharging over fire alarms, losses to leakage, or contaminations during maintenance tasks.

The following data sources were used:

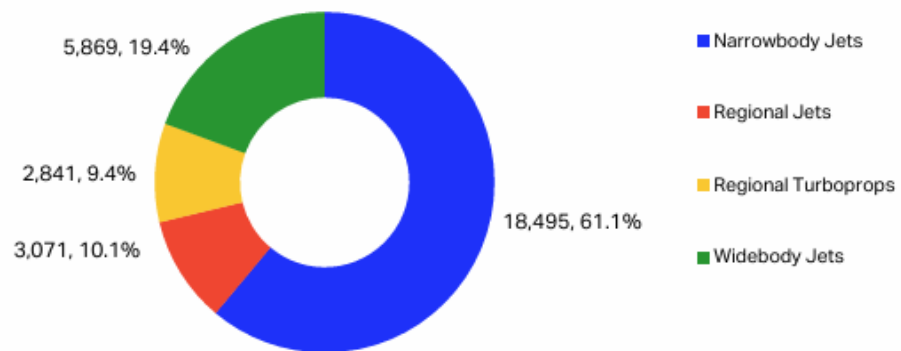
- IATA The global commercial aircraft fleet 2025, IATA (2025).
- Boeing Commercial Market Outlook 2025–2044, Boeing (2025)
- Airbus Global Market Forecast 2025-2044, Airbus (2025)
- Embraer Market Outlook 2025-2044, Embraer (2025)
- ATR Turboprop Market Forecast 2025-2044, ATR (2025)
- Honeywell 2025 Global Business Aviation Outlook, Honeywell (2025)

The analysis used the following assumptions:

- Current in-service fleet is classified in market categories, considering the number of aircraft presented in the IATA report 2025 and adding a category to cover business aircraft: widebody jets, narrowbody jets, regional jets, turboprops, and business aircraft.
- Composition of global commercial active fleet by manufacturer is extracted from “The global

commercial aircraft fleet” published by IATA in August 2025, as shown in Figure 3.2 below:

Figure 3.2 Aircraft Categories per IATA Report



Source: IATA Sustainability and Economics, Cirium Fleets Analyzer

- The market share is assumed to be uniformly distributed within manufacturers, e.g., a 50/50 split between Boeing and Airbus for widebody jets market.
- The quantity of halon in each aircraft category was estimated based on experience and historic data from aircraft manufacturers, accounting for fire extinguisher bottles installed for cargo compartments and engine/APU fire suppression systems.
- To avoid divulging confidential business information, such as the exact halon 1301 quantity for a specific aircraft type, the following approach was used: for each aircraft type (e.g., widebody jet, narrowbody jet, etc.) an average quantity was estimated by the CCHRAG, as well as a “low” value and a “high” value, to account for smaller and larger aircraft variants respectively. These are referred to a “min” and “max” in the table below. CCHRAG believes that “average” scenario is the most likely.
- The quantity of newly produced aircraft is estimated for the next 20 years based on the market overview published by most OEMs as presented in the Reference Data. It allows the prediction of future needs for halon 1301 systems for these aircraft.
- To predict worldwide deliveries and total fleet development over the next 20 years, a linear growth rate was assumed. The total forecasted growth quantity from the combined outlooks was divided by 20 to derive an annual average.
- A portion of halon 1301 may also be recovered and recycled from retired aircraft, thus becoming available to account for future demands either.

These various inputs are summarized in Tables 3.2 and 3.3 below.

Table 3.2 Halon 1301 Quantities per Aircraft Type and Overall Total Fleet Usage

Halon demand to replenish emitted systems (in-service fleet)													
Market Class	Active Fleet	Halon in Cargo Firex System per aircraft (kg) <i>Typical HRD + LRD bottles Note 2</i>			Halon in Engine/APU Firex System per aircraft (kg) <i>Typical Engine + APU bottles Note 2</i>			Total Halon Charge per aircraft (kg) <i>Cargo + Engine/APU Firex Systems</i>			Total Halon Charge in Market Class <i>(metric ton)</i>		
		Min	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max
Widebody jet	5,869	103	154	197	21	33	43	124	187	240	730	1,098	1,411
Narrowbody jet	18,495	17	26	36	15	20	20	32	47	57	600	860	1,049
Regional jet	3,071	14	20	27	5	9	14	18	29	41	56	91	125
Turboprop jet	2,841	0	0	0	7	9	11	7	9	11	19	26	32
Business jet	25,000	0	0	0	7	9	11	7	9	11	170	227	284
Total	55,276										1,575	2,302	2,901

Table 3.3 Aviation Fleet Growth and Future Halon 1301 Requirements

Market Class	Predicted Yearly deliveries <i>Data Source: Publically available Market Forecasts / Outlooks from</i>	Total yearly Halon demand for Cargo Firex (kg)			Total yearly Halon demand for Engine + APU Firex (kg)			Total yearly Halon demand for the new aircraft deliveries (kg)			Total yearly Halon demand for the new aircraft deliveries (tonnes)		
		Min	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max
Widebody jet	400	41,289	61,706	78,947	8,439	13,158	17,241	49,728	74,864	96,189	50	75	96
Narrowbody jet	1,700	28,925	44,351	61,706	26,225	34,710	34,710	55,150	79,061	96,416	55	79	96
Regional jet	436	5,935	8,902	11,869	1,978	3,956	5,935	7,913	12,858	17,804	8	13	18
Turboprop	89	-	-	-	606	808	1,010	606	808	1,010	1	1	1
Business jet	780	-	-	-	5,309	7,078	8,848	5,309	7,078	8,848	5	7	9
Total	3,405							118,705	174,669	220,265	119	175	220

3.11.2 Updated Halon 1301 Run-out Date

The following methodology was used to calculate the range of possible run-out dates:

The starting point is the 2022 Assessment Report, where the various sectors of the global halon 1301 bank are detailed, as shown in the Table 3.4 below. These estimates were reviewed by the FSTOC and adjusted according to the knowledge of the various subject-matter experts. Additionally, a range of emissions from each of the sectors were estimated, according to the knowledge of FSTOC subject-matter experts. The ranges for the available bank are +/- 10%, as was used previously. The military, both installed and reserves, depending upon the scenario, may be changed so that the total global bank is set to 41,973, which is the year 2014 in the FSTOC model. This allows for a broader range of scenarios to be considered.

Table 3.4 Latest Estimates of the Halon Bank, by Sector

Source	Quantity (tonnes)	
	2022 Assessment Report	2026 Estimate
Japan	16,455	16,359
Military installed	2,250	2,250-3,300
Military reserves	1,992	992-2,616
Oil and gas facilities	1,500	1388
Oil and Gas reserves	0	463
Nuclear installed	361	333
Nuclear reserves	131	167
Aviation Installed	4,001	1574 – 3112
Aviation Bank	90	90
Computer facilities/ Available Bank	7,331	4,170-8,592
Maritime	199	83
Worldwide Bank Total	34,310	From FSTOC Bank model: 31,661 From Runout date model 30,897 – 31,444

Two different approaches were employed to determine the run-out date:

1. Emissions were set for each sector except for civil aviation and the aviation emissions % were then adjusted to match the average of the total emissions from the FSTOC model from the period 2015 – 2024, and
2. The emission rates for aviation, oil and gas, and reserves were set, and the emissions % for installed systems (available and unavailable) were adjusted to match the average of the total emissions from the FSTOC model from 2015 – 2024.

The FSTOC model for the bank and emissions of halon 1301 has proved to be consistent with the emissions derived from atmospheric measurements of halon 1301. The historic FSTOC model and this new model were not altered in any way based on the atmospheric derived emission estimates from AGAGE, NOAA, or other atmospheric derived emissions so as to keep the FSTOC models completely independent. The fixed or estimated emission factors were then used to model the decrease in the halon 1301 bank until the available bank is depleted. This provides the halon 1301 run-out date (1).

Since some of the halon 1301 resides in reserves, the model then allows those reserves to be used to continue supporting the enduring uses, including civil aviation. This gives a second run-out date. This process was completed for 20 scenarios. The scenarios showing the earliest and latest runout dates, as well as examples of implausible scenarios, are provided in Table 3.5 below:

Table 3.5 Select Halon 1301 Run-out Date Scenarios

	Available Bank, t	Set Emission Rates	Set Aviation installed, t	Derived Aviation emission %	Run-out date (1)	Run-out date (2)
1	6,413	1% for O&G, 0.1% for Reserves 3% for other installed uses	Avg – 2,476	12.1%	2035	2036
2	5,883	1 % for O&G, 0.1% for Reserves 3% for other installed uses	High – 3112	10.1%	2033	2035
3	4,170	2 % for O&G, 0.1% for Reserves 2% for other installed uses 10% less available bank	High – 3112	12.5%	2031	2034
4	8,592	1 % for O&G, 0.1% for Reserves 3% for other installed uses 5% more available bank	Low – 1,687	14.4%	2039	2039
		<i>1 % for O&G, 0.1% for Reserves 3% for other installed uses 10% less available bank</i>	<i>Low – 1,687</i>	<i>19.2%*</i>	<i>2034</i>	<i>2037</i>
	Available Bank, t	Set Emission Rates	Set Aviation installed, t	Derived Installed Systems emission %	Run-out date (1)	Run-out date (2)
5	5,279	1 % for O&G, 0.1% for Reserves 8.5% for Aviation	High – 3112	3.39%	2033	2035
6	5,801	1% for O&G, 0.1% for Reserves 10% for Aviation	Avg – 2,476	3.55%	2034	2036
7	5,803	1% for O&G, 0.1% for Reserves 12% for Aviation	Avg – 2,476	3.28%	2033	2036
8	7,365	1% for O&G, 0.1% for Reserves 8% for Aviation Reduce reserves by 276 t	Avg – 2,476	4.04%*	2037	2042
		<i>1% for O&G, 0.1% for Reserves 8% for Aviation Reduce reserves by 299 t</i>	Avg – 2,476	<i>4.52%*</i>	<i>2037</i>	<i>2039</i>

Based on all 20 scenarios, the latest estimates fall between 2030 – 2042, a much smaller range than in the 2022 Assessment Report. However, the FSTOC believes several of the scenarios are not plausible based on resulting aviation or other installed uses emission rates e.g., aviation emission rates of 19.2 % or installed uses emissions rate of 4% or more. These are shown with an asterisk (*) and in *italics*.

This provides a probable runout date range of 2031 – 2039, or 2035+/-4 years.

One additional analysis was performed to help to establish which scenarios gave the best yearly emissions match to the FSTOC model. Two scenarios provide runout dates of 2034 with a yearly match range of 100% - 101% and 2037, with a yearly match range of 96% - 103%, further confirming the range of 2035+/-4 years.

Parties may wish to consider determining what, if any, changes may be needed to the EUN and Evaluation Processes, given that every individual party will be unable to determine their halon 1301 civil aviation needs i.e., production and consumption, on an annual basis.

3.12.3. MRO Location Information

The ICCAIA provided the FSTOC with the location of all the major MRO sites. They are listed in Tables Table 3.6 and Table 3.7 below.

Table 3.6 MRO Locations by Region

Region	No. Countries	No. MRO Locations
Africa	8	9
Asia -Pacific	16	46
Europe	12	27
North America	3	30
Central America	3	3
South America	4	8
Totals	71	123

Table 3.7 MRO Locations in Europe

Country	No. MRO Locations	Country	No. MRO Locations
Belgium	3	Malta	1
Denmark	2	Netherlands	1
Estonia	1	Norway	2
France	3	Switzerland	1
Germany	3	Turkey	2
Lithuania	2	UK	6
Grand Total			27

It is believed that these locations are where halon 1301 is removed from aircraft, and if there are any significant emission arising from this activity then these halon 1301 emissions may be observed. The 27 European MRO locations are shown graphically in Figure 3.3.

To tie the MRO locations to emissions, the FSTOC is working with atmospheric scientists who are making Inversion Technique for Emission Modelling (InTEM) measurements of gases of interest to the Montreal Protocol. InTEM is a top-down atmospheric monitoring system developed by the UK Met Office to verify national GHG inventories by comparing high-quality measurements from a 4-tower UK network with emissions estimates, Manning (2021). This technique allows the location of “pollution events” (in other words, halon 1301 “hot-spots”). An example of these kind of data is shown for NW Europe in Figure 3-4.

Figure 3.3 European MRO Locations

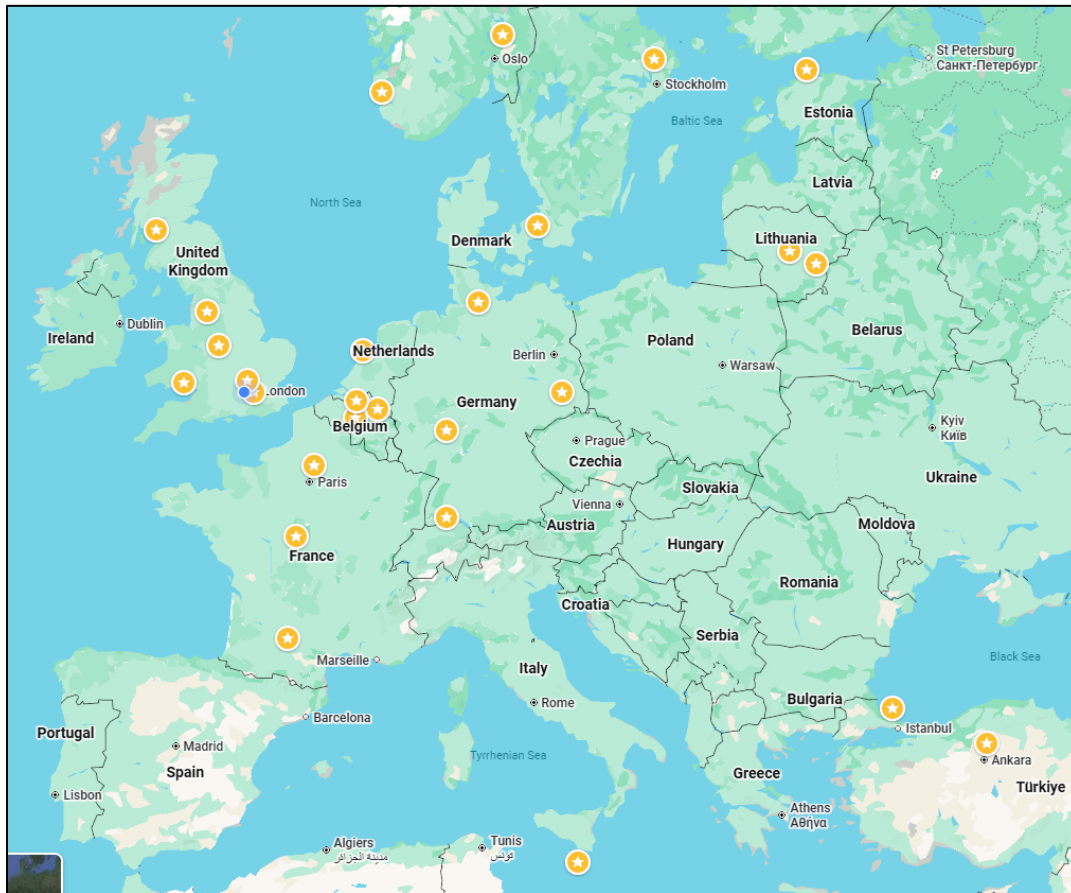
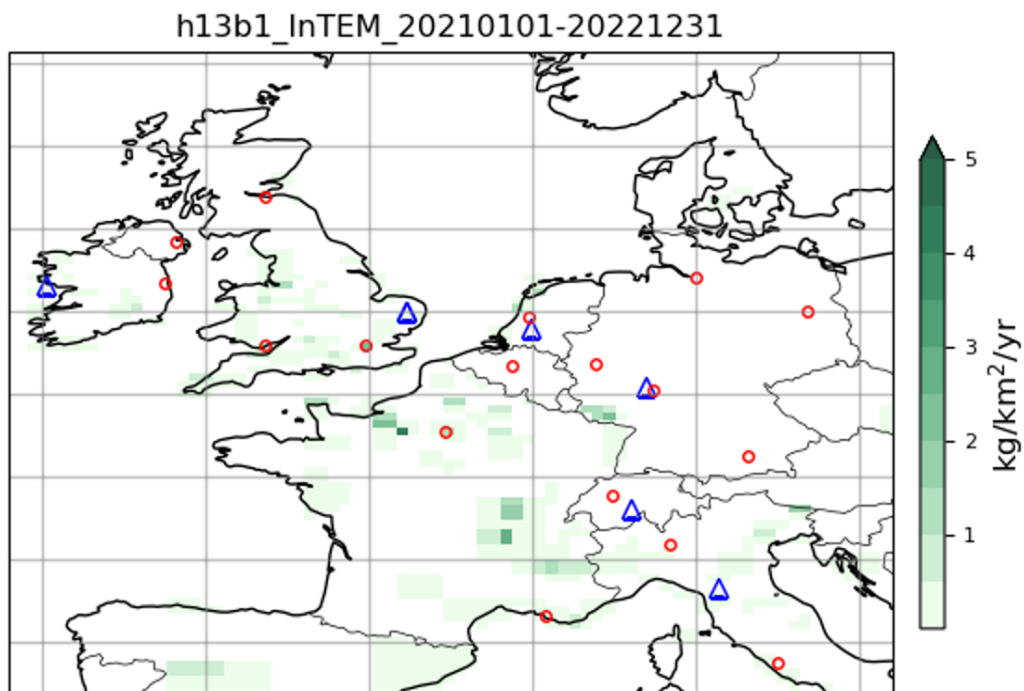


Figure 3-4 Typical Halon 1301 Emission "hot-spots"



This is for a two-year period (1 January 2021 to 31 December 2022). The red circles are capital cities, and the blue triangles are AGAGE measurement stations. The green squares indicate halon 1301 emissions in kg/km²/year.

From a simple comparison of the two figures, it can be seen that some MRO locations lie at or near to halon 1301 emission hot-spots, but others do not. The FSTOC plans obtain further data of this type to see if which MRO locations correlate to localised 1301 emissions. This is an on-going task.

3.12 References

- Airbus (2025): Airbus Global Market Forecast 2025-2044, <https://www.airbus.com/en/products-services/commercial-aircraft/global-market-forecast>
- ATR (2025): ATR Turboprop Market Forecast 2025-2044, <https://www.atr-aircraft.com/turboprop/turboprop-market-forecast-2025-2044/>
- Boeing (2025): Boeing Commercial Market Outlook 2025–2044, <https://www.boeing.com/commercial/market/commercial-market-outlook>
- Embraer (2025): Embraer Market Outlook 2025-2044, <https://www.embraer.com/eca/marketoutlook/en/>
- Honeywell (2025): Honeywell 2025 Global Business Aviation Outlook, <https://aerospace.honeywell.com/us/en/pages/honeywell-annual-business-aviation-outlook#download>
- IATA (2025): IATA The global commercial aircraft fleet 2025, <https://www.iata.org/en/iata-repository/publications/economic-reports/the-global-commercial-aircraft-fleet/>
- Manning (2021): Manning, A. J., Redington, A. L., Say, D., O'Doherty, S., Young, D., Simmonds, P. G., Vollmer, M. K., Mühle, J., Arduini, J., Spain, G., Wisher, A., Maione, M., Schuck, T. J., Stanley, K., Reimann, S., Engel, A., Krummel, P. B., Fraser, P. J., Harth, C. M., Salameh, P. K., Weiss, R. F., Gluckman, R., Brown, P. N., Watterson, J. D., and Arnold, T.: Evidence of a recent decline in UK emissions of hydrofluorocarbons determined by the InTEM inverse model and atmospheric measurements, *Atmos. Chem. Phys.*, 21, 12739–12755, <https://doi.org/10.5194/acp-21-12739-2021>, 2021

4 Methyl Bromide TOC (MBTOC) Progress Report

4.1 Introduction

The MBTOC met on 23-26 March 2026, in Shizuoka, Japan. The meeting was attended in person by 11 members from the following parties: Argentina, Australia, Colombia, Germany, Japan, Morocco, the Philippines, Türkiye, Uruguay and the United States, and virtually by four members from China, New Zealand and Australia. MBTOC currently has 16 members including one corresponding expert from Australia. As noted in the TEAP’s Matrix of Needed Expertise (Annex 5), the MBTOC continues to seek expertise in agricultural trade and biosecurity.

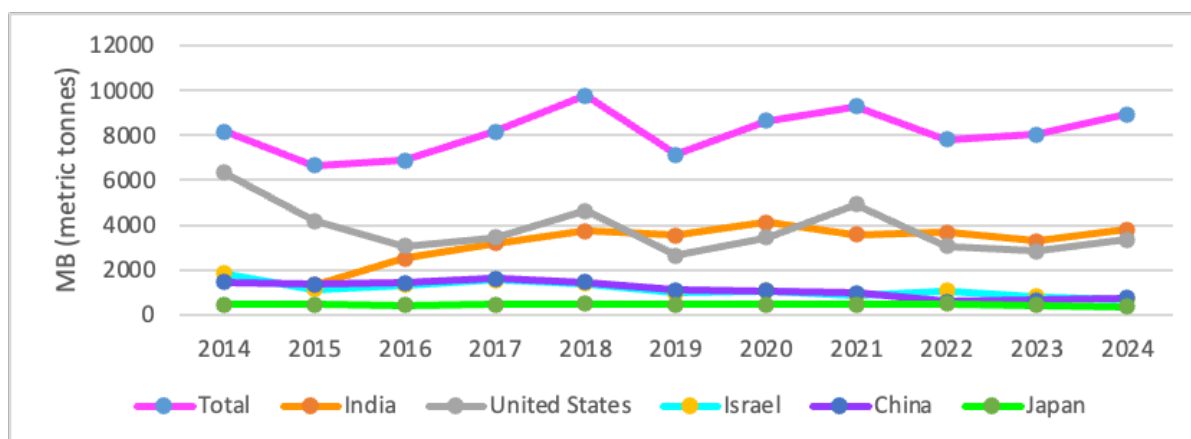
During its meeting, MBTOC visited the port of Yokohama where treatment of imported fruits and vegetables with hydrogen cyanide (HCN) was observed; this fumigant has proven to be an efficient alternative to MB. MBTOC further observed pre-export treatment of cars with heat to comply with requirements of importing countries (e.g. New Zealand and Australia).

4.2 MB production and consumption for QPS applications

The reported global production of MB for QPS in 2024 was 8,935 tonnes, up from 8,026 tonnes in 2023 (Figure 4.1). Production currently occurs in five parties – China, Israel, India, Japan and the United States. Together, India and the United States account for over 75% of global production.

Currently, the only U.S. company producing MB, has reported that will not seek to renew its license and will no longer produce MB as of the end of 2026 (Baca, 2025).

Figure 4.1 MB production for QPS uses by party 2012 – 2024 (tonnes)

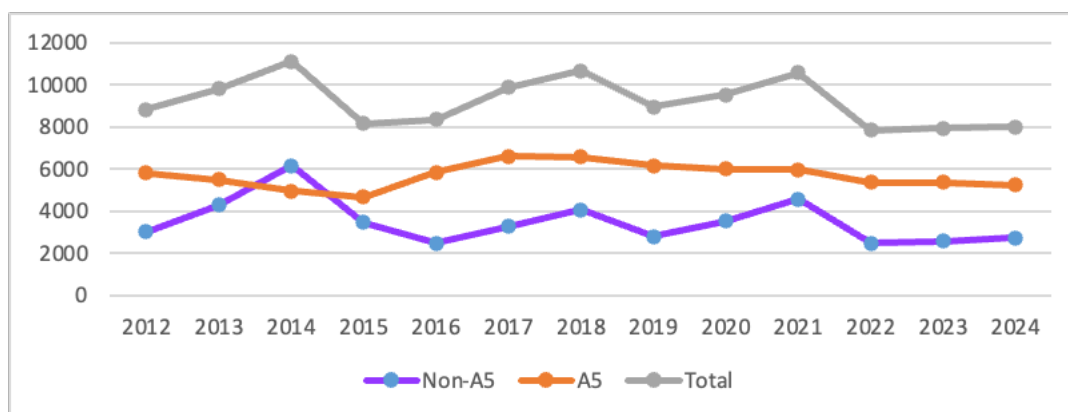


Source: Ozone Secretariat Data Access Centre, accessed March 2026

4.3 Global QPS consumption trends and data reporting

Reported consumption over the past decade continues to show year-to-year fluctuations. Non-A5 consumption has fallen significantly since 2021, but global consumption has not varied as much due to variations in A5 consumption. This may be at least in part attributable to the site of fumigation moving from non-A5 exporting parties to A5 importing parties. Consumption in A5 parties in 2024 (5,251 tonnes) was almost double that of non-A5 parties (2,752 tonnes) as shown in Figure 4.2 below.

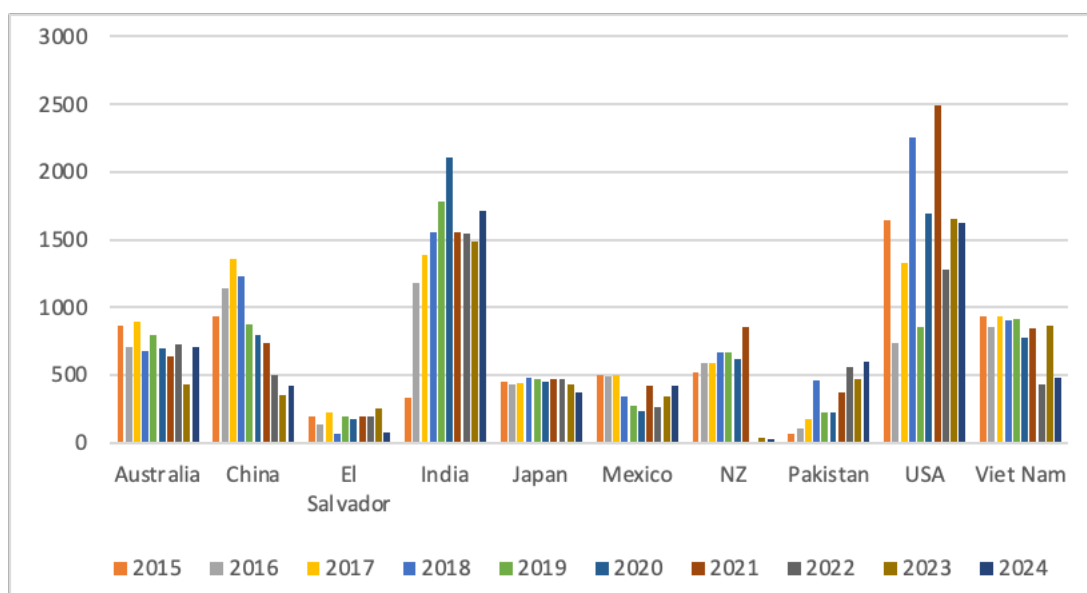
Figure 4.2 QPS consumption A5/non-A5 2012 – 2024 (tonnes)



Source: Ozone Secretariat Data Access Centre, accessed March 2026

Reported consumption of MB for QPS has dropped by about 20% over the past few years, with a slight increase in 2024. Some major users in some parties which had reduced use significantly in 2023 and recent prior years (e.g., Australia, China, India, Mexico, Pakistan) have reported increased consumption in 2024 (Figure 4.3). On the other hand, some countries have reported a significant reduction between 2023 and 2024 (e.g., Vietnam).

Figure 4.3 QPS consumption for the top 10 consuming parties since 2015 (tonnes)



Source: Ozone Secretariat Database, 2026

The reported global QPS **consumption** of MB in 2024 was about 8,000 tonnes, slightly up from 7,968 tonnes reported in 2023. When analysing production and consumption data as reported by the parties under Article 7 of the Protocol, MBTOC encountered several reporting errors which, although corrected with help from the Ozone Secretariat, appear to indicate reporting difficulties for some parties. This has been previously noted in MBTOC reports and makes it difficult for MBTOC to accurately report on bottom-up consumption contributing to atmospheric concentration of MB.

Despite 151 parties reporting MB use for QPS purposes since 1986, only about 50 have reported MB use for QPS applications over the past five years.

The top 10 consumers over the period 2015-2024 as shown in Figure 4.3, account for 88% of global usage of MB over the last decade. New Zealand and China have sharply reduced consumption in recent years, whilst India and Pakistan have increased consumption.

A more detailed analysis of the consumption data reported under Article 7 showed that:

- The United States and India are the largest consumers of MB for QPS accounting for almost half of the reported global consumption. In the U.S. consumption has remained around 1,600 tonnes over the past two years; India reported 1,706 tonnes, a 10% increase over the previous three years. Other countries who have consistently consumed over 500 tonnes annually over the last decade include Australia, India, Viet Nam and Pakistan.
- New Zealand has continued to dramatically decrease MB QPS consumption; although it reported a minor increase from 6 to 26 tonnes from 2022 to 2024. This is still a very sharp reduction from the 857 tonnes reported in 2021. This has been achieved by adopting a range of options to replace or reduce the amount of MB needed for fumigation This includes modified use of phosphine as an alternative for timber fumigation in ship holds, adoption of MB recapture technologies (thus increasing cost, making bark removal competitive) and changes to MB head space regulations to allow for using less MB per fumigation while still achieving the required concentration over time to meet the quarantine schedule. In addition, negotiations have occurred for MB treatment to be done in hold on arrival in India, and not in New Zealand thus just moving some MB treatment offshore.
- Uruguay reported high consumption of MB for QPS in 2022 (142 tonnes), but this decreased to 78 tonnes in 2023 and 76 tonnes in 2024. Exports of round wood from Uruguay to India, which requires logs to be fumigated with MB before shipping, expanded in 2022 but decreased in 2023.
- Reported consumption in El Salvador, which was around 200 tonnes from 2015 to 2023 declined substantially to 75 tonnes in 2024. OIRSA (the International Regional Organization for Plant and Animal Health) is a Central American organization providing quarantine services for its nine member parties, including all MB imports for those parties¹⁸.
- The highest consuming party for QPS MB use (i.e., the United States) is the only party categorising pre-plant soil treatment with MB for nursery crops as a QPS use. In other parties this use was considered a controlled use and phased out under the critical use process. In 2009 up to 1476 tonnes of MB were reported (TEAP, 2009) to be used for nursery uses from the United States under QPS; the use appears to have decreased, but MBTOC has no access to accurate information on this use.

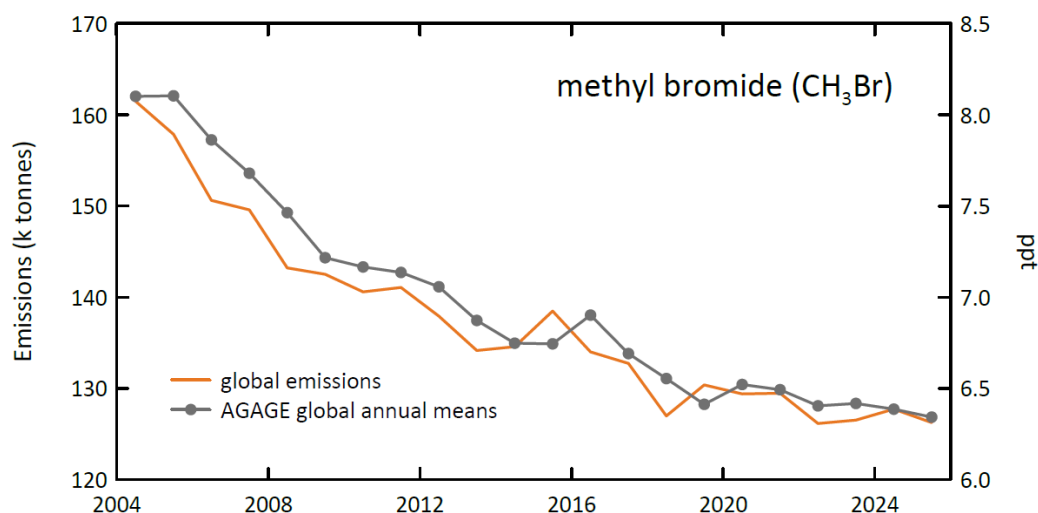
4.4 MB atmospheric concentrations and emissions

Data on global atmospheric concentration of MB (Figure 4.4) show that the decline in global atmospheric concentrations of MB has mirrored the decline in MB modelled atmospheric emissions. It also matches the decline in or controlled use under the Montreal Protocol. Since 2019 however the decrease in atmospheric MB concentration has slowed/ceased as the phase out of controlled uses of

¹⁸ MBTOC is however unclear as to how OIRSA member parties report their individual MB consumption. High figures from El Salvador (where OIRSA headquarters are located) would suggest that consumption of the individual members is aggregated and reported jointly, however some members like Mexico, Guatemala, Honduras, Nicaragua, and Costa Rica report individually, while others like Panama and Belize do not report any consumption].

MB comes to an end. Further declines are unlikely to occur unless the 6-7,000 tonnes of MB emitted from QPS uses or other unknown sources are reduced.

Figure 4.4 MB concentrations in the troposphere of the Southern Hemisphere since the late-1990s (blue line and black lines) plotted against global emissions



At its March 2026 meeting in Japan, MBTOC discussed the discrepancy in global atmospheric concentration of MB compared to the natural baseline obtained from observations of upper atmosphere concentrations (‘top-down’) and known anthropogenic sources (‘bottom-up’). Reported data from parties indicates there is still a substantial source of anthropogenic emissions coming from QPS uses of MB (est. 6-7,000 tonnes). Recent reports also indicate that unreported uses of MB may still be occurring for controlled uses (Van Horne and Johnston, 2026) thereby contributing to the discrepancy.

4.5 Tighter restrictions on health and safety requirements for MB use

Several key parties which use MB for QPS applications already have or are planning to introduce reductions in workplace concentrations for MB and the associated environmental concentrations that are acceptable in air in view of its toxicity to humans. Such reductions, from the current 5 ppm to 1 ppm, will have a major impact of MB use, particularly because they also carry an imposition of larger buffer zones (Safe Work Australia, 2025). Compliance with these limits is difficult, industrially onerous and complex, and this is forcing measures to minimise MB emissions, recapture or adopting alternatives, including non-chemical alternatives.

Notably, similar regulations are being proposed or adopted for some of key alternatives to MB, for example phosphine (Safe Work Australia, 2025).

These changes will make MB use (and potentially the use of some alternatives) substantially more difficult for QPS treatments. They are also likely to lead to a significant increase in overall treatment costs for MB, given the direct and indirect expenses associated with compliance with new restrictions. In New Zealand, for example, the decrease in Threshold Limit Values (TLV) for emissions from 5 to 1 ppm, has spurred the adoption of recapture technologies despite application costs of MB increasing two-fold. On a positive note, steep increases in MB costs are encouraging adoption of certain alternatives such as debarking of timber.

In jurisdictions where the size of buffer zones around fumigations is set by the risk of emissions (quantity, concentration, dilution rates), recapture helps to limit such emissions and thus allowing buffer zone sizes to be reduced. The new limits which propose lowering acceptable levels of MB concentrations in air will thus increase buffer zones substantially. In port situations where large QPS fumigations are typically conducted, the space available to accommodate these buffer zones is very limited, with major implications for MB fumigation.

In New Zealand, it has been possible to successfully comply with these restrictions at ports by using recapture of MB on a large scale that involves recycling activated carbon. This practice has led to a 98 % emission reduction of the 40 tonnes of MB used on logs exported from the port of Tauranga, i.e. equivalent to only 0.8 tonnes of MB emitted (Genera pers. comm., 2025).

As per Decision XXV/4, MBTOC reviews the health effects of MB use and environmental acceptability. Over the past two decades, numerous studies have characterised the health hazards associated with exposure to MB (Gemmill et al., 2013, De Souza *et al.*, 2013, Bulathsinghala and Shaw, 2014). A study by McCall et al. (2016) found that the effects of exposure to what are believed to be safe and appropriate concentrations of MB under federal guidelines still had hazardous effects. More recently, research in Korea reported high and hazardous exposure levels to MB among workers conducting chamber and tent fumigations, underscoring the need for appropriate protective equipment (Jeong *et al.*, 2020). A further study, also conducted in the Korean port of Busan indicated that occupational exposure to MB can have negative effects on workers' health even when they do not show symptoms of toxicity (Park *et al.*, 2020). More recent evidence also indicates that MB exposure may negatively affect cognitive processing and autonomic nervous system function in asymptomatic workers, reinforcing concerns about chronic exposure without obvious clinical signs (Choi *et al.*, 2025).

Around 40% of all containerized maritime imports to the US, including fresh fruit, pass through the ports of Long Beach and Los Angeles, collectively known as the San Pedro Bay Ports. Following neighbourhood concerns about exposures related to nearby fumigation facilities, a state-operated MB ambient air monitor was established in west Long Beach in 2023. Air monitoring near a school in Long Beach, California, USA, revealed MB levels averaging 2.1 ppb, far exceeding the 1 ppb safety threshold, due to nearby fumigation facilities. Over 600 homes were affected (CARB, 2025).

Concerns about the ongoing MB use for quarantine in the USA leading to considerable emissions and increased contents in neighbouring air when emitted, have been expressed in a study by Van Horne and Johnston (2026).

Similarly, in February 2025, a factory in Perai, Malaysia, was shut down after a fatal MB exposure incident left one worker dead, another critical, and six under observation (The Star, 2025)

4.6 Update on alternatives under evaluation or implemented to replace MB for QPS

4.6.1 Chemical alternatives

Despite MB use for QPS purposes being exempted from controls under the Montreal Protocol, various parties have issued national policies to eliminate or reduce this use; others have tightened its use by minimising the number of treatments for a given commodity or sector. A considerable amount of research now shows that several alternatives are as effective as MB, and that some of these can provide more rapid treatment and are safer and less harmful to the quality of the product being treated. The following sections provide updates on such alternatives recently and over the past few years.

4.6.1.1 Sulfuryl fluoride

Sulfuryl fluoride (SO₂F₂, SF) is a widely used fumigant for treating commodities and buildings but have been raised concerns due to its high global warming potential (GWP, which is 4,480 times greater than CO₂). Recently, Allabakshi and Pignatello (2024) have found that passing vent streams through an alkaline solution of hydrogen peroxide solution in a spray scrubber removes SF fumes, and this can be used to minimise its emissions.

A critical challenge is the EU's 2024 ban on SF for wood preservation and insect control due to human health concerns and lack of efficacy data (Hall, pers. comm. 2025). European authorities have expressed alarm over increased SF use to meet the requirements for log and container disinfection imposed by importing countries such as China. Container fumigation needs to be conducted in special areas in ports, which are fenced in observation of buffer zones. Currently, projects to install recapture equipment for SF are under way, and consideration is being given to moving from SF towards debarking the logs or/and treating them with water prior to export. An extension for SF is expected only for the treatment of artifacts like churches against wood boring insects - which falls under biocidal (not agricultural) treatment.

In New Zealand, SF is occasionally given emergency use permits for quarantine use for controlling termites on arrival; a recent example is treatment approved on a large yacht, "under section 49F(1) ... for the eradication of West Indian drywood termite, *Cryptotermes brevis*, in the special emergency declared by the Minister for Biosecurity on 28 July 2025. The approval is subject to the controls in Schedule 2. 4.2... approval expires on 31 July 2027." There is also increasing support for SF approval to treat New Zealand logs exported to China.

SF is now registered in the Philippines and is a potential one-to-one replacement for MB when fumigating commodities and structures, including wood packaging material. If successfully implemented, SF could significantly reduce reliance on MB for these uses in the Philippines (Gonzalez, pers. comm, 2026).

4.6.1.2 Phosphine

For many years, phosphine (PH₃) has been used as an alternative to QPS MB, initially for pre-shipment uses and, more recently, for other uses such as log fumigation. The black pine bark beetle *Hylastes ater* and the burnt pine longhorn beetle *Arhopalus fesus* are major insect pests of *Pinus radiata* in New Zealand and are currently listed as undesirable on imported *P. radiata* logs from New Zealand by AQISQ the Chinese quarantine authorities

QPS fumigation with phosphine in transit (in hold) together with debarking (for logs that are carried as deck cargo) is replacing MB fumigation in various instances, for example in shipments from New Zealand to China. Since log exports from New Zealand to China amounted to 19.2 million cubic metres in 2025 (MPI 2026), it is estimated that the alternative treatment in ship holds in transit already replaces some 2,000 tonnes of MB per year.

Recently, an alternative application system has been approved for phosphine as a bi-lateral agreement between China and New Zealand. Phosphine was applied into the hold, under recirculation, through a diluter from cylinderised 100% phosphine gas. This differs from the older application system involving tablets or bags of aluminium phosphide that generate phosphine gas over a period of days when water vapour enters into contact with metal phosphide. This newer system follows a general trend for phosphine fumigations of commodities and can lead to more controllable phosphine-time profiles and improved management of residue, flammability and other safety issues. The combined system of external supply of phosphine in hold and debarking of deck cargo was used on 50 shipments between 1 January and 31 March 2026 (Syensqo pers comm).

In Türkiye, phosphine is registered for use on stored grain, dried fruit, tobacco, and fresh produce such as tomatoes, peppers, and flowers (MAF 2024) and is successfully used in place of MB. It is a very important tool for controlling pests in silos, warehouses, in shipped commodities and at ports for QPS. Phosphine use is strictly regulated due to high toxicity concerns. The Ministry of Agriculture and Forestry (MAF) oversees its application, requiring licensing, proper training, and adherence to safety procedures. Only certified professionals are permitted to carry out fumigation, and there are strict limits on allowable residue levels in food products (MAF 2011).

Due to the widespread use of phosphine as an alternative to MB, extensive studies on resistance monitoring and management have been conducted, particularly in stored grain insects. It has been determined that resistance has developed in some of these insect species in different regions of Türkiye (Koçak *et al.* 2015, 2018a, b; Sağlam *et al.* 2015; Tingiş *et al.* 2018; Bozkurt *et al.* 2022; Yılmaz and Koçak 2023). In many countries worldwide, including Türkiye, phosphine exposure due to illegal use, misuse, or accidental exposure can occasionally result in poisoning and even death.

In Türkiye, the Ministry of Agriculture and Forestry (MAF) has taken a significant step by implementing the “Plant Prescription” system, effective January 1, 2026, to prevent the improper, unnecessary and excessive use of all plant protection products, including fumigants, and to enhance the effectiveness of inspections. Under this system, plant protection products will only be purchased with a prescription issued electronically by an authorized agricultural engineer (MAF 2025).

Cylinderised phosphine, is now being used on export commodities in the Philippines, including cut flowers, to control insect pests such as thrips and leafminers that could be problematic at entry point; a similar use has been reported in Colombia previously by MBTOC.

Phosphine fumigation had a synergistic effect with forced hot-air treatment against Oriental fruit fly *Bactrocera dorsalis* eggs and third instar larvae on dragon fruit compared to the standard heat treatment alone without impacting fruit quality (Ma *et al.* 2025).

4.6.1.3 Ethane dinitrile (EDN)

EDN continues to be adopted as a replacement for MB in various quarantine applications. Registration is still pending in Europe.

The New Zealand EPA has recently approved EDN for use on export but not import of logs and timber. This approval has the potential of reducing the remaining MB use on logs. However, some requirements still need to be met particularly in relation to safe application methods and acceptance by trade partners.

Australia, Malaysia, the Republic of Korea, South Africa and Uruguay currently accept EDN as a phytosanitary treatment for specific wood products.

4.6.1.4 Ethyl formate

Ethyl formate (EF) in combination with CO₂, is being increasingly used for treating a wide range of fresh produce previously using MB as a QPS treatment especially against surface pests. Examples are registration for grapes, citrus and kiwifruit imported into the United States, citrus treated on arrival in Republic of Korea and treatment of containers and vehicles for controlling brown marmorated stink bug (BMSB), *Halyomorpha halys* in New Zealand and Australia (DAFF, 2026; MPI, 2026).

In the Republic of Korea, where several species of hitchhiker snails were detected in cargo, Domingue *et al.* (2024) reported that EF (70 g/m³ at 22°C) was as efficient as MB for controlling these pests. EF also gave complete control of pineapple mealybugs *Dysmicoccus brevipes* with no apparent negative impact on pineapple quality (Kwon *et al.*, 2024) and of snail and fly pests *Achatina fulica* and

Lycoriella mali) of imported orchids (Kwon *et al*, 2023). Mealybugs *Pseudococcus comstocki* on imported grapes are also controlled by liquid EF, a new formulation not causing phototoxicity or alterations of the grapes (Lee *et al*, 2022).

A study by Shan *et al* (2026) evaluated the synergistic effect of EF combined with 10 % CO₂ to enhance penetration and toxicity against *Pseudococcus jackbeardsleyi* in pineapple. Insect mortality was significantly influenced by EF concentration, treatment temperature, and developmental stage.

Ramadan *et al.* (2025) conducted residue analysis of EF on both dry and semi dry date fruits in addition to studying its sorption and desorption. Kim *et al* 2025 results suggest that EF fumigation and nematocidal dip treatment are two feasible phytosanitary measures for use on imported plants.

The brown marmorated stink bug (BMSB), *Halyomorpha halys* (Hemiptera: Pentatomidae) is a sap sucking insect native to China, Japan, Korea and Taiwan that has become invasive in North America, Europe and Chile. It causes significant damage to a wide array of economically important crop species. Ethyl formate has been successfully tested against overwintering BMSB by Kawagoe (2022) with a 4-hour treatment schedule using 15 g/m³ EF and 3% CO₂

A mixture of EF and CO₂ has been approved as a quarantine treatment by Australia and New Zealand as it efficiently controls the brown marmorated stink bug (BMSB) where treatment of a wide range of cargo is required for seven months of the year.

Table grapes imported from Chile into the US are regularly fumigated with MB as a condition of entry, to prevent the introduction of regulated pests. Fumigation with a combination of EF and CO₂ following a cold storage period efficiently controls the European grapevine moth, *Lobesia botrana* and the Chilean false red mite, *Brevipalpus chilensis* (Myers and Castro, 2024).

Research is further showing that a combination of EF and phosphine is effective for controlling pests on perishables. Zou *et al* (2025) investigated the effects of PH₃ fumigation alone and in combination with EF on insecticidal activity across all developmental stages of Papaya mealybug *Paracoccus marginatus* and its influence on the quality of plant products. *Paracoccus marginatus* eggs are the most tolerant stage to PH₃, and PH₃ at a dosage of 1g/m³ for 8 h at 25°C achieved a 99.9968 (Probit 9) mortality rate. Combined fumigation of PH₃ (0.5g/m³) and EF (2g/m³) for 8 hours at 25°C did not adversely affect the lifespan and quality of three succulent plant species.

Mealybugs on ginger flower *Alpinia purpurata*, one of the main cut flowers exported from Hawaii, can trigger shipment rejection. Fumigation with a combination of EF (20 g/m³) and PH₃ (2 g/m³) for 4 h at 23°C resulted in complete control of adults and eggs of *P. citri* with no significant reduction in flower quality (Kwon *et al*, 2024). EF has recently (August 2025) been registered in the United States for citrus, kiwifruit and grapes and is undergoing more trials.

4.6.1.5 Hydrogen cyanide

Hydrogen cyanide (HCN) continues to be used as a QPS treatment on a range of fresh agricultural products, e.g. bananas and pineapples because MB can affect product quality. This is usually restricted to products in which skins are removed prior to consumption. MBTOC observed HCN application in Japan, where HCN has been used for many decades for treating for imported fresh fruits and vegetables such as banana, pineapple and asparagus stored in specially made fumigation warehouses equipped with a scrubber of sodium hydroxide solution. Treatment is conducted in gas-tight enclosures with walls specially coated with concrete and coating plus gas-tight doors. After the treatment, gas is ventilated through big filters placed on the roof of the premises to prevent emissions of HCN in air.

In Europe, HCN is increasingly used for controlling insects in empty structures like flour mills, and empty silo bins to replace the alternative SF which is under reconsideration due to its high GWP.

HCN use continues to grow for structural fumigation in the EU. It is currently registered in Australia, the EU, Pakistan, South Africa and Singapore for structural fumigation.

Phytosanitary treatments to limit the spread of BMSB from the United States is required by importers. Application of HCN at 22.4 mg for 6 h, resulted in complete control of BMSB (Lourie *et al*, 2024). HCN further continues to be used for transport vehicles and empty ship holds by several parties.

Spillotis and Mitrea (2025) investigated the efficacy of HCN as an alternative on its application in a wheat mill located in Romania. Results showed that 100% mortality of larval and adult stages of *Tribolium confusum* despite challenges such as wind interference and partial structural leakage, highlighting both the efficacy and sensitivity of HCN performance to environmental and infrastructural variables (Spillotis et al 2025).

4.6.1.6 Methyl iodide alone or in combination with CO₂

Methyl iodide (MI) is currently registered for treatment of wood products in Japan and is under consideration for similar applications in South Korea and Australia. In South Korea, Choi and Park (2025) investigated the sorption characteristics of several MB alternatives, including MI, in wood pellets. These wood pellets are imported into Korea and routinely fumigated with MB and phosphine to control a range of stored-product pests. In Australia, MI is being evaluated as a potential alternative to MB for log export treatments, particularly for access to key markets such as China and India. Recent data shows that MI applied at 30 g/m³ is effective in eradicating insect pests in logs, including *Sirex noctilio* larvae, a major quarantine pest of concern to several countries, including India and China (McFarlane and Mattner 2025a). While these findings are promising, further large-scale trials are required to validate MI performance under varying climatic conditions and to better understand its sorption and desorption characteristics. Furthermore, building on research conducted in Japan, the use of MI in combination with CO₂ is being explored in Australia for treatment of wood products for QPS use.

MI is also being investigated as a phytosanitary treatment for other commodities in both Japan and Australia, including fodder (Australia) and fresh vegetables (Japan). In Australia, preliminary trials examining MI as an alternative to MB for treatment of export fodder infested with stored-product pests have shown encouraging results. Specifically, MI did not adversely affect fodder quality and was effective against pests such as *Tribolium castaneum* adults, larvae and egg life stages at application rates of 20 g/m³. However, additional data are required before MI can be registered for use on fodder in Australia (McFarlane and Mattner 2025b).

4.6.2 Non-chemical alternatives

4.6.2.1 Heat/cold

Heat is a well-documented alternative to MB, which has been in use as a phytosanitary treatment for decades, for example for controlling insect pests in flour and feed mills, and other empty structures like roof areas. (Fields, 1992).

Heat treatment technology has almost completely replaced MB fumigation for treating wood packing material (WPM) in China. From 2012-2014, 897.8 tonnes of MB were used for WPM, averaging about 300 tonnes a year. In 2023, only 2 tonnes were used for this purpose, with heat now being the primary treatment of choice (Fenfen pers. comm., 2024).

MBTOC observed heat treatment of used cars in Yokohama, Japan, which were being prepared for export to New Zealand. The target pest is the brown marmorated stink bug (BMSB), *Halyomorpha halys*, a quarantine pest in the destination country. Cars are treated at 60°C for 10 minutes in large

sheds with insulation; a warm-up period of about 10 minutes is required for warming up and later 10 minutes for cooling down plus 10 minutes for handling, for a total of 40 minutes per lot. This treatment has proven to be technically and economically feasible. In other countries (e.g. Kenya), treatment for this same pest is achieved with MB fumigation (Kinyanjui, 2026).

4.6.2.2 Debarking timber

Debarking is expanding as a QPS treatment for logs prepared for export, for instance from New Zealand or from Europe to China (TEAP, 2025).

4.6.2.3 Irradiation

The growth in domestic trade and exports volumes using irradiation as a market access treatment in Australia has increased significantly over the last 15 years (Kingham and Roberts, 2022). In the 2019-2020 season, Australia exported 5,837 pallet loads of 10 different types of irradiated fresh produce to five countries.

4.6.2.4 Controlled atmospheres

In Vietnam, a continuous in-line controlled atmosphere (CA) treatment process, which takes only 40 minutes, kills insects attacking dry commodities in all stages of development. The treatment is conducted within a compartment at 55-70 °C (depending on the product) and a very low oxygen environment, where the product is dropped in and any insects present are eliminated within 30 minutes. A conveyor belt then takes the product to a second compartment at 15 - 25 °C where it is cooled down to ambient temperatures by mechanical means. The cooling process also enables moisture control of the product. The system works with a heat pump and cooling system, with high energy efficiency and is currently commercially operated for treating nuts and trailed for dried fruit products and fresh fruit (Bergwerff, pers comm., 2026).

Products that may be treated with controlled atmosphere include rice, cashew nuts, almonds, macadamias, and other edible nuts, cacao beans, coffee, spices and many other dry products. CA treatments can be applied in rooms or chambers as well as containers equipped with CA equipment, well-sealed tarped (sheeted) bag stacks (six-side sealing) or CA ‘cocoon’ Worldwide there are more than 500 purpose-built facilities in operation for use with CA on the products specified above. One such country, Vietnam, has more than 100 (Bergwerff, pers. comm. 2026).

4.7 Other Issues

4.7.1 Pest risk analysis and MB consumption reduction in Japan

Since 2000, MB consumption for QPS uses has been steadily declining in Japan. This is partially due to factors related to international trade, for example a reduction of log imports due to high tariffs or bans, whilst simultaneously increasing imports of sawn timber and plywood that do not require treatment, a move that carries commercial benefits.

For other commodities traditionally requiring MB treatment however, an efficient means of reducing MB use for QPS has been to reduce the number of pests considered targets under QPS lists within a country. Over the last twenty years, Japan has conducted regular reviews to declassify pests from a QPS list to a non-QPS status and this has reduced the use of their requirement for MB use (MAFF 2025; MAFF 2026).

4.7.2 IPPC: ISPM approvals in the last 12 months

MBTOC regularly reviews developments occurring under the International Plant Protection Convention (IPPC). In the last year, three irradiation treatments were approved under ISPM (International Standards for Phytosanitary Measures) 28, which covers phytosanitary treatments for regulated pests. Separate annexes were approved under this adopted standard to control mealybug insects of fruits, vegetables and plants, including the Citrus Mealybug (*Planococcus lilacinus*; Annex 47), the Papaya Mealybug (*Paracoccus marginatus*; Annex 48) and the Aerial Root Mealybug (*Pseudococcus baliteus*; Annex 49).

The minimum absorbed dose of 183 Gy and 185 Gy is required to control *P. baliteus* eggs and *P. marginatus* eggs, respectively (ISPM 2026 a,b); while a minimum absorbed dose of 163 Gy is required to control *P. lilacinus* 2nd instar nymphs (ISPM 2026c).

In addition, three irradiation treatments were revoked under ISPM 28 during this period. Presumably because the absorbed dose was insufficient to control the target species and life stage, these decisions affected species within the genus *Anastrepha*, including the Mexican Fruit Fly (*Anastrepha ludens*; Annex 01), the West Indian Fruit Fly (*Anastrepha obliqua*; Annex 02) and the Sapodilla Fruit Fly (*Anastrepha serpentina*; Annex 03) (ISPM 2026d,e,f).

Although these approvals represent progress, the availability of irradiation facilities is limited, and the capital cost and construction time to build new facilities are significant. Therefore, these approvals are unlikely to significantly reduce the use of methyl bromide to control these regulated pests in the international trade of agricultural commodities.

4.8 References

- Ackery, P.R., Doyle, A.M., Pinniger, D.B. (2005). Heat treatment of entomological drawers using the Thermo Lignum® heat process. *Collection Forum* 19 (1-2), 15 - 22.
- Ackery, P.R., Testa, J.M., Ready, P.D., Doyle, A.M., Pinniger, D.B. (2004). Effects of high temperature pest eradication on DNA in entomological collections. *Studies in Conservation* 49, 35 - 40.
- Allabakshi S.M., Pignatello J.J. (2024). Peroxide-assisted defluorination of SO₂F₂: efforts in pathways & optimization. In: Obenauf, G. L., ed., *Proceedings of the 2024 Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions*, October 29-31, Orlando, USA, <http://mbao.org>.
- Anonymus (2007). Wissenschaftlich-Technische Arbeitsgemeinschaft für Bauwerkserhaltung und Denkmalpflege (WTA) [Scientific-Technical Working Group for Keeping and Conservation of Buildings]: Merkblatt E1-1-06/D Heißluftverfahren zur Bekämpfung tierischer Holzzerstörer in Bauwerken [Leaflet E1-1-06/D Heated Air Procedure for the Control of Animal Pests in Buildings]. Fraunhofer IRB Verlag, (ed), ISBN-13: 978 3816773474, 16 pp.
- Baca, B (2025). Methyl bromide status and alternatives for phytosanitary applications. *Annual International research on Methyl Bromide Alternatives and Emission Reductions*. San Diego, CA, USA; 27-29 October 2025. <https://mbao.org/static/docs/confs/2025-sandiego/papers/baca.pdf>
- Badriraju, S. (2014). Comparison of heat and sulfuryl fluoride for management of stored-product insects. Conference: Integrated Pest Management in Stored Products and Innovation in Alternatives. February 21-22, 2014, Monterrey, Mexico, 107 slides. <http://apps2.semarnat.gob.mx:8080/sissao/archivos/Bhadriraju%20Subramanyam.pdf>
- Bergweff, F. (2026). Personal communication.
- Bozkurt, H., Isikber, A., Saglam, O. (2022). Phosphine resistance in Turkish populations of *Sitophilus oryzae* L. (1763) (Coleoptera: Curculionidae). *Journal of the Entomological Research Society* 24. 195 - 208. <https://www.doi.org/10.51963/jers.v24i2.2253>.
- Bulathsinghala, A.T., Shaw, I.C. (2014). The toxic chemistry of methyl bromide. *Human Experimental Toxicology* 2014, J33(1), 81-91. <https://doi.org/10.1177/0960327113493299>.
- CARB; 2025; Ambient Air Monitoring for Methyl Bromide in West Long Beach; <https://ww2.arb.ca.gov/capp/cst/ch2/wcwlw/methyl->

- <https://calmatters.org/environment/2025/04/la-communities-toxic-fumigant-methyl-bromide/> <https://lbpost.com/news/health/methyl-bromide-long-beach-more-communities/>
- Choi, N.R., Park, M.G. (2025). Sorption characteristics of various fumigants depending on the loading ratio of wood pellets. *Journal of Stored Products Research*, 113: 1-6
- DAFF (2026). Department of Agriculture, Fisheries and Forestry. Australian Government. Seasonal measurements for brown marmorated stink bug (BSMB). <https://www.agriculture.gov.au/biosecurity-trade/import/before/brown-marmorated-stink-bugs>
- De Souza, A., Narvencar, K.P.S., Sindhoora, K.V. (2013). The neurological effects of methyl bromide intoxication. *Journal of Neurological Science* 335 (1-2), 36-41.
- Fenfen, K (2024). Personal communication.
- Fields, P.G. (1992). The control of stored-product insects and mites with extreme temperatures. *Journal of Stored Products Research*. 28, 89 - 118.
- Finkelmann, S., Navarro, S., Rindner, M., Dias, R. (2006). Use of heat for disinfestation and control of insects in dates: Laboratory and field trials. *Phytoparasitica* 34(1), 37 - 48.
- Gemmill, A., Gunier, R.B., Bradman, A., Eskenazi, B., Harley, K.G. (2013). Residential proximity to methyl bromide use and birth outcomes in an agricultural population in California. *Environmental Health Perspectives* 121(6):737-43. <https://doi.org/10.1289/ehp.1205682>.
- Genera Company (2026). Personal communication
- Gonzalez, A (2026). Personal communication.
- Hall, M (2025). Personal communication
- Heaps, J.W. (1988). Turn on the heat to control insects. *Dairy Food Sanit.* 8, 416-418.
- Hu X., Yao B., Muhle J., Rhew R.C., Fraser P., O'Doherty S., Prinn R., Fang X. (2024). Unexplained high and persistent methyl bromide emissions in China. *Nat. Commun.* 15, 8901. <https://doi.org/10.1038/s41467-024-53188-3>
- ISPM (International Standards for Phytosanitary Measures) 28 (2026a). Phytosanitary treatments for regulated pests. PT 49: Irradiation treatment for *Pseudococcus baliteus*. Adopted and published in 2026. Pages 1 to 5. https://assets.ippc.int/static/media/files/publication/en/2026/04/PT_49_2026_En_Ir_PseudococcusBaliteus_Post-CPM-20_2026-04-14.pdf.
- ISPM (International Standards for Phytosanitary Measures) 28 (2026b). Phytosanitary treatments for regulated pests. PT 48: Irradiation treatment for *Paracoccus marginatus*. Adopted and published in 2026. Pages 1 to 5. https://assets.ippc.int/static/media/files/publication/en/2026/04/PT_48_2026_En_Ir_ParacoccusMarginatus_Post-CPM-20_2026-04-14_difv3bA.pdf. Viewed April 21, 2026.
- ISPM (International Standards for Phytosanitary Measures) 28 (2026c). Phytosanitary treatments for regulated pests. PT 47: Irradiation treatment for *Planococcus lilacinus*. Adopted and published in 2026. Pages 1 to 5. https://assets.ippc.int/static/media/files/publication/en/2026/04/PT_47_2026_En_Ir_PlanococcusLilacinus_Post-CPM-20_2026-04-14.pdf. Viewed April 21, 2026.
- ISPM (International Standards for Phytosanitary Measures) 28 (2026d). Revoked PT 01 (2009): Irradiation treatment for *Anastrepha ludens*. <https://www.ippc.int/en/publications/627/>. Viewed April 21, 2026.
- ISPM (International Standards for Phytosanitary Measures) 28 (2026e). Revoked PT 02 (2009): Irradiation treatment for *Anastrepha obliqua*. <https://www.ippc.int/en/publications/628/>. Viewed April 21, 2026.
- ISPM (International Standards for Phytosanitary Measures) 28 (2026f). Revoked PT 03 (2009): Irradiation treatment for *Anastrepha serpentina*. <https://www.ippc.int/en/publications/629/>. Viewed April 21, 2026.
- Jeong, J.Y, G.y. Yi, S.J. Cho and S.H. Park (2020). Assessment of methyl bromide exposure levels in fumigation workers on import and export plant. *Journal of Korean Society of Occupational and Environmental Hygiene* 30(1): 50-57. <https://doi.org/10.15269/JKSOEH.2020.30.1.50>
- Kingham L. and Roberts P.B (2022), AM19002 Building Capacity in Irradiation, A review of the regulatory environment for phytosanitary irradiation as a trade pathway for Australian exports, New South Wales Department of Primary Industries, Australia. Unpublished
- Kinjanjui, M. (2026). Second-hand car dealers oppose mandatory fumigation rule. *The Eastleigh Voice*, February 4, 2026. https://eastleighvoice.co.ke/business/286196/second-hand-car-dealers-oppose-mandatory-fumigation-rule#google_vignette
- Koçak, E., Schlipalius, D., Kaur, R., Tuck, A., Ebert, P., Collins, P., Yılmaz, A. (2015). Determining phosphine resistance in rust red flour beetle, *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) populations from Turkey. *Turkish Journal of Entomology* 39(2), 129-136. <https://doi.org/10.16970/ted.17464>.

- Koçak, E., Yılmaz, A., Alpkent, Y.N., Bilginturan, S. (2018a). Phosphine resistance of rusty grain beetle *Cryptolestes ferrugineus* (Coleoptera: Laemophloeidae) populations in Turkey. *Agronomy* 61(1), 284 - 290.
- Koçak, E., Yılmaz, A., Alpkent, Y.N., Ertürk, S. (2018b). Phosphine resistance to some coleopteran pests in stored grains across Turkey. *Integrated Protection of Stored Products, IOBC-WPRS Bulletin* 130, 303 - 310.
- Kwon, T.H, Zarders, D., Lee, B.H., Kim, D.B., Dong, H., Cha, D.H. (2024). Ethyl formate and phosphine fumigation for control of mealybug in cut flowers. In: Obenauf, G. L., ed., *Proceedings of the 2024 Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions*, 29-31 October, Orlando <http://mbao.org>.
- Lee B.H., Hong K.J., Park M.G. (2022). The efficacy, phytotoxicity, and safety of liquid ethyl formate used to control the grape (Campbell Early) quarantine pest *Pseudococcus comstocki*. *Appl. Sci.*, 12, 9769. <https://doi.org/10.3390/app12199769>
- Lourie A.P., Corbett S.M., Walse S.S. (2024). Hydrogen cyanide fumigation to control brown marmorated stinkbug. In: Obenauf, G. L., ed., *Proceedings of the 2024 Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions*, 29-31 October, Orlando, USA <http://mbao.org>.
- Ma, Y., Li, L., Li, B. L., Q., Ren, Y.L., and Wang, P. (2025). Phosphine fumigation followed by forced hot-air treatment for postharvest control of *Bactrocera dorsalis* in dragon fruit. *Journal of Pest Science* 98:799–810. <https://doi.org/10.1007/s10340-024-01848-0>.
- McFarlane, D. and Mattner, S. (2025a). Developing methyl iodide for Australian log export. In: Obenauf, G. L., ed., *Proc. 2026 Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, October 27-29 Orlando, Florida, USA*
- McFarlane, D. and Mattner, S. (2025b). Methyl bromide alternatives for Australian log and fodder exports. In: Obenauf, G. L., ed., *Proc. 2026 Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, October 27-29 Orlando, Florida, USA*
- MAF (2011). *Plant Quarantine Fumigation Regulation*. Official gazette 19.06.2011. Official gazette number: 27969, <https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=15057&MevzuatTur=7&MevzuatTertip=5> (Access Date:03/24/2026).
- MAF (2024). *Regulation on the Licensing and Marketing of Plant Protection Products*. Official gazette: 03/14/2024 Official gazette number: 32484, <https://www.resmigazete.gov.tr/eskiler/2024/03/20240314-5.htm>, (Access Date:03/24/2026).
- MAFF (2025): List of quarantine pests The Regulation for Enforcement of the Plant Protection Act. Ministerial ordinance of the Ministry of Agriculture, Forestry and Fisheries Attached table 1 No. 50 on Nov.10, 2025 (in Japanese). https://www.maff.go.jp/pps/j/law/houki/shorei/shorei_12.html_12.html
- MAFF (2026) [Pests subjected to import plant quarantine and the revision of import phytosanitary measures in Japan. Ministry of Agriculture, Forestry's and Fisheries, Japan \(in Japanese\).](https://www.maff.go.jp/j/syouan/keneki/kikaku/minaoshi_keneki.html)
- McCall, J., Harris, D., Berk, M. (2016). Examination of the Effects of Chronic Exposure to Federally-Regulated and Approved Levels of Methyl Bromide in Dock Workers: A Case Series (S8.003) *Neurology* April 5, 86 no. 16 Supplement S8.003.
- Metaxas, A.C., Meredith, R.J. (1983). *Industrial Microwave Heating*, Peregrinus Ltd., London, 357 pp.
- MPI (2026). Ministry for Primary Industries. New Zealand Government. Brown marmorated stink bug: requirements for importers. <https://www.mpi.govt.nz/import/vehicles-machinery-parts/brown-marmorated-stink-bug-requirements-for-importers>
- Myers S., Castro D. (2024). Evaluation of cold storage followed by ethyl formate and CO2 fumigation as a phytosanitary measure for Chilean table grapes. In: Obenauf, G. L., ed., *Proceedings of the 2024 Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions*, 29-31 October, Orlando <http://mbao.org>.
- Park M.G, Choi, J., Hong, Y.S., Park, C.G., Kim, B.G., Lee, S.Y., Lim, H.J., Mo, H.H., Lim, E., Cha, W. (2020) Negative effect of methyl bromide fumigation work on the central nervous system. *PLoS ONE* 15(8): e0236694. <https://doi.org/10.1371/journal.pone.0236694>
- Ramadan, Gomaa R. M., Hegazi, Yasser H., Shawir, Mohamed S., Badawy, Mohamed E. I., Phillips, Thomas W. and Abo-El-Saad, Mahmoud M. (2025) Sorption, desorption, and residue analysis of the fumigant ethyl formate in date using cooled methanol extraction and GC-MS. *Journal of Stored Products Research* 111, May 2025, 102540.
- Robbie Ramlose (2025). Personal Communication
- Safe Work Australia (2025). Changes to workplace exposure limits. Safe Work Australia, May 2025, www.swa.gov.au

- Sağlam Ö., Edde, P., Phillips, T.W. (2015). Resistance of *Lasioderma serricornis* (Coleoptera: Anobiidae) to fumigation with phosphine. *Journal of Economic Entomology* 108(5), 2489 - 2495.
- Shan.C., Li.L., Li.B., Gao.L., Du.B., McKirdy.J.S., Liu.T (2026). , Synergistic ethyl formate and carbon dioxide fumigation for quarantine disinfestation of *Pseudococcus jackbeardsleyi* and quality preservation in pineapple, *Postharvest Biology and Technology*, Volume 231, <https://doi.org/10.1016/j.postharvbio.2025.113963>.
- Spillotis, Spyros-Angelos and Mitrea, Ion (2025) Efficacy of hydrogen cyanide fumigation against *Tribolium confusum* at a wheat mill in Gorj Romania. *Research Journal of Agricultural Science* 57(1):223-229.
- Star, The (2025). <https://www.thestar.com.my/news/nation/2025/02/01/worker-in-penang-killed-another-in-serious-condition-after-exposure-to-dangerous-chemicals>.
- Syensqo, 2026 pers comm
- TEAP (2025). Technology and Economic Assessment Panel: May 2025 Progress Report. UNEP, Nairobi.
- Tingiş, A., Işikber, A.A., Sağlam, Ö., Bozkurt, H., Doğanay, İ.Ş. (2018). Screening of phosphine resistance in *Sitophilus oryzae* (L.) (Rice Weevil) populations in Turkey. In: [Adler, C.S.](#); [Opit, G.](#); [Fürstenau, B.](#); [Müller-Blenkle, C.](#); [Kern, P.](#); [Arthur, F.H.](#); [Athanassiou, C.G.](#); [Bartosik, R.](#); [Campbell, J.](#); [Carvalho, M.O.](#); [Chayaprasert, W.](#); [Fields, P.](#); [Li, Z.](#); [Maier, D.](#); [Nayak, M.](#); [Nukenine, E.N.](#); [Obeng-Ofori, D.](#); [Phillips, T.](#); [Riudavets, J.](#); [Throne, J.](#); [Schöller, M.](#); [Stejskal, V.](#); [Talwana, H.](#); [Timlick, B.](#); [Trematerra, P.](#); eds., *Proceedings of the 12th International Working Conference on Stored Product Protection (IWCSPP)*, 7-11 October 2018, Berlin, Germany, Vol 1, 1130 pp. 1017 - 1021.
- Van Horne, Y.O., Johnstone, J.E. (2026). Exceptional use: examining methyl bromide applications in California 2016–2022. *Environ. Res. Commun.* 8, 011003, DOI 10.1088/2515-7620/ac3227, 63 references, <https://iopscience.iop.org/article/10.1088/2515-7620/ac3227>, 10 pp.
- Yılmaz, A., Koçak, E. (2023). Comparing bioassay and diagnostic molecular marker for phosphine resistance in Turkish populations of *Rhyzopertha dominica* (F., 1792) (Coleoptera: Bostrichidae). *Turkish Journal of Entomology* 46(4), 431 - 440. <https://doi.org/10.16970/entoted.1109466>.
- Zou, H., Li, L., Li, B., Ren, Y., and Liu, T. (2025). Phosphine and phosphine plus ethyl formate for controlling papaya mealybug (Hemiptera: Pseudococcidae) on succulents. *Journal of Economic Entomology* 118(1):152-159. <https://doi.org/10.1093/jee/toac270>.

5 Medical and Chemicals TOC (MCTOC) Progress Report

5.1 Introduction

This chapter provides an update to information on the production and use of controlled substances for chemical feedstock. There is no compelling new information available on process agent uses, *n*-propyl bromide, laboratory and analytical uses, aerosols. In response to a request from Canada for TEAP to evaluate a destruction technology for consideration for the list approved by parties for the purposes of the Montreal Protocol, MCTOC reports its evaluation and recommendation. This report also includes an update of information on medical uses, including a response to Decision XXXVI/6, *Developments regarding metered-dose inhalers with low-global-warming-potential propellants*.

MCTOC met online during January to March and at a hybrid meeting on 24-27 March in Vienna at the Vienna International Centre. The hybrid meeting was attended in person by 14 participants (5 from A5 parties and 9 from non-A5 parties) and virtually by 18 participants (6 from A5 parties and 12 from non-A 5 parties).

As noted in the TEAP's Matrix of Needed Expertise (Annex 5), MCTOC continues to seek expertise in the following areas: aerosols and metered dose inhalers manufacturing, carbon tetrachloride (CTC) and very short-lived substances (VSLs) global manufacturing and use, semiconductor and other electronics manufacturing, end-of-life management and destruction technologies.

5.2 Use of controlled substances for chemical feedstock

Feedstocks are chemical building blocks that allow the cost-effective commercial synthesis of other chemicals. Controlled substances (ODS and HFCs) can be produced and/or imported or exported for use as feedstocks. As raw materials, feedstocks are converted to other products, except for de minimis residues and emissions of unconverted raw material.

Emissions from the use of feedstock consist of residual levels in the ultimate products, and fugitive leaks in the production, storage and/or transport processes. Handling ODS and HFC feedstocks in a responsible, environmentally sound manner requires significant investments and effort by industry. Emissions are regulated through pollution control measures.

The definition of production under the Montreal Protocol excludes the amounts of controlled substances entirely used as feedstock in the manufacture of other chemicals. Notwithstanding, parties are required to report the production of controlled substances for feedstock uses annually.¹⁹ Similarly, the definition of consumption excludes controlled substances entirely used as feedstock, nevertheless, imports and exports of controlled substances to be used entirely as feedstock must be reported by parties.

Parties are required to report the production, import and export of controlled substances for feedstock uses annually. Reported feedstock is a valuable data set that can be correlated with related emissions of controlled substances, either from their production, use or with the expected impact of emission abatement measures. However, there are some products that are not reported because they are

¹⁹ Montreal Protocol on Substances that Deplete the Ozone Layer, 1987, Article 7, paragraph 3.

intermediates not isolated in a chemical manufacturing process.²⁰ These intermediates may also be emitted in low quantities and detected by atmospheric monitoring.²¹

In chemical production, a non-isolated intermediate in a chemical process is not considered as a finished product while it remains within the chemical process. As such, a non-isolated intermediate is not commonly reported. For example, the formation of the intermediate HCFC-21 is not commonly reported as a feedstock in the process of manufacturing HCFC-22. However, a substance that is isolated, most likely purified to a specification, and then used in a distinct, separate process, would be considered as a finished product and subject to reporting as production for feedstock use. For example, when HCFC-21 was isolated and then used in the production of HCFC-225, its production was reported as feedstock.

The 2026 MCTOC Assessment Report will have an expanded section of feedstock production, use and emissions from their use.

Reported feedstock production, and use, as ozone-depletion potential (ODP) tonnes, was at a maximum in 1993 (712,170 ODP tonnes), and reached a minimum in 1998 (328,902 ODP tonnes). In the period 1997 to 2016 the reported quantity was less than 500,000 ODP tonnes annually. In 2022, the quantity peaked at 684,711 ODP tonnes, which is less than that reported in 1993. The large increase in ODS as metric tonnes is due to the increased use of ODS feedstocks with lower ODPs, such as HCFC-22. Figure 5.1 shows the trend as metric and ODP tonnes.

Figure 5.1 Trend in reported ODS feedstock production 1992 to 2024

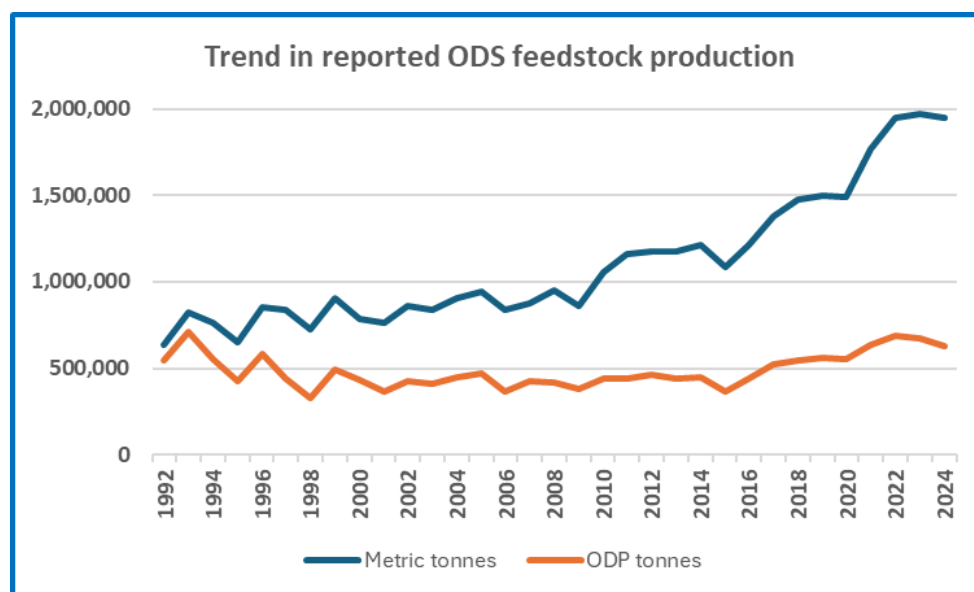


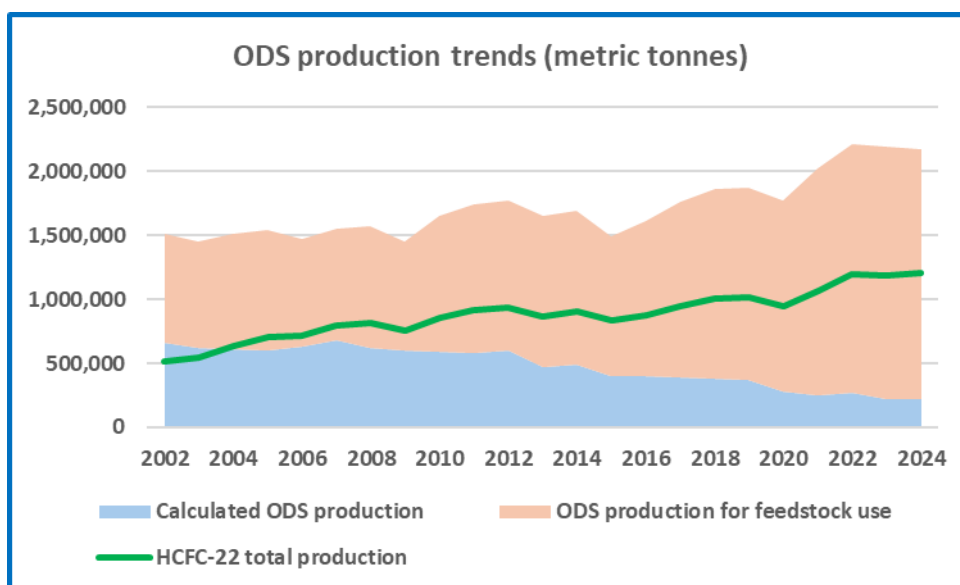
Chart note: There are two obvious errors, due to the trends for adjacent years, in the reported data for 1996 and 1997 for one substance from one party. The quantities for 1996 and 1997 have been adjusted to match the trend. These adjustments have the effect of reducing the total reported ODP and metric tonnes for these years. Total reported production of ODS since 2002 has increased, due to production for feedstock offsetting the decrease in calculated production (which correspond to total production minus feedstock uses minus destruction minus quarantine and pre-shipment uses for

²⁰ UNEP, 2021, *2021 TEAP Report, Volume 1, Progress Report*, September 2021. Section 5.3.5. UNEP, 2021, *Report of the technology and economic assessment panel, Volume 1: Progress Report*, September 2021, Section 5.3.5. <https://ozone.unep.org/system/files/documents/TEAP-May2024-Progress-Report.pdf> Accessed March 2026

²¹ Vollmer, M.K., Mühle, J., Henne, S., *et al.*, Unexpected nascent atmospheric emissions of three ozone-depleting hydrochlorofluorocarbons, *PNAS*, 2021, **118**(5), e2010914118. doi: [10.1073/pnas.2010914118](https://doi.org/10.1073/pnas.2010914118).

methyl bromide), as shown in Figure 5.2. The figure also shows total reported HCFC-22 production (calculated and for feedstock use).

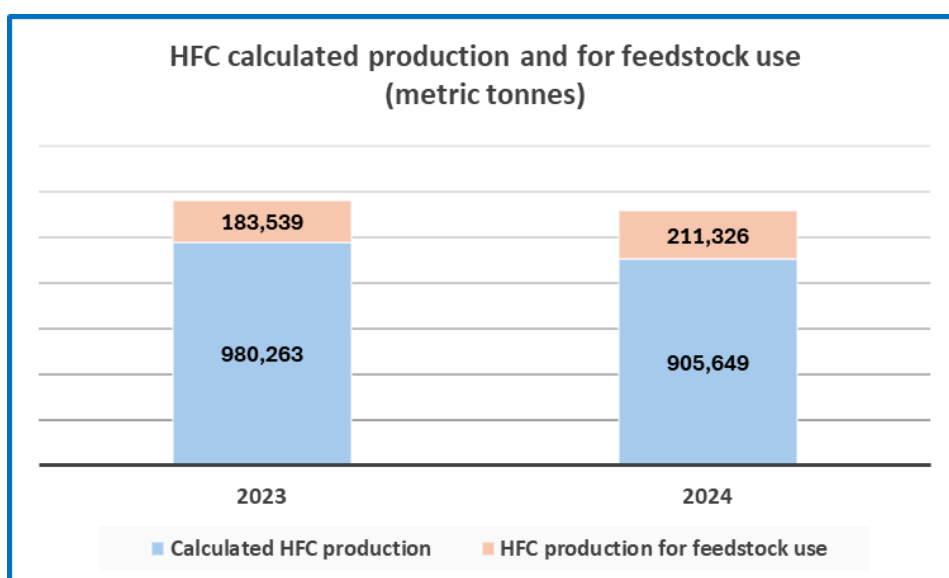
Figure 5.2 Total reported ODS production, 2002–2024



The proportion of HCFC-22 as a percentage of total reported ODS production increased significantly in the period 2002 to 2007, and since then its share is over 50% of total ODS production, due to the increasing use of HCFC-22 as a feedstock.

Annex F feedstock data reported for 2023 and 2024 is sufficiently complete to be representative of the production of HFCs for feedstock use. Figure 5.3 shows the reported HFC calculated production and production for feedstock use. In 2024, the share of HFC produced for feedstock use was about 19% of total HFC production. However, although there is a significant reduction in the calculated total production of HFCs between 2023 and 2024, it requires additional years data to determine if this is a trend.

Figure 5.3 Total reported HFC production and for feedstock use, 2023 and 2024 (tonnes)



5.2.1 Recent and historical trends in the production and use of controlled ODS as feedstock

In 2024, total production and import reported for feedstock uses of ODS was 1,947,949 tonnes,²² a slight decrease to the quantity in 2023 (1,965,768 tonnes). Reporting of the 2023 data has been revised by the Ozone Secretariat and shows minor differences to that reported in the 2025 TEAP Progress Report. Figure 5.4 shows that since 2020 the most notable difference is the increase in Annex C1 (HCFCs) feedstock use. Figure 5.4 also includes Annex F (HFCs) used as feedstock, now that the HFC feedstock data reported from 2023 is sufficiently complete. The feedstock data reported before 2023 is incomplete due to the timing of reporting obligations, for example, depending on when some parties ratified the Kigali Amendment.

Figure 5.4 Annual reported controlled substances for feedstock use, categorised by Montreal Protocol Group, 2002–2024 (tonnes)²³

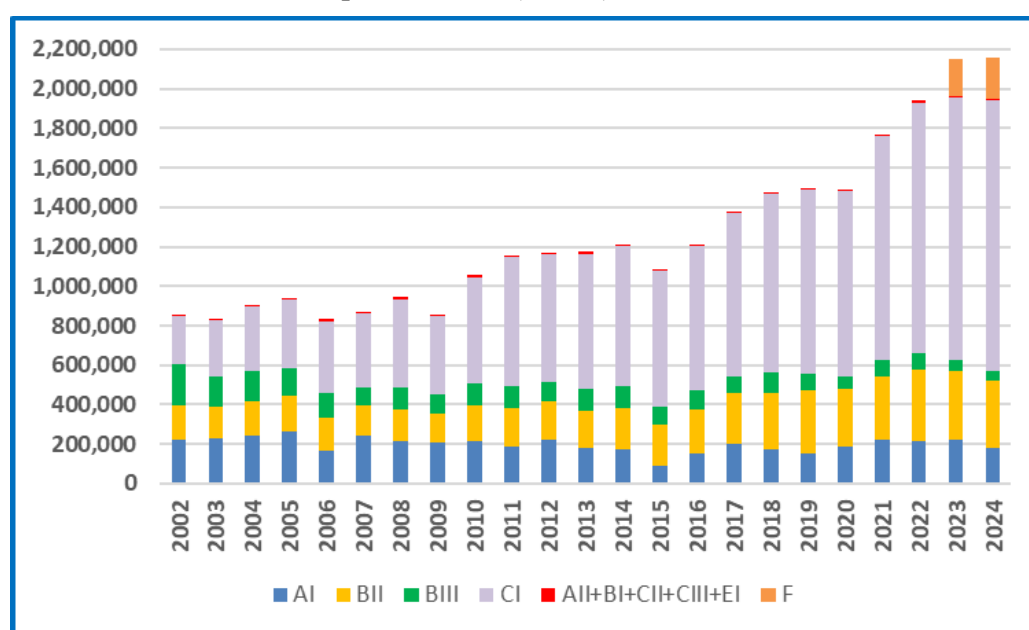


Chart note: Annex F is included from 2023, due to insufficient or no data for previous years

Table 5.1 shows the reported amounts of ODS used as feedstock in 2023 and 2024. The 2024 reported total production and import of ODS for feedstock use is 1,947,949 tonnes and represents 630,928 ODP tonnes, a decrease compared to 2023.²⁴

²² All quantities in tonnes or ODP tonnes are rounded to the nearest whole tonne, unless otherwise stated.

²³ Annex AI CFCs -11, -12, -113, -114, -115; Annex BII carbon tetrachloride; Annex BIII 1,1,1 trichloroethane; Annex CI HCFCs. Annex AII Halons -1211, -1301, -2402; Annex BI CFCs -13, -111, -112, -211, -212, -213, -214, -215, -216, -217; Annex CII HBFCs; Annex CIII bromochloromethane; and Annex EI methyl bromide; Annex F HFCs.

²⁴ While ODP tonnes are included, it should be noted that presenting production for feedstock use in ODP tonnes, these are tonnes produced for feedstock, not tonnes emitted. From the total amount of ODS produced for feedstock use, only a relatively minor to insignificant quantity will be emitted depending on the abatement technologies and containment measures utilised.

Table 5.1 Reported amounts of ODS used as feedstock in 2023 and 2024

Substance	ODP	2023 (tonnes)	2024 (tonnes)
HCFC-22	0.055	978,084	990,395
Carbon Tetrachloride Annex BII	1.1	348,609	343,035
HCFC-142b	0.065	287,982	314,881
1,1,1-trichloroethane (methyl chloroform) Annex BIII	0.1	52,482	46,667
Bromochloromethane Annex CIII	0.12	4,413	3,296
Methyl Bromide Annex E1	0.6	3,297	3,052
CFC-113	0.8	100,000–1,000,000	
CFC-113a, CFC-114, HCFC-124, HCFC-133a, HCFC-141b, HCFC-244		10,000–100,000	
Bromotrifluoromethane (Halon 1301), HCFC-21, HCFC-225cb, HCFC-241, HCFC-242		1,000–10,000	
CFC-12, HCFC-123, HCFC-225, HCFC-225ca, HCFC-243		10–1,000	
Other substances		< 10	
Total Metric Tonnes		1,965,768	1,947,949
(Total ODP tonnes*)		674,725	630,928

Table Explanatory notes:

Note 1: Data Confidentiality. For some substances, due to the limited number of parties reporting production for feedstock use or imports for feedstock use, quantities have been approximated. For those substances that are the only substance in an Annex, the quantity is given, irrespective of the number of parties, because this information is published by the Ozone Secretariat in its annual report to the MOP. This applies to 1,1,1-trichloroethane (methyl chloroform), bromochloromethane and methyl bromide. The confidentiality rule applied is that there must be at least 3 reporting parties for the substance, with each party having greater than a 5% share.

Note 2: Several substances have changed the reporting bands from 2023 to 2024. Of particular note are HCFC-133a which has moved into the higher 10,000 - 100,000 tonne band; and HCFC-241 and HCFC-225cb which have both moved into the higher 1000 - 10,000 band. However, to simplify the table the bands are correct for 2024, but several substances were in different bands in 2023

Note 3: Reporting of the 2023 data has been revised by the Ozone Secretariat and shows minor differences to that reported in the 2025 TEAP Progress Report. In particular, the HCFC-22 production and the total ODS production for feedstock use show minor changes.

Note 3: While the corresponding ODP tonnes are shown, it should be noted that these are ODP tonnes produced for feedstock, not ODP tonnes emitted. From the total amount of ODS used as feedstock, a relatively minor to insignificant quantity will be emitted depending on the abatement technologies and containment measures utilised. The ODP tonnes are calculated from the reported data.

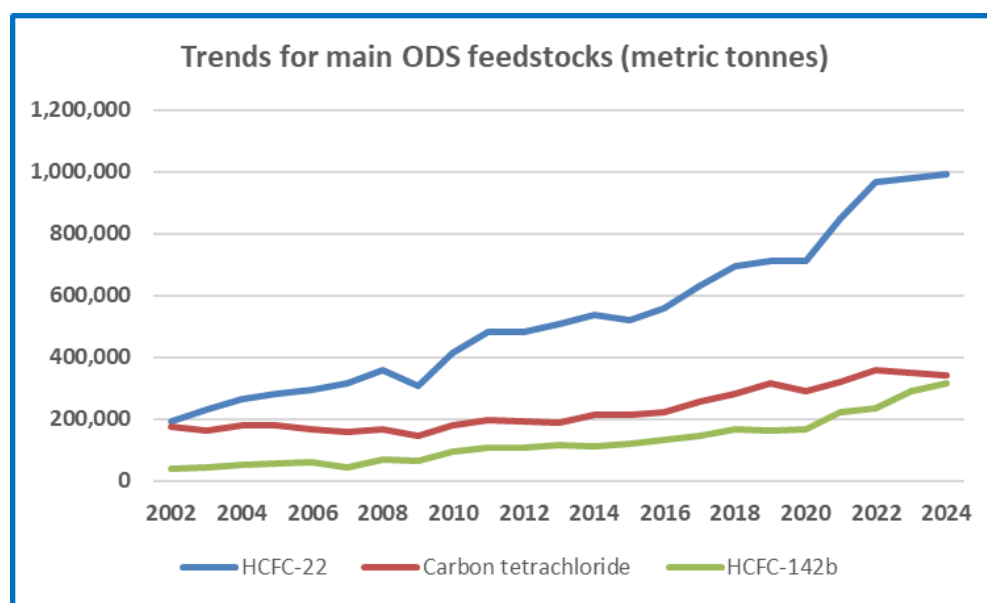
The proportions of the largest ODS feedstocks in 2024 were similar to those in 2023: HCFC-22 (51% of the total mass quantity, 50% in 2023), CTC (18%), and HCFC-142b (16%, an increase from 15% in 2023). HCFC-22 is, by a considerable margin, the largest feedstock used, with 990,395 tonnes reported in 2024, an increase from the revised quantity reported for 2023 (978,084 tonnes).

HCFC-22 is mainly used to produce tetrafluoroethylene (TFE), which can be both homo- and co-polymerized to make stable, chemically resistant fluoropolymers, such as polytetrafluoroethylene, with many applications. TFE may also be used to produce HFC-125. Vinylidene fluoride (VDF, 1,1-difluoroethylene, HFO-1132a) is made from HCFC-142b, with reported feedstock use increasing in 2024 (314,881 tonnes) compared to 2023 (287,982 tonnes). VDF is used as a monomer for polyvinylidene fluoride (PVDF) derived polymers and is also used as a component in refrigerant blends. The feedstock use of CTC has increased in recent years, due to growing demand for lower GWP

HCFO/HFOs and perchloroethylene (PCE), but the reported quantity in 2024 (343,035 tonnes) is slightly lower compared to 2023 (348,609 tonnes). Although the quantities used cannot be disclosed due to data confidentiality, a notable change since 2019, is the increasing use of C₃ HCFCs as feedstock which can be used for production of HFOs and HCFOs, HCFC-242fa is used in the production of HCFO-1233zd(E) and HCFC-244bb is used in the production of HFO-1234yf.

The trends in the production for feedstock use for the main ODS feedstocks are shown in Figure 5.5, The figure shows, in recent years, a less rapid increase in HCFC-22 feedstock use, a relatively stable use of CTC, but a marked increase in the use of HCFC-142b, which is used to make the monomer vinylidene fluoride.

Figure 5.5 Trends in annual reported production for feedstock use of the current main ODS for the years 2002–2024 (tonnes)



5.2.2 Production of HFCs used as feedstock

Annex F feedstock data reported from 2023 is sufficiently complete to be representative of the production of HFCs for feedstock use. Table 5.3 shows the reported amounts of HFCs produced for feedstock use in 2023 (183,539 tonnes) and 2024 (211,326 tonnes). The increase in production of HFC for feedstock use in 2024 is mainly due to HFC-152a, with reported HFC-236ea also increasing into the 1,000–10,000 tonne band in 2024.

Although the applicable confidentiality rules have been used for the data in Table 5.3, other publicly available data is available. The United States has published production of HFCs for feedstock use for 2024 as a requirement of the AIM Act.²⁵ The published feedstock production for 2024 is HFC-245fa: 15,727.8 tonnes, HFC-152a: 1,200 tonnes, and HFC-41: 0.7 tonnes.

²⁵ U.S. Environmental Protection Agency, September 2025, *Expanded HFC Data*, <https://www.epa.gov/climate-hfcs-reduction/hfc-data-hub/expanded-hfc-data#2023-Production>. Accessed ^{March} 2026.

Table 5.2 Reported amounts of HFC used as feedstock in 2023 and 2024

Substance	GWP	2023 Tonnes	2024 Tonnes
HFC-152a	124	> 100,000	
HFC-245fa	1030	10,000–100,000	
HFC-236ea	1370	1,000–10,000	
HFC-23	14,800	707	710
HFC-125, HFC-134a, HFC-143a, HFC-236fa, HFC-32, HFC-41		10–1,000	
Total Metric Tonnes		183,539	211,326

Table Explanatory notes: The confidentiality rules applied are the same as for ODS (see Table 5.1). Some substances have changed the reporting bands from 2023 to 2024. However, to simplify the table the bands are correct for 2024, but some substances were in different bands in 2023.

The dehydrofluorination²⁶ of 1,1-difluoroethane (HFC-152a) is the most broadly used chemical process to produce vinyl fluoride (used to produce polyvinylfluoride, a polymer used mainly in weather resistance, low flammability coatings). HFC-152a can also be used as a feedstock to produce vinylidene fluoride (CH₂CF₂), via photo-chlorination to obtain HCFC-142b followed by dehydrochlorination.

5.3 Information on best practices to control emissions

Best practices available to control emissions include optimising plant design, equipment, operation, maintenance; instrumentation and monitoring of process and emissions; training and instruction for plant operators; periodic mass balancing; technologies for destruction or for separation and chemical transformation to treat unwanted co-products or by-products and abate their emissions; and regulatory controls to provide the economic framework to ensure any or all of the above emissions mitigation measures are implemented by operators, and to require emissions and other reporting.

These were described in Section 2.5 of the 2022 MCTOC Assessment Report on Production emissions and their mitigation, which was re-produced in Section 5.3.6.1 of the 2024 TEAP Progress Report.

5.4 Process agents

MCTOC reviewed the process agent data for 2024 reported to the Ozone Secretariat under decisions X/14(4) and XXI/3(1) by China, the European Union, Israel, and the United States. MCTOC has not identified compelling new information to report to parties in this progress report on developments in process agents.

5.5 Laboratory and analytical uses

MCTOC has reviewed the current information reported to the Ozone Secretariat on production and import of controlled substances used for laboratory and analytical uses. It has also reviewed available information on analytical standards using controlled substances. Considering decision XXXI/5(7),

²⁶ Tang, H., Dang, M., Li, Y., Li, L., Han, W., Liu, Z., Li, Y., Li, X., Rational design of MgF₂ catalysts with long-term stability for the dehydrofluorination of 1,1-difluoroethane (HFC-152a), *RSC Advances*, 2019, **9**, 23744–23751. <https://doi.org/10.1039/C9RA04250D>.

MCTOC has not identified compelling new information to report to parties in this progress report on developments in laboratory and analytical uses.

5.6 *n*-Propyl bromide

MCTOC has reviewed available information on *n*-propyl bromide. Considering decision XXX/15(6), MCTOC has identified no new information to report to parties since the 2025 progress report.

5.7 Destruction of controlled substances

Decision XXX/15 (5) requests the TEAP, following the submission of the report called for in decision XXX/6, to provide a review of destruction technologies, if new compelling information becomes available. MCTOC has considered available information on destruction technologies and has not identified any compelling new information to report to parties, other than responding to a specific request from Canada to evaluate a destruction technology (section 5.7.1).

5.7.1 *Evaluation of a destruction technology submitted by Canada for consideration by parties*

5.7.1.1 *Background*

Environmentally sound destruction of surplus or contaminated ODS and HFCs at end-of-life is encouraged by the Montreal Protocol because it avoids unnecessary emissions and helps protect the stratospheric ozone layer and/or the climate.

The Montreal Protocol does not mandate the destruction of ODS or Annex F Group I HFCs. The exception is HFC-23 (Annex F, Group II) generated in manufacturing facilities, from which emissions must be destroyed to the extent practicable using technologies approved by parties.

The use of destruction technologies approved by parties applies to the amounts of controlled substances destroyed and accounted for within the Protocol's definition of 'production'. The Protocol's definition of 'production' of controlled substances subtracts the amounts destroyed from the amounts produced. Article 7 data reporting requires production data to be reported by parties, including the amounts of controlled substances destroyed by technologies approved by parties. The Protocol also allows Parties to manufacture an amount of controlled substance almost equivalent to the quantity destroyed with technology listed as approved, within the same year as destruction, and within the same group of substances.

Parties have taken several decisions to approve destruction technologies for the purposes of the Montreal Protocol's definition of production and production data reporting requirements. Over time, the list of destruction technologies approved by parties has been updated, with the current list of approved destruction technologies contained in Annex II of the report of the 30th Meeting of the Parties, as modified by the 35th Meeting of the Parties in decision XXXV/5.

Under decision XXXV/5, parties are invited to submit information to the Ozone Secretariat relevant to a review of destruction technologies. Under decision IV/11, TEAP is requested to evaluate technology submissions and prepare recommendations for consideration by the parties to the Montreal Protocol at their annual meeting.

In the preamble to decision XXX/6, parties:

- Noted that DRE is the criterion considered in their approval of destruction technologies, and
- Suggested that parties also consider TEAP's other technical advice on emissions of substances other than controlled substances in the development and implementation of their domestic regulations.

According to the preamble to decision XXX/6, TEAP evaluates destruction technologies for their destruction and removal efficiency and make recommendations to parties for potential approval for the list of approved technologies. TEAP also provides technical advice about emissions of other pollutants and the technical capability of destruction technologies as part of its assessment for consideration by parties.

As outlined in the 2022 TEAP Progress Report, Volume 1, the TEAP assessment considers the following parameters:

1. DRE²⁷, which is a minimum of 99.99% for concentrated sources and 95% for dilute sources (e.g., foams)
2. Emissions of halogenated dioxins and furans²⁸
3. Emissions of other pollutants: acid gases (HCl, HF, HBr/Br₂), particulate matter (total suspended particles, TSP), and carbon monoxide (CO)
4. Technical capability, where the technology has demonstrated destruction on at least a pilot scale or demonstration scale, and for which the processing capacity is no less than 1.0 kg/hr of the substance to be destroyed, whether ODS, HFC or a suitable surrogate.

The DRE is a measure of the efficiency of destruction and is the basis of TEAP's recommendations to parties. The 99.99% DRE minimum for concentrated sources of controlled substances is considered protective for minimising ozone depletion and climate impact. In the case of controlled substances contained in products such as closed cell foams and considered dilute sources, a DRE of 95% minimum is adopted for assessment purposes.

The following technical performance assessment and advisory criteria used for TEAP assessments of destruction technologies represent a minimum DRE for destroying ODS/HFCs and maximum advisory levels of emissions of pollutants to the atmosphere that would be considered as an acceptable minimum level of technical capability.

²⁷ Destruction and Removal Efficiency (DRE) is determined by subtracting from the mass of a chemical fed into a destruction system during a specific period of time the mass of that chemical alone that is released in stack gases and expressing that difference as a percentage of the mass of that chemical fed into the system. If interconversion to other controlled species is possible, it is recommended that analysis is used to measure emissions and that any controlled species is taken into account when determining DRE.

²⁸ Depending on the waste stream, polychlorinated dibenzodioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), polybrominated dibenzodioxins (PBDDs), polybrominated dibenzofurans (PBDFs), polyfluorinated dibenzodioxins (PFDDs), polyfluorinated dibenzofurans (PFDFs). For mixed substance destruction, mixed halogenated dioxins and furans can be formed.

Table 5.3 Technical Performance Assessment and Advisory Criteria

Performance Qualification	Units	Concentrated Sources	Diluted Sources (e.g., foams)
DRE	%	99.99	95
Dioxins/furans	ng-ITEQ/Nm ³	0.2	0.5
HCl/Cl ₂	mg/Nm ³	100	100
HF	mg/Nm ³	5	5
HBr/Br ₂	mg/Nm ³	5	5
Particulates (TSP)	mg/Nm ³	50	50
CO	mg/Nm ³	100	100

Notes to the table:

All concentrations of pollutants in stack gases and stack gas flow rates are expressed on the basis of dry gas at normal conditions of °C and 101.3 kPa, and with the stack gas corrected to 11% O₂ (as referred to by normal cubic metre, Nm³). NB. Different stack gas conditions may apply in different countries for different technologies.

ITEQ: International Toxic Equivalents.²⁹

Acid gases will be assessed based on the specific halogen species present in the waste stream.

TSP – total suspended particles

5.7.1.2 Submission by Canada

Canada submitted confidential and non-confidential information to the Ozone Secretariat regarding a patented plasma arc technology utilising steam for evaluation by TEAP. With relevant expertise, MCTOC has evaluated the technology on behalf of TEAP and provides its evaluation and recommendation for consideration by parties. During its evaluation, MCTOC requested clarifications of Canada about information provided in the submission.

5.7.1.3 Evaluation process

The evaluation process involved several steps:

- Three MCTOC members with relevant experience and expertise independently reviewed the confidential information submitted by Canada.
- MCTOC’s evaluation was conducted according to the technical performance assessment and advisory criteria used for TEAP assessments of destruction technologies, as described above, and based on the performance criteria established by the Montreal Protocol, namely the demonstrated minimum destruction removal efficiency (DRE). MCTOC also considered the performance advisory criteria for dioxin/furans, other listed pollutants, and a minimum capacity level to demonstrate technical capability.
- Data was considered for the specific substances, CFC-12, CFC-11, HCFC-22, HFC-134a, as provided in the submission, to demonstrate DRE.

²⁹ The International Toxic Equivalents (ITEQ) scheme was established by NATO in 1988. More recently the TEFs were re-evaluated by the World Health Organisation and the revised TEQ scheme is generally universally accepted, with the updated TEFs used in the TEQ calculation. Some of the data reviewed by the 2018 TFDT quotes TEQ values. A detailed discussion of ITEQ and TEQ is on page 13 of 2018 TEAP Report, Volume 2: Decision XXIX/4 TEAP Task Force Report on Destruction Technologies for Controlled Substances

- MCTOC also considered the issue of the potential suitable category for this technology within the existing list of generic destruction technologies approved by parties, and whether MCTOC would recommend it as a separate unique generic technology category or as a variant of a generic technology category already approved and listed.
- MCTOC requested clarification from Canada on aspects of the submission, and additional information was provided by Canada, namely: the rationale for steam plasma arc technology, as that separate name and classification, being considered for possible approval by parties for purposes of the Montreal Protocol as a distinct generic destruction technology category, as opposed to being considered as a variant of other plasma arc technology, already listed as an approved generic category of destruction technology; and information considered confidential.
- Following Canada’s clarifications, the three reviewers independently revised their evaluations taking into consideration the responses submitted.
- Two peer reviewers, an MCTOC member and a TEAP member with relevant experience and expertise, considered the submission information, the clarifications provided, and the three evaluations and provided their additional advice for MCTOC’s consideration.
- MCTOC discussed the evaluations at its online and hybrid meetings and reached consensus on the recommendation.

5.7.1.4 Evaluation summary

The technology is described by Canada and patents as steam plasma arc and as a patented³⁰ plasma hydrolysis technology for the destruction of environmentally harmful chemical gases.

One patent³¹ describes the technology as: “Nitrogen, helium, argon or mixture thereof is used as a shroud gas...Superheated steam is used as the main plasma forming gas.” and “In operation, the steam plasma torch heats the reactor to the desired operating conditions and the precursor material is injected into the plasma plume. The highly reactive hydrogen and hydroxyl ions present in the steam plasma hydrolyse the precursor material in the high temperature hydrolysis zone.”

Another patent³² further describes the technology as: “The steam plasma torch includes a metallic cathode, a metallic ignition anode and a metallic working anode... A plasma arc is initiated with helium or another monoatomic gas between the cathode and the ignition anode. Once the arc is stabilized, a plasma forming steam is injected...and the arc is transferred from the ignition anode to the working anode. Nitrogen, helium, argon or mixture thereof is used as a shroud gas. The shroud gas protects the metallic cathode from premature oxidation and hence increases the working life of the cathode. Superheated steam is used as the main plasma forming gas.

³⁰ Canadian patent CA 2,771,640, US patents US 8,716,546B2, US 8,961,887, US 9,506,648, US 9,562,684, US 10,551,062 and European patent EP 2686100.

³¹ Carabin, P., Rao, L., Steam Plasma Arc Hydrolysis of Ozone Depleting Substances, Canadian Patent CA 2771640 A1 2012/09/18, Sep. 18, 2012. Note that schematic numbering system has been removed from the quoted citation text for the purposes of this report’s clarity.

³² Carabin, P., et al., Steam Plasma Arc Hydrolysis of Ozone Depleting Substances, US Patent Number, US 8,716,546 B2, May 6, 2014. Note that references to schematics and schematic numbering system have been removed from the quoted citation text for the purposes of this report’s clarity.

The steam plasma torch, in addition to acting as a heat source, provides reactive oxygen, hydroxyl and hydrogen ions necessary for the destruction of the precursor material and prevents the formation of undesired side products, such as Cl, F, CF.”

The technology’s destruction mechanism employs high-temperature steam plasma hydrolysis. The function of the steam is to provide intense heat and highly reactive species to break down the controlled substances into smaller molecules, such as carbon monoxide (CO), hydrogen fluoride (HF), hydrogen chloride (HCl), and hydrogen (H₂).

Based on MCTOC’s review of submitted performance data provided by Canada, the technology demonstrated that the DREs achieved for the destruction of CFC-12, CFC-11, HCFC-22 and HFC-134a are greater than 99.99% by at least an order of magnitude. Therefore, the technology has demonstrated the capability to meet the DRE performance criteria³³ for these controlled substances and qualifies for the purposes of destruction under the Montreal Protocol for concentrated sources of Annex A group 1, Annex C group 1, Annex F group 1 controlled substances.

Emissions of dioxins and furans are below 0.2 ng-ITEQ/Nm³, and emissions of other pollutants, acid gases (HCl, HF), particulate matter (total suspended particles, TSP), and carbon monoxide (CO), are also below the recommended thresholds. The technology has demonstrated the processing capacity above the minimum advisory criteria of 1 kg/hr of the substance being destroyed (in the range 30–50 kg/hr depending on controlled substance processed).

5.7.1.5 Recommendation

TEAP recommends that the technology, under a new generic category Steam Plasma Arc, be approved for destruction of concentrated sources of Annex A Group 1, Annex C Group 1, Annex F Group 1 controlled substances for the purposes of the Montreal Protocol.

5.7.1.6 Steam plasma arc technology

Although this steam plasma arc technology appears to be technically similar to previously approved argon and nitrogen plasma arc technologies, which can also use steam, Canada explained that the plasma is formed by steam and not the inert gas and that the inert gas is used as a shield gas to protect the back electrode (cathode) from excessive oxidation. The Canada submission and publicly available patents state that the technology involves a two-stage destruction process based on high temperature hydrolysis followed by medium temperature oxidation.

MCTOC considers the steam plasma arc technology as described to be a distinct destruction technology category in the listing of approved technologies. Data submitted for the submitted steam plasma arc technology is for a more limited range of controlled substances than those approved for other plasma arc technologies previously approved by parties.

The May 2018 TEAP Destruction Technologies Task Force Report³⁴ notes that for plasma systems steam can play a significant role in the reaction environment. The introduction of steam into the system may help reduce transformation or interconversion risks, particularly those associated with the recombination of halogenated species and the formation of undesirable by-products. The latter may

³³ Although the submission states that the destruction technology was tested on more than 60 compounds, including perchlorinated and brominated compounds, no supporting data were provided for these compound classes. Therefore, beyond the controlled substance categories where data were presented, no data-based assessment could be made for these other substances.

³⁴ UNEP, 2018, *2018 Report of the Technology and Economic Assessment Panel*, Volume 2, Decision XXIX/4 TEAP Task Force Report on Destruction Technologies for Controlled Substances, May 2018.

include other controlled substances that could otherwise be emitted. The 2002 TEAP Task Force Report on Destruction Technologies³⁵ also indicates that plasma arc technologies can utilise steam as source of hydrogen in the pyrolysis process to prevent formation of CF₄ and facilitate more complete ODS destruction for a given feed rate.

MCTOC has evaluated this technology and made a recommendation for approval of the technology based on the DRE performance criteria being demonstrated for certain controlled substances and additional information received in the submission.

Associated with this is the recommendation for addition of a new generic category of destruction technology designated Steam Plasma Arc, within which the submitted technology would fall, specifically for destruction of concentrated sources of Annex A Group 1, Annex C Group 1, Annex F Group 1 controlled substances based on the data available. The table of approved destruction technologies as modified is provided below.

³⁵ UNEP, 2002, *Report of the Technology and Economic Assessment Panel*, Volume 3B, Report of the Task Force on Destruction Technologies, April 2002.

Table 5.4 Recommendations for list of approved destruction technologies

Notes: The existing list of destruction technologies approved by decisions of parties to the Montreal Protocol is shown in the table below, along with the recommendation relevant to this evaluation, which is shown in the table below in red italics.

Technology	Applicability										
	Concentrated Sources									Dilute Sources	
	Annex A		Annex B			Annex C	Annex E	Annex F			Annex F
	Group 1	Group 2	Group 1	Group 2	Group 3	Group 1	Group 1	Group 1	Group 2		Group 1
Primary CFCs	Halons	Other CFCs	Carbon Tetrachloride	Methyl Chloroform	HCFCs	Methyl Bromide	HFCs	HFC-23	ODS	HFCs	
DRE	99.99%	99.99%	99.99%	99.99%	99.99%	99.99%	99.99%	99.99%	99.99%	95%	95%
Cement Kilns	Approved	Not Approved	Approved	Approved	Approved	Approved	Not Determined	Approved	Not Determined		
Gaseous/Fume Oxidation	Approved	Not Determined	Approved	Approved	Approved	Approved	Not Determined	Approved	Approved		
Liquid Injection Incineration	Approved	Approved	Approved	Approved	Approved	Approved	Not Determined	Approved	Approved		
Municipal Solid Waste Incineration										Approved	Approved
Porous Thermal Reactor	Approved	Not Determined	Approved	Approved	Approved	Approved	Not Determined	Approved	Not Determined		
Reactor Cracking	Approved	Not Approved	Approved	Approved	Approved	Approved	Not Determined	Approved	Approved		
Rotary Kiln Incineration	Approved	Approved	Approved	Approved	Approved	Approved	Not Determined	Approved	Approved	Approved	Approved
Thermal Decay of Methyl Bromide	Not Determined	Not Determined	Not Determined	Not Determined	Not Determined	Not Determined	Approved	Not Determined	Not Determined		
Argon Plasma Arc	Approved	Approved	Approved	Approved	Approved	Approved	Not Determined	Approved	Approved		
Steam Plasma Arc	<i>Recommend for approval</i>	<i>Unable to assess</i>	<i>Unable to assess</i>	<i>Unable to assess</i>	<i>Unable to assess</i>	<i>Recommend for approval</i>	<i>Unable to assess</i>	<i>Recommend for approval</i>	<i>Unable to assess</i>		
Inductively coupled radio	Approved	Approved	Approved	Approved	Approved	Approved	Not Determined	Not Determined	Not Determined		

Technology	Applicability										
	Concentrated Sources									Dilute Sources	
	Annex A		Annex B			Annex C	Annex E	Annex F			Annex F
	Group 1	Group 2	Group 1	Group 2	Group 3	Group 1	Group 1	Group 1	Group 2		Group 1
Primary CFCs	Halons	Other CFCs	Carbon Tetrachloride	Methyl Chloroform	HCFCs	Methyl Bromide	HFCs	HFC-23	ODS	HFCs	
frequency plasma											
Microwave Plasma	Approved	Not Determined	Approved	Approved	Approved	Approved	Not Determined	Not Determined	Not Determined		
Nitrogen Plasma Arc	Approved	Not Determined	Approved	Approved	Approved	Approved	Not Determined	Approved	Approved		
Chemical Reaction with H ₂ and CO ₂	Approved	Approved	Approved	Approved	Approved	Approved	Not Determined	Approved	Approved		
Gas Phase Catalytic De-halogenation	Approved	Not Determined	Approved	Approved	Approved	Approved	Not Determined	Approved	Not Determined		
Superheated steam reactor	Approved	Not Determined	Approved	Approved	Approved	Approved	Not Determined	Approved	Approved		
Thermal Reaction with Methane	Approved	Approved	Approved	Approved	Approved	Approved	Not Determined	Not Determined	Not Determined		
Thermal decay of methyl bromide	Not Determined	Not Determined	Not Determined	Not Determined	Not Determined	Not Determined	Approved	Not Determined	Not Determined		

5.8 Metered dose inhalers

This section provides information on pressurised metered-dose inhalers (pMDIs) relating to Decision XXXVI/6, *Developments regarding MDIs with low-GWP propellants*:

- 1. To encourage parties to promote coordination between national environmental and health authorities on raising awareness of metered-dose inhaler propellants with low global warming potential and the availability of other alternatives, including their impact on climate and the environment, recognizing the need to ensure patient access to critical health remedies;*
- 2. To invite parties that produce metered-dose inhalers to submit to the Ozone Secretariat, on a voluntary basis, preferably by June 2025 or when it becomes available, any relevant information on progress in the development of metered-dose inhaler products using lower-global-warming-potential propellants, on the availability of other alternatives and on the implementation of lessons learned during previous metered-dose inhaler propellant transitions;*
- 3. To request the Technology and Economic Assessment Panel to continue to provide in its annual progress reports updated information on low-global-warming-potential metered-dose inhaler propellants and to complement its 2026 quadrennial assessment report with timely information, including on the availability, technical feasibility, economic viability, safety and market penetration of those propellants in parties operating under paragraph 1 of Article 5 of the Montreal Protocol on Substances that Deplete the Ozone Layer and in parties not so doing;*
- 4. To encourage parties to revisit the issue, no later than 2027, in the light of updated information provided by the Technology and Economic Assessment Panel in its 2026 quadrennial assessment report.*

Two parties (the EU and the United States) provided information relevant to decision XXVI/6, paragraph 2, on progress in the development of lower GWP pMDIs, the availability of alternatives, and lessons learned during previous pMDIs propellant transitions. Details provided therein will be incorporated into the 2026 MCTOC Assessment Report.

5.8.1 *Developments in asthma management*

Asthma is characterised by airway inflammation and bronchoconstriction, and the Global Initiative for Asthma (GINA) 2025 report emphasises that controlling inflammation with inhaled corticosteroids (ICS) is the foundation of safe, effective care. ICS-containing medication, used together with reliever therapy as appropriate, reduces the risk of severe exacerbations and death compared with relying on bronchodilators alone. Overreliance on short-acting bronchodilators (SABAs) is linked to higher risk of severe attacks.³⁶

The 2025 update also reinforces practical priorities for health systems and patients: improve access to affordable ICS-containing inhalers, ensure correct inhaler technique, and address risk factors for exacerbations. The report notes that environmental considerations of inhalers are important, but maintaining access to essential medicines is paramount. The vast majority of asthma deaths occur in low- and middle-income countries, where availability and cost barriers limit access to ICS, and addressing these supply and affordability gaps is essential to reduce preventable morbidity and mortality.

³⁶ Global Initiative for Asthma, 2025 *Global Strategy for Asthma Management and Prevention*, updated November 2025. <https://www.ginasthma.org>. Accessed March 2026.

5.8.2 *Developments in COPD management*

The Global Initiative for Chronic Obstructive Lung Disease (GOLD) 2026 Report continues to emphasise optimisation of long-acting bronchodilator combinations and the use of inhaled corticosteroids guided by blood eosinophil counts.³⁷ Since the 2025 Progress Report, biologic therapies targeting type-2 inflammatory pathways (including anti-IL-4/IL-13 and anti-IL-5 agents) have received regulatory approval in several non-Article 5 Parties for selected patients with chronic obstructive pulmonary disease (COPD) and elevated eosinophil counts (a marker of type-2 airway inflammation) who continue to experience exacerbations despite maximal inhaled therapy. Clinical trials demonstrate reductions in exacerbation frequency, which may also reduce reliance on reliever inhalers in eligible populations.^{38,39} As injectable products, biologic therapies do not require inhaler propellants. Their introduction raises considerations relating to cost, infrastructure and equitable access. Uptake remains limited in many Article 5 Parties due to availability and affordability constraints.

5.8.3 *Current market size and trends*

pMDIs, dry powder inhalers (DPIs), aqueous soft mist inhalers (SMIs), and other delivery systems such as nebulisers all play a role in the treatment of asthma and COPD. pMDIs globally are estimated to account for about 70% of all doses prescribed, equivalent to over 43 billion doses annually of which 33 billion doses are for salbutamol pMDIs. In comparison, salbutamol accounts for less than 0.5% of doses taken from DPIs.⁴⁰

The average growth rate for pMDI doses over the last 5 years has been 1.6% p.a. for salbutamol versus 3.5% p.a. for controllers/preventers. In the last 12 months, overall pMDI use has declined by 1.3%, while controller pMDI doses have continued to increase by 1.6%.

As global total HFC consumption declines, the proportion used in pMDIs is growing. For example, in the UK in 2022, pMDIs accounted for 11% of fluorinated (F)-gas use in CO₂e-equivalent terms, compared to 8% a decade ago.⁴¹

Under the new EU F-gas Regulation 2024/573, the pMDI sector is brought into scope of the HFC phase-down from 2025, transitioning from its previous exemption. The Regulation establishes a quota-based system that applies to virgin HFCs, including HFC-152a used in medical applications, while exempting HFOs (HFO-1234ze(E)), non-fluorinated alternatives, and recycled or reclaimed refrigerants. The recent update will reduce overall HFC emissions rapidly to 5% of baseline by 2030,⁴² which could potentially impact the availability of pharmaceutical-grade HFC for pMDIs. It is

³⁷ Global Initiative for Chronic Obstructive Lung Disease. *Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: 2026 report*, 2026, <https://goldcopd.org/2026-gold-report-and-pocket-guide/>. Accessed March 2026.

³⁸ Bhatt SP, Rabe KF, Hanania NA, *et al.*, Dupilumab for chronic obstructive pulmonary disease with type 2 inflammation: a pooled analysis of two phase 3, randomised, double-blind, placebo-controlled trials, *Lancet Respir Med.*, 2025, **13**(3), 234–243.

³⁹ Sciruba FC, Criner GJ, Christenson SA, *et al.*, Mepolizumab to prevent exacerbations of COPD with an eosinophilic phenotype, *N Engl J Med.*, 2025, **392**(17), 1710–1720.

⁴⁰ UNEP, 2025, *Report of the Technology and Economic Assessment Panel*, Volume 1, Progress Report, May 2025.

⁴¹ National Atmospheric Emissions Inventory, *Greenhouse Gas Emissions Data*, <https://naei.energysecurity.gov.uk/greenhouse-gases/greenhouse-gas-emissions-data>. Accessed March 2026.

⁴² European Union, *Regulation (EU) 2024/573 of the European Parliament and of the Council of 7 February 2024 on fluorinated greenhouse gases*, 2024, <https://eur-lex.europa.eu/eli/reg/2024/573/oj>. Accessed March 2026.

anticipated that by then, pharmaceutical-grade HFC will likely be the majority of HFC used. As a safeguard, the EU is committed to a review of the impact of this latest regulation on healthcare in 2028 to address any potential shortages. It is also worth noting that the EU F-gas regulations impose a restriction from 1 January 2028 on the import and export of products containing HFCs to countries that have not ratified the Kigali Amendment.⁴³ These restrictions would appear to include the import and export of pMDIs containing controlled F-gases, meaning that from 1 January 2028 some countries might be unable to receive imported HFC pMDIs manufactured in, and exported from, the EU, although it is unclear how the aforementioned review of the impact on healthcare might affect these requirements.

The United States remains the largest inhaler market and a high user of pMDIs. Taken together with the top five European markets (France, Germany, Italy, Spain, and UK), sales were \$11.7 billion in the year to June 2024. These markets have previously been dominated by a few multinational companies, with the top five EU markets accounting for two thirds of all doses sold. More recently, two India-based manufacturers have introduced lower price pMDIs into the United States. The fastest growing and most expensive inhalers are the triple combination of LABA, ICS and long-acting antimuscarinic antagonist (LAMA) which are available as both pMDIs and DPIs.

pMDIs are filled in bulk, typically with one month's therapy for regular maintenance treatment dispensed in a single filling operation. DPIs (both single-dose capsule and multi-dose) take significantly longer to fill. The "dose" is generally two inhalations from a pMDI versus one inhalation from a DPI. Since there are more than twice as many doses manufactured in pMDI format, to replace pMDIs with DPIs would require substantial capital investment and time. However, establishing a manufacturing plant for pMDIs with more flammable lower GWP propellants also needs careful planning and capital investment.⁴⁴

5.8.4 The security of current pharmaceutical-grade HFC propellant supplies during transition

The challenges in maintaining a supply of current pharmaceutical-grade propellants through the conversion period to the new lower GWP replacement propellants are becoming clearer. They differ around the world but include both operational and regulatory matters. However, almost all pharmaceutical-grade HFC propellants for non-A5 parties are manufactured by a single UK company.

Operationally, pharmaceutical propellants are usually produced in two stages i.e. industrial synthesis followed by purification.

Synthesis of the precursor industrial-grade HFC-134a is a continuous process that cannot be turned down to a much lower rate; 60% of the plant production capacity is a typical lower limit. Phase down of non-pharmaceutical uses of HFCs is therefore forcing consolidation or closure of production plants, especially in non-5 parties. A change to an alternative source of industrial-grade HFCs fit for purification to pharmaceutical-grade requires a thorough review to manage a new set of impurities from the new source material, and work is ongoing on this.

Purification is performed in batches that can be scaled down to produce smaller amounts when demand for pharmaceutical grade HFC-134a and HFC-227ea declines as transition progresses. This will have a significant upward pressure on cost, because fixed costs are spread across lower volumes.

⁴³ As of 24 April 2026, parties that have not ratified the Kigali Amendment are Afghanistan, Algeria, Antigua and Barbuda, Democratic Rep. of the Congo, Dominica, Equatorial Guinea, Guyana, Iran (Islamic Rep. of), Iraq, Israel, Jamaica, Kazakhstan, Libya, Madagascar, Monaco, Myanmar, Qatar, South Sudan, State of Palestine, Sudan, Suriname, Timor-Leste, Ukraine, Uzbekistan, Yemen.

⁴⁴ Wilkinson A., Woodcock A. High-quality and low-carbon asthma care go hand in hand, *Eur Respir J.*, 2024, **64**(1), 2400638. <https://doi.org/10.1183/13993003.00638-2024>

This should not impact availability providing the increased cost is bearable by users. It seems likely that pharmaceutical grade HFC-134a and HFC-227ea will be needed and available into the early 2030s. One major supplier of pharmaceutical-grade HFC propellants expects limitation of HFC-134a supply in regions like Europe from 2030 onwards.

Many pMDIs are manufactured in the EU. Stockpiling of either industrial-grade feedstock or finished pharmaceutical-grade propellant or both, has been previously discussed as a means of cushioning any shortfalls, especially for non-5 markets. However, with the introduction in the EU of a tightly controlled pharmaceutical quota scheme from 2025, this will become more difficult but will probably remain possible at a modest (100s tonnes) level taking advantage of quota potentially freed up by the Inward Processing Relief (IPR) scheme (see below).

The available EU carbon quota may be sufficient to cover the needs for HFC-134a and HFC-227ea for pMDIs for use within the EU. However, over half of EU pMDI production is exported and there is insufficient quota to cover this.⁴⁵ Instead, the complex IPR customs duty scheme can be used as a way of identifying HFCs in pMDIs that are being re-exported. This entails a significant administrative burden for both the manufacturer and user of the propellants which may take over one year. The first successful transactions using this took place in 2025. In the United States, a quota system is also operating for the use of high-GWP pharmaceutical propellants, with an annually assigned quota based on previous consumption and a forward reduction strategy. Applications for quotas through to 2030 are due by April 30, 2026.

In A5 Group 2 parties, Kigali Amendment HFC baselines are still being established. As A5 parties that have ratified the Kigali Amendment follow its control steps, it is possible that increasing HFC demand for RACHP might put pressure on supply of inhaler propellants. There are manufacturers of pharmaceutical grade HFC-134a in India and China, and these manufacturers are also planning to supply pharmaceutical grade HFC-152a and HFO-1234ze(E).

5.8.5 Transition to lower GWP propellants

The transition from high- to lower GWP propellants in pMDIs presents many challenges in addition to the key objectives of proving safety and efficacy of the new inhalers. These include the context of global environmental legislation; the continuity and stability of supply of pharmaceutical grade HFCs; the continued availability and affordability of alternative devices; regulatory approval and launch of lower GWP pMDIs; and patient acceptability.

Two pharmaceutical-grade lower GWP propellants, HFC-152a⁴⁶ and HFO-1234ze(E)⁴⁷, are in research and development for a range of drugs in pMDIs.

After a major effort over several years, the first launch of a pMDI containing a lower GWP propellant has occurred in the UK. A second company has also filed for approval in the UK. Two companies

⁴⁵ Regulation (EU) 2024/573 of the European Parliament and of the Council of 7 February 2024. Article 17, Annex VII and Annex VIII. <https://eur-lex.europa.eu/eli/reg/2024/573/oj/eng>. Accessed April 2026.

⁴⁶ Orbia, 2023, *Kindeva Drug Delivery and Orbia Fluorinated Solutions (Koura) Announce Collaboration for Low GWP Propellant Conversion*, December 5, 2023. <https://www.orbia.com/this-is-orbia/news-and-stories/Kindeva-Drug-Delivery-and-Orbia-Fluorinated-Solutions-Koura-Announce-Collaboration-for-Low-GWP-Propellant-Conversion/>. Accessed March 2026.

⁴⁷ Honeywell, 2022, *Honeywell Begins Production Of Near-Zero Global-Warming-Potential Medical Propellant*, October 26, 2022. <https://www.honeywell.com/us/en/press/2022/10/honeywell-begins-production-of-near-zero-global-warming-potential-medical-propellant>. Accessed March 2026.

have announced the successful completion of clinical studies with the intention to obtain marketing authorisation.

One manufacturing process design review and risk assessment determined that HFO-1234ze(E) can be safely introduced into manufacturing facilities.⁴⁸ However, consideration is still needed on the flammability of all propellant mixtures with ethanol.

- HFC-152a is a colourless and odourless gas that has been in use since the 1990s and is already manufactured in large volumes and widely used in several non-medical applications. HFC-152a is more flammable than HFC-134a, and pMDI manufacturing facilities require capital investment to manage fire risk. Work to fill the inhalation toxicology gaps was initiated in 2016 and is now successfully completed. To date, all pre-clinical and clinical safety studies on pharmaceutical-grade HFC-152a have shown no toxicity.⁴⁹ Currently, one company has an Investigational New Drug (IND) authorisation in place to support clinical trials,⁵⁰ and has submitted a Drug Master File to the U.S. Food and Drug Administration (FDA) in March 2026. A company in China submitted a Drug Master File (DMF) to the FDA in 2023.
- HFO-1234ze(E) is a colourless and odourless gas that has been manufactured in large volumes and widely used in many non-medical applications for over 10 years.⁴⁸ In 2022, one company opened a commercial-scale production facility for pharmaceutical-grade HFO-1234ze(E) propellant in the United States. Pharmaceutical-grade HFO-1234ze(E) has shown no pre-clinical or clinical toxicity.^{51,52} DMF filings are complete for the United States, Japan, and China.⁴⁹

Development of pMDIs is a complex process involving revised ways of manufacturing, new clinical trials, and new regulatory approvals. MCTOC understands that there are at least ten companies globally that have indicated they are developing pMDIs containing lower GWP propellants (using

⁴⁸ Honeywell, 2025, *Solstice® Air Hfo-1234ze(E), An Ultra-Low Global Warming Potential (GWP) Medical Propellant For Metered Dose Inhalers*, November 2025. <https://prod-edam.honeywell.com/content/dam/honeywell-edam/pmt/oneam/en-us/medical-propellant/documents/Solstice-Air-Brochure.pdf>. Accessed March 2026.

⁴⁹ Mohar, I., Lewandowski, T., Johnson, S., et al., Safety Overview of Zephex® 152a as a Low Global Warming Potential Medical Propellant, *Respiratory Drug Delivery* 2025, Volume 1, 2025, 57–65, <https://www.rddonline.com/rdd/article.php?id=0&sid=103&ArticleID=3150&return=1>. Accessed March 2026.

⁵⁰ Koura Global, *Zephex 152a - 1,1-Difluoroethane as an Excipient in a Medicinal Product* <https://www.kouraglobal.com/applications/medical-propellants/zephex-152a/>. Accessed March 2026.

⁵¹ Giffen PS, et al., The Nonclinical Assessment of Trans-1,3,3,3-tetrafluoropropene (HFO-1234ze (E)), a Near Zero Global Warming Potential Propellant for Use in Metered Dose Inhalation Products, *Int J Toxicol.*, 2024, **43**(1), 4–18. <https://journals.sagepub.com/doi/full/10.1177/10915818231206025>.

⁵² Aurivillius M, et al., Relative bioavailability of budesonide/glycopyrrolate/formoterol fumarate triple therapy delivered using next generation propellants with low global warming potential, *Pulm Pharmacol Ther.*, 2023, **83**, 102245. doi: 10.1016/j.pupt.2023.102245.

HFC-152a^{53,54,55} using HFO-1234ze(E)^{47,56}; and using one or both of the new propellants.^{57,58} Some of these companies are working with Contract Development and Manufacturing Organisations (CDMOs).⁵⁹ These companies have made public their development programs, either via press releases, open reporting of clinical trials or their statements regarding environmental sustainability.

One company recently announced the submission of a registration application for a lower GWP pMDI product in China, the EU, Japan, the UK, and the United States. Approval of this product has now been achieved in the UK and EU with the product subsequently launched in the UK.⁶⁰ A second company announced submission of a lower GWP ICS to the UK Medicines and Healthcare products Regulatory Agency (MHRA) in December 2025.⁶¹

⁵³ Chiesi, 2022, *Koura opens world's first HFA-152a medical propellant production facility*, 30 March 2022. <https://www.chiesi.com/en/media-hub/press-releases/koura-opens-worlds-first-hfa-152a-medical-propellant-production-facility>. Accessed April 2026.

⁵⁴ Cipla, A pharmaceutical composition of salbutamol and pharmaceutical green propellant, WIPO WO 2024/033941 A1, 15 February 2024. <https://patents.google.com/patent/WO2024033941A1/en>. Accessed April 2026.

⁵⁵ Glenmark, 2024, *Integrated Annual Report FY 2024*. https://glenmarkpharma.com/gpl_pdfs/investors/reports_presentations/GPL_Annual_Report_2324a.pdf. Accessed March 2026.

⁵⁶ AstraZeneca, 2024, *AstraZeneca announces the completion of the clinical programme to support the transition of Breztri to next-generation propellant with near-zero Global Warming Potential*, 9 September 2024. <https://www.astrazeneca.com/media-centre/press-releases/2024/astrazeneca-announces-the-completion-of-the-clinical-programme-to-support-the-transition-of-breztri-to-next-generation-propellant-with-near-zero-global-warming-potential.html>. Accessed April 2026.

⁵⁷ Lupin, 2023, *Taskforce on Climate Disclosures (TCFD) Report*. <https://www.lupin.com/wp-content/uploads/2023/08/lupin-ir-2023-tcf-d-v4.pdf>. Accessed March 2026.

⁵⁸ Mundipharma, 2024, *Mundipharma and Vectura announce plans to reformulate flutiform® (fluticasone propionate/formoterol fumarate) pressurised metered-dose inhaler (pMDI) as a commitment to reducing the product's carbon footprint*, 18 April 2024. <https://www.mundipharma.com/Mundipharma-and-Vectura-announce-plans-to-reformulate-flutiform>. Accessed March 2026.

⁵⁹ Kindeva, 2024, *Kindeva Drug Delivery invests in second manufacturing line for greener inhalers at UK manufacturing site*, May 6, 2024. <https://www.kindevadd.com/news/kindeva-drug-delivery-invests-in-second-manufacturing-line-for-greener-inhalers-at-uk-manufacturing-site/>. Accessed April 2026.

⁶⁰ Medicines and Healthcare products Regulatory Agency, *MHRA approves world's first low-carbon version of COPD inhaler Trixeo Aerosphere*, 2025. <https://www.gov.uk/government/news/mhra-approves-worlds-first-low-carbon-version-of-copd-inhaler-trixeo-aerosphere>. Accessed March 2026.

⁶¹ Chiesi, 2025, *MHRA Submission Marks New Step in Chiesi's Carbon Minimal Inhaler Journey*, December 18, 2025. <https://www.chiesi.com/en/media-hub/news/mhra-submission-carbon-minimal-inhaler-chiesi>. Accessed April 2026.

Several clinical trials have been reported in the clinical trials database, as listed in the footnotes.^{62,63,64,65,66,67,68,69,70}

5.8.6 Intellectual property (IP) considerations

The Intellectual Property (IP) position is a major consideration for companies that are still debating whether to develop a lower GWP pMDI. An extensive summary was provided in the TEAP 2025 Progress Report and will also be available in the MCTOC 2026 Assessment Report. Table 5.5 provides an update from last year's progress report. Of note, one company in the United States has filed and gained rapid approval of two patents since the 2025 TEAP Progress Report, one of which is for epinephrine. This moiety has played a significant role in the provision of affordable treatment of asthma in the United States and is available over the counter at a lower cost.

⁶² ClinicalTrials.gov ID NCT05875025, Sponsor Chiesi Farmaceutici S.p.A., *Study to Assess the Effect of the New HFA-152a Propellant on Mucociliary Clearance*, <https://clinicaltrials.gov/study/NCT05875025>, Last Update Posted 2024-11-12. Accessed April 2026.

⁶³ ClinicalTrials.gov ID NCT05472662, Sponsor Chiesi Farmaceutici S.p.A., *A Study to Compare the Effects of Two Propellants in Adults With Mild Asthma*, <https://clinicaltrials.gov/study/NCT05472662>, Last Update Posted 2024-10-15. Accessed April 2026.

⁶⁴ ClinicalTrials.gov ID NCT06264674, Sponsor Chiesi Farmaceutici S.p.A., *Comparison Between CHF5993 pMDI 200/6/12.5 µg HFA-152a VS CHF5993 pMDI 200/6/12.5 µg HFA-134a in Subjects with Asthma (TRECOS)*. (TRECOS), <https://clinicaltrials.gov/study/NCT06264674>, Last Update Posted 2025-11-17. Accessed April 2026.

⁶⁵ ClinicalTrials.gov ID NCT05791565, Sponsor GlaxoSmithKline, *Green (Sustainable) VENTOLIN - Pharmacokinetics (PK) Study in Healthy Participants*, <https://clinicaltrials.gov/study/NCT05791565>, Last Update Posted 2024-09-23. Accessed April 2026.

⁶⁶ ClinicalTrials.gov ID NCT06433908, Sponsor GlaxoSmithKline, *A Study to Compare the Pharmacokinetics (PK) of Salbutamol Administered Via Metered Dose Inhalers (MDI) Containing Propellants HFA-152A (Test) or HFA-134A (Reference) in Healthy Participants Aged 18 to 55 Inclusive*, <https://clinicaltrials.gov/study/NCT06433908>, Last Update Posted 2026-01-12. Accessed April 2026.

⁶⁷ ClinicalTrials.gov ID NCT06433921, Sponsor GlaxoSmithKline, *A Study to Compare the Relative Potency of Salbutamol Administered Via Metered Dose Inhalers (MDI) Containing Propellants HFA-152a to HFA-134a in Mild Asthmatics Aged 18 to 65 Inclusive*, <https://clinicaltrials.gov/study/NCT06433908>, Last Update Posted 2025-10-28. Accessed April 2026.

⁶⁸ ClinicalTrials.gov ID NCT06506266, Sponsor GlaxoSmithKline, *Study of the Effect of HFA-152a and HFA-134a Propellants on Mucociliary Clearance in Healthy Participants*, <https://clinicaltrials.gov/study/NCT06506266>, Last Update Posted 2024-12-16. Accessed April 2026.

⁶⁹ ClinicalTrials.gov ID NCT06702462, Sponsor GlaxoSmithKline, *A Study to Assess the Potential for Airway Sensitivity Reactions With Propellants HFA-152a (Test) and HFA-134a (Reference) Administered Via Pressurized Inhalers in Adults With Mild Asthma*, <https://clinicaltrials.gov/study/NCT06702462>, Last Update Posted 2025-08-26. Accessed April 2026.

⁷⁰ ClinicalTrials.gov ID NCT06261957, Sponsor GlaxoSmithKline, *A Study to Assess and Compare Safety and Tolerability of 3 Months Treatment With Salbutamol Administered Via MDI Containing Propellant HFA-152a or HFA-134a in Participants ≥ 18 Years of Age With Asthma*, <https://clinicaltrials.gov/study/NCT06261957>, Last Update Posted 2026-02-27. Accessed April 2026.

Table 5.5 Some potential patent protection for lower GWP pMDIs. (Granted patents listed where known in bold)

Reference	Propellant	Main Feature
EP4452227B1	HFC-152a	Salbutamol sulphate with ethanol
WO2023212191A9	HFO 1234ze(e)	Combination of albuterol and budesonide
WO2024181972A1	HFC or HFO	High dose suspension formulations (>0.5 mg)
US12496272B1	HFO 1234ze(e)	Epinephrine suspension
US12383516B1	HFO 1234ze(e)	Albuterol with a surfactant but without a co-solvent

5.8.7 Valves, coatings, gaskets

The hardware involved in pMDIs, e.g., cans, valves, gaskets etc. have been found to be suitable for use with new lower GWP propellants, supported by successful stability studies and the running of several clinical trials with the new lower GWP MDI formulations. Some minor changes may still be needed, but these should not significantly limit the rate of development of pMDIs with new lower GWP propellants.

5.8.8 Global regulatory activity related to pMDI products containing lower GWP propellants

5.8.8.1 European Union

As reported previously, in September 2023 European Medicines Agency (EMA) issued a guidance “*Questions and answers on data requirements when transitioning to low global warming potential (LGWP) propellants in oral pressurised metered dose inhalers*”. Additional guidance was issued in 2024 “*Questions and answers on data requirements when transitioning to low global warming potential (LGWP) propellants in oral pressurised metered dose inhalers*”.^{71,72}

5.8.8.2 United Kingdom

In December 2025, the UK government concluded an F-gas consultation aimed at accelerating the phase down of HFCs. Proposed targets would establish a faster phase-down than that in the EU, although not resulting in a complete phase out by 2050. It was also proposed that pMDIs would remain exempted from these targets, as under current UK legislation. The UK government response to this consultation is expected in the Spring of 2026. One salbutamol pMDI containing HFC-134a has been approved over the last 12 months.

⁷¹ European Medicines Agency, 2023, *Committee for Medicinal Products for Human Use (CHMP). Questions and answers on data requirements when replacing hydrofluorocarbons as propellants in oral pressurised metered dose inhalers*, EMA/CHMP/83033/2023. https://www.ema.europa.eu/en/documents/scientific-guideline/questions-answers-data-requirements-when-transitioning-low-global-warming-potential-lgwp-propellants-oral-pressurised-metered-dose-inhalers_en.pdf. Accessed March 2026.

⁷² European Medicines Agency, 2024, *Committee for Medicinal Products for Human Use (CHMP). Guideline on the requirements for demonstrating therapeutic equivalence between orally inhaled products (OIP) for asthma and chronic obstructive pulmonary disease (COPD)*. EMA/CHMP/101453/2024. https://www.ema.europa.eu/en/documents/scientific-guideline/draft-guideline-requirements-demonstrating-therapeutic-equivalence-between-orally-inhaled-products-oip-asthma-chronic-obstructive-pulmonary-disease-copd_en.pdf. Accessed March 2026.

5.8.8.3 United States

The FDA regulatory approach was set out in a joint workshop in December 2024.⁷³ Although FDA have discussed this topic in additional public meetings, the position has not significantly changed. Two pMDIs containing HFC-134a have been approved over the last 12 months.

FDA advice continues to differ significantly from EMA guidance. FDA has additional *in vitro* and clinical requirements, requiring companies to undertake additional laboratory studies and clinical trials.

5.8.9 Developments in LMICs

No new multi-country data on inhaler availability in A5 parties have been published since the 2025 TEAP Progress Report. Respiratory societies and patient organisations remain very concerned that persistent gaps in access and affordability continue to affect many low and middle-income-countries (LMICs) across A5 party markets.⁷⁴ Controller/preventer therapies, including inhaled corticosteroids and combination inhalers, remain poorly available and often unaffordable, with only a minority of facilities meeting the World Health Organization's (WHO) 80% availability target for essential respiratory medicines.⁷⁵ Small changes in the price of inhalers can have a disproportionate impact on patients in these settings, making even modest cost increases a significant barrier to care. These challenges have prompted ongoing advocacy by professional societies and patient organisations to improve registration, strengthen supply chains, and ensure fair and sustainable pricing. As of early 2026, severe natural gas shortages are emerging due to the conflict in the Middle East disrupting supplies. As natural gas prices rise, industrial and residential consumers are using more biomass fuels, especially in LMICs. This is likely to cause and/or worsen COPD and asthma.

Small- and medium-sized manufacturers are particularly vulnerable; without access to technology licences, investment for scale-up, or regulatory expertise, many may struggle to transition to lower GWP formulations, further widening global inequalities. In practice, consolidation or partnerships with larger contract manufacturing organisations may be the only viable way for these smaller producers to continue supplying their markets while keeping essential inhalers accessible and affordable.

5.8.9.1 Market patterns in LMICs

In most LMICs in Southeast Asia, Africa and South America, relatively inexpensive SABA (salbutamol) HFC-134a pMDIs continue to dominate the market. Exceptionally, in India pMDIs only account for one quarter of prescribed doses, with single dose DPIs (99% of all DPIs) still dominating the market. Salbutamol pMDI is essentially a commodity product and very price sensitive. If either there is patent protection for the new propellants or there is no technology transfer, then the price of the new propellants from the propellant suppliers becomes a critical issue for Article 5 markets. Affordability of effective asthma medications is a key driver for patients and prescribers, as well as commercial interests for asthma medications in most Article 5 parties, including for products

⁷³ FDA and the Center for Research on Complex Generics, *Navigating the Transition to Low Global Warming Potential Propellants*, <https://www.complexgenerics.org/education-training/navigating-the-transition-to-low-global-warming-potential-propellants/>. December 4–5, 2024. Accessed April 2026.

⁷⁴ Forum of International Respiratory Societies, 2025, *Clinicians Urge Affordable Inhalers for COPD and Asthma on Universal Health Coverage Day*, December 13, 2025. <https://firsnet.org/on-universal-health-coverage-day-leading-clinicians-call-for-affordable-access-to-lifesaving-inhaled-medicines-for-copd-and-asthma/>. Accessed April 2026.

⁷⁵ Stolbrink *et al.*, Availability, Cost and Affordability of Essential Medicines for Chronic Respiratory Diseases in Low-Income and Middle-Income Countries: A Cross-Sectional Study. *Thorax*. 2024, **79**(7), 676–679. doi: 10.1136/thorax-2023-221349. <https://thorax.bmj.com/content/79/7/676.long>.

imported for example into sub-Saharan African parties where there is no local manufacturer. If the pricing level is not around the same as the existing HFC-134a pricing, then lower GWP products may not be viable in A5 parties until generic propellant suppliers can enter the market.

According to search results from the China Pharmaceutical Intelligence Network⁷⁶, a total of 96 inhalation preparation varieties were approved for marketing in China in 2025. These approvals are from 56 marketing authorization holders. Among these, 10 are imported drug products (including 2 Sevoflurane for inhalation), and 86 are domestically produced drug products. All domestic products are generic drugs, comprising 11 types of inhalation liquid preparations for nebulization and 1 DPI product. No MDI products have been approved in 2025.

5.8.9.2 Propellant manufacture and supply in LMICs

Existing suppliers in India and China have indicated that they will continue to provide security of supply for continued use of pharmaceutical-grade HFC-134a in LMICs for a lengthy period, to allow a progressive transition.

Manufacturers and component suppliers continue the development of lower GWP propellants and compatible container closure systems, but regulatory phasedown schedules and competing RACHP sector demand continue to create supply and price risks for pharmaceutical-grade HFCs.

5.8.9.3 Pharmaceutical company progress in LMICs

Three companies in India and one in Bangladesh have commenced development of lower GWP pMDI products.^{56,57,60} It is difficult to gauge progress as there is no convention in these countries to register clinical trials in a public database. In addition, MCTOC understands that several generics manufacturers in Latin America are developing lower GWP pMDIs. In Pakistan, available public data does not suggest pMDI manufacturers have yet initiated development work on lower GWP pMDIs. One propellant supplier in China had a Drug Master File (DMF) for HFC-152a accepted for review by the FDA in 2023. Two companies in China have initiated development of bulk propellant HFO-1234ze(E). A DMF has been filed in China for HFO-1234ze(E) as a medical propellant.⁴⁸

5.8.10 Plastics

In addition, the EU has introduced legislation restricting the marketing of disposable plastic items in common use, where suitable alternatives exist.⁷⁷ The overall conclusion is that while there may be an immediate focus on the global warming impact of an inhaler, companies must not lose sight of the other environmental impacts deriving from their use, both pMDIs and DPIs.

⁷⁶ www.Yaozh.com. Accessed March 2026.

⁷⁷ European Union. Directive (Eu) 2019/904 of the European Parliament And Of The Council Of 5 June 2019 on the reduction of the impact of certain plastic products on the environment. <https://eur-lex.europa.eu/eli/dir/2019/904/oj>, Accessed March 2026.

6 Refrigeration, Air Conditioning and Heat Pumps TOC (RTOC) Progress Report

6.1 Introduction

The RTOC membership for 2026 comprises 42 experts, including four co-chairs. Currently, there are 22 members from non-A5 parties and 20 members from A5 parties. Gender balance is improving with 11 women and 31 men in the committee at present.

The four co-chairs hold weekly online meetings to track and make progress. In 2025, the RTOC membership held several online meetings and two hybrid meetings, one in Sonderborg, Denmark and the other in Foshan, China, to finalise the RTOC 2026 Assessment Report and establish the peer-review process. In 2026, RTOC continues to have online monthly meetings and had a hybrid meeting in 15-17 April 2026 in Osaka, Japan. The meeting was attended in-person by 25 RTOC members and one consultant from the following parties: Australia, Belgium, Brazil, Burkina Faso, China, Columbia, Czechia, Denmark, Egypt, Germany, India, Italy, Indonesia, Japan, Lebanon, Norway, Tunisia, United Kingdom, United States, and virtually by members from the following parties: United Kingdom, Germany, Jordan, the Netherlands, and the United States.

As noted in the TEAP's Matrix of Needed Expertise (Annex 5), RTOC is seeking an expert in marine refrigeration; this need was met by a consultant from a non-A5 party.

The following are key developments in the RACHP sector.

6.2 Over-Arching Topics (Cross-Cutting)

During 2025 RTOC introduced a new chapter on Cross Cutting Issues in its 2026 Assessment Report. The RACHP industry is currently navigating a transition to lower GWP refrigerants, balancing regulatory pressures, technological innovation, lifecycle refrigerant management (LRM), and the need for substantial skills development.

6.2.1 Refrigerants and Environmental Sustainability

In 2025, the transition to lower GWP refrigerants is accelerating, driven by the Kigali Amendment and regional regulations such as the EU, United States, Japan and China. Lower GWP refrigerants (e.g., HFC-32, R-454BHCs, R-744 (CO₂), R-717 (ammonia), and unsaturated HFCs (HFO/HCFO)) are being introduced into many applications.

In several non-A5 parties, LRM is becoming increasingly important especially recovery, recycling, and reclamation (RRR) of refrigerants because the HFC phase-down trajectory will limit the availability of new refrigerant to service current equipment. Data on RRR activities is available or fragmented.

6.2.2 Thermal Load Reduction, Energy Efficiency, and Integrated Systems

Energy saving (through load reduction, increased equipment EE or integrated systems) remains central to reduced GHG emissions targets, with the industry increasingly integrating digital tools to achieve it.

Reducing thermal loads through improved building insulation and design directly lowers the demand on heating and cooling systems and operational costs. Predictive maintenance tools, and Explainable Artificial Intelligence (XAI) are already delivering measurable benefits: reduced energy use, enhanced fault detection, and improved long-term system performance.

Heat recovery as well as Integrated systems that utilize both cold and hot sides of the refrigeration cycle are gaining traction, particularly in district systems, geothermal applications, and thermal storage solutions.

6.2.3 Refrigerant Charge Reduction

Refrigerant charge reduction in RACHP equipment is expanding (e.g. microchannel heat exchangers and brazed plate heat exchangers) and can enable up to 50% charge reduction.

6.2.4 Refrigerant and System Safety

Safety standards are being updated globally and adopted nationally to address flammable, higher-toxicity and higher-pressure refrigerants. The goal is to align standards at International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) levels to better support conversions to lower GWP refrigerants while ensuring safety. The Climate and Clean Air Coalition has released guidance for developing countries on the implementation of international safety standards for RACHP systems.

6.2.5 RACHP Design for Extreme Climate Conditions, Digitalization, and Economic Sustainability

RACHP equipment is being designed to withstand extreme conditions including high- and low-ambient temperatures, extreme humidity, and unstable power supplies, with a focus on enhancing system resilience, efficiency, and reliability. Digitalization is transforming the sector, with AI integration emerging as a prominent theme. Demand control and grid connectivity enhance energy grid stability, reduce peak loads and optimize use of renewable energy sources, thus reducing the indirect emissions of RACHP applications.

A critical challenge is the skills and manpower shortage. The Association of European Refrigeration Component Manufacturers (ASERCOM) in its 2025 convention identified training, safety, and certification as pressing issues, particularly as technicians require enhanced skills to handle flammable refrigerants and digital tools.

The high upfront costs for RACHP equipment prove challenging especially for A5 Parties, although service-based business models are emerging to reduce capital expenditure (CAPEX) barriers.

6.2.6 Policies and Standards

Policy developments in 2025 were significant. Next to the EU's F-Gas Regulation (EU 2024/573) which was updated in 2024, some other national and regional regulations were enacted in 2025 and early 2026. In the United States, California and New York have introduced regulatory measures restricting HFC refills in certain refrigeration and air conditioning equipment, with California implementing its ban starting last year.

6.2.7 Key gaps identified in 2025

- Data on RRR activities: Reporting remains fragmented and underestimated.
- Harmonized training and certification: A global standard for technician competence is available (ISO22712) but the implementation is not global nor fully aligned across regions.
- Guidelines for extreme environments: Corrosion-resistant equipment for island nations and high-humidity regions remains documented but only partially addressed.

6.3 Refrigerants

6.3.1 New single-component refrigerants

No new single-component refrigerants were approved since 2025.

6.3.2 New refrigerant mixtures

Since the publication of the 2025 TEAP Progress Report, seven new refrigerant blends have received designations and classifications from the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 34 and/or from the ISO 817.⁶⁸ All seven of these blends are zeotropic (exhibit glide) and are listed in the Table 6.1 below.

GWP and ODP values are presented as in the RTOC 2022 Assessment Report and the GWP 100-year values from the Montreal Protocol are also listed. Most of these blends contain fluids that are not regulated under the Montreal Protocol and the contribution from these are not included. None of the new fluids have an ODP listed in the Montreal Protocol. EEAP has published trifluoroacetic acid (TFA) yields in their 2022 Assessment Report; however, recent publications have indicated significant variability in the yield data. RTOC will address the TFA yields of the refrigerants and their blends (TFA yield for blends can be calculated from the component values as a weighted average number) in the 2026 Assessment Report. A more detailed discussion on TFA can be found in Chapter 7 of this progress report.

Table 6.1 Some characteristics of new refrigerant blends

Refrigerant Designation	Refrigerant Composition (Mass %)	Molecular Weight (kg/kmol)	Bubble Point/ Dew Point (°C)	Safety Class	GWP 100-year	GWP 20-year	ODP	GWP 100-year in Montreal Protocol
R-496A	R-14/23/116 (18.0/37.8/44.2)	93.9	-112/-90.6	A1	12 474	9 651		5 594 ^a
R-497A	R-1270/1311 (15.0/85.0)	126.5	-34.7/-29.0	A2	1	1	0.077	^b
R-498A	R-170/290/1311 (7.0/8.0/85.0)	117.9	-60.5/-33.5	A3	1	1.1	0.077	^b
R-499A	R-170/290 (8.0/92.0)	42.5	-54.0/-44.5	A3	1	1.2		^b
R-4101A	R-32/152a/1311 (11.0/30.5/58.5)	102.9	-39.0/-31.5	A2L	130	457	0.053	112 ^a
R-4102A	R-134a/1234ze(E)/1233zd(E) (10.0/60.0/30.0)	117.1	-15.7/-4.2	A1	149	413	0.000 ^c	143 ^a
R-4103A	R-32/152a/1311/1234ze(E) (10.0/22.0/17.0/51.0)	94.4	-34.9/-26.8	A2L	109	386	0.015	95 ^a

^a Blend containing one or more components which are not regulated under the Montreal Protocol, and the GWP of the blend does not include the contributions of these components.

^b Blend containing no components which are regulated under the Montreal Protocol.

^c R-4102A has ODP less than 0.001.

6.3.3 Refrigerant Safety

The transition to lower GWP refrigerants has continued to intensify the focus on safety within the RACHP sector, with increasing adoption of flammable refrigerants. While the fundamental hazard categories: flammability, toxicity, and operating pressures remain unchanged, recent developments reflect a shift toward a more structured and system-level approach to safety. There is growing emphasis on chemical stability of emerging refrigerant molecules, the application of quantitative risk assessment (QRA) methodologies, and the need to address safety across the full equipment lifecycle, including phases not comprehensively covered by existing standards (e.g., transport and end-of-life).

Significant progress has also been made in the refinement of risk mitigation measures, such as component and system tightness and releasable charge ventilation strategies, and the integration of these approaches into evolving safety standards (see Table 6.2). Additionally, the greater recognition of the importance of technician behaviour recognized as a critical determinant of risk has underscored the importance of training in the use of flammable refrigerants. The risks associated with external fires due to electrical failures, overheating, or ignition of flammable debris are also gaining significant attention, especially in the USA and elsewhere. Overall, these developments indicate a transition from descriptive safety considerations toward a more comprehensive, risk-based and implementation-oriented framework.

Table 6.2 Summary of current status of selected RACHP safety standards

Standard	Scope	Latest Status	Key Developments
ISO 5149 (series)	All RACHP systems	Under revision	Inclusion of new risk mitigation concepts (e.g., releasable charge, updated test methods)
IEC 60335-2-40	ACs, HPs	Under revision	Expanded provisions for flammable refrigerants, charge limits, mitigation measures
IEC 60335-2-89	Commercial refrigeration appliances	Under revision	Inclusion of split systems, small cold rooms using flammable refrigerants
ISO 14903	Component/system integrity	Revised (2025)	Updated methods for leak tightness qualification

6.4 Servicing and Lifecycle Refrigerant Management

This topic is presented in item 6.11

6.5 RACHP Banks, Consumption and GHG Emissions

Efforts to model RACHP refrigerant banks, consumption patterns, and associated GHG emissions have gained momentum, but there are substantial data gaps, particularly in A5 parties. Initiatives such as the African Centre of Excellence for Sustainable Cooling and Cold Chains (ACES) are helping to address critical information gaps related to energy use and energy-related CO₂ emissions in the RACHP sector through the development and application of advanced modelling approaches.

Looking forward, strengthened national data systems for RACHP-related reporting will be essential to understand emissions, quantify model accuracy, and provide relevant information for policymakers. Comprehensive modelling integrates refrigerant management, energy efficiency improvements, and the transition to lower GWP alternatives, thereby aligning the Kigali Amendment with the objectives of the Paris Agreement. To support these integrated climate action, A5 parties, may wish to consider how to prioritize robust and transparent collection and analysis. This will require expanded capacity-building initiatives, enhanced technical support and training, and improved access to open-source modelling tools to enable the development of evidence-based and sustainable cooling strategies.

These tools may allow parties to project future RACHP consumption and associated emissions under various phase-down scenarios. Advancing LRM through policies that promote the recovery and

recycling of refrigerants, with reclamation and/or destruction as appropriate (according to infrastructure, funding, economics, geography, etc.) can deliver substantial, cost-effective emission reductions in the near term, while reinforcing long-term mitigation goals. As will be detailed in the 2026 RTOC Assessment Report, robust refrigerant bank models are critical for estimating both baseline emissions and the potential for mitigation.

Building on the progress achieved in 2025, fostering collaboration and transparency is vital to advancing mitigation efforts across the global RACHP sector. Enhanced regional and international cooperation, particularly in data sharing, harmonized methodologies, and model comparability will strengthen coordination and enhance the effectiveness of mitigation strategies. Ongoing efforts to reduce information gaps on RACHP energy use and refrigerant consumption, supported by international programmes, underscore the importance of shared and transparent data frameworks. Such frameworks are fundamental to ensuring credible emissions tracking and enabling informed, evidence-based policy action.

6.6 The Cold Chain

6.6.1 *Sealed refrigeration appliances and commercial refrigeration systems*

In the domestic refrigeration sector, the global transition from HFC-134a to the lower-GWP HC refrigerant HC-600a is well established. Stand-alone commercial refrigeration continues its transition toward HC-290, with this trend now extending to several A5 parties.

In commercial refrigeration systems requiring larger refrigerant charges, regulatory frameworks in regions in the EU and United States have introduced restrictions on the use of HFCs with a GWP of 150 or higher in specific commercial refrigeration applications, often linking these limits to charge size thresholds.

Globally, HCs, R-717 (ammonia), and R-744 adoption are increasing in food retail systems. R-744 is also being deployed in condensing units across commercial applications. At the same time, a range of lower GWP HFC/HFO blends are also being increasingly used for retrofitting existing R-404A and HFC-134a equipment as well as new equipment. A2L blends of the lower GWP HFC/HFOs are also being used in nA5 parties alongside of R-744 and HC-290.

6.6.2 *Transport refrigeration*

In road and intermodal transport, R-404A, HFC-134a and R-452A remain widely used, although the next generation of equipment will deploy R-454A or HFO-1234yf A2L flammable refrigerants. These flammable refrigerants presenting safety and cost challenges that slow broader adoption.

6.6.3 *Industrial refrigeration*

Industrial refrigeration systems supporting the cold chain, including operational adjustments and equipment improvements in systems are using refrigerants such as R-717, R-744, and lower GWP HFCs. The scope has included optimization of control parameters, performance verification of compression and condensation systems, and reinforcement of temperature monitoring. These actions led to improved setpoint stability, reduced temperature deviation events, and enhanced control of refrigeration-related operational risks.

There is no new information to report for industrial refrigeration since the last progress report.

6.7 Comfort cooling and heating

6.7.1 *Small size AC and HPs – to air*

In small-capacity (<20-25 kW) air-to-air systems, the refrigerant transition from high GWP towards lower GWP refrigerants is ongoing. While R-410A and, even HCFC-22 are still used in some new equipment, many small self-contained portable units have switched to HC-290, whereas other self-contained and split type equipment now use HFC-32, R-454B and some HC-290.

Air-to-Air systems are increasingly used as reliable and efficient heat pumps to satisfy heating needs even in low-ambient-temperature regions down to minus 35°C.

Reducing energy consumption is driving the global trend toward inverter-type compressors in small split systems. Risk mitigation for using flammable refrigerants continue to be investigated across all stages of the equipment lifecycle.

6.7.2 *Large size AC and HPs – to air*

For large AC and heat pumps (>20-25 kW), the market structure is dominated by standard package and rooftop units (RTU), ducted splits, and variable refrigerant flow (VRF) systems, with VRF systems are growing fastest globally while RTUs remain strongest in North America and the Middle East.

Refrigerant transitions vary significantly by region, product type, and regulatory pathway; R-410A remains dominant in some regions but is declining, with the market shifting toward HFC-32 and R-454B. HC-290 has also been introduced in Europe. The limitations provided by safety classifications (A2L/A3) and corresponding charge limits in safety standards could come into conflict with the Kigali Amendment and F-gas phase-down schedules which are driving lower GWP options.

Globally, there is ongoing tightening of Minimum Energy Performance Standards (MEPS) to drive energy efficiency improvements, with variable speed compressors, heat recovery systems, and energy recovery systems integration as primary technologies.

6.7.3 *Small size AC and HPs – to water*

In small-capacity (<20-25 kW) water systems, air-to-water heat pumps dominate with a long-term growth trajectory reinforced by government incentives and regulatory frameworks. Adoption is expanding into low-ambient-temperature markets, where design and control improvements are progressively narrowing the efficiency gap compared to fossil-fuel-based heating systems.

Historically dominated by R-410A, this segment is now being replaced by HFC-32 in split systems and HC-290, in monoblock systems, while R-744 remains dominant in Japan for sanitary hot water heat pumps.

6.7.4 *Large size AC and HPs – to water*

Rapid data centre growth is driving large-scale chiller production volumes up to three-fold with new low-GWP refrigerant technologies in non-Article 5 countries, and higher-GWP HFCs continuing in A5 Parties. Novel data centre cooling technologies are emerging with HFO chillers in the forthcoming AR2026 RTOC report.

The transition to lower-GWP refrigerants is progressively expanding at the global level, as acceptable alternatives mature in terms of product availability and supply chains, and as safety standards and building codes evolve to accommodate the use of flammable refrigerants.

6.8 Other applications

6.8.1 Industrial refrigeration – non-food and non-pharmaceuticals – and heat engines

Refrigerants such as R-717 (Ammonia), R-744 (CO₂) and HCs continue to be the primary refrigerants for these applications. For cryogenics, petrochemical industry and gas liquefaction cascaded systems, such as auto cascaded using mixed refrigerant cycle (MRC), are increasing their lower investment costs. Large HP systems for heating applications are using different HCs and R-718 (steam), but also in combination with R-717 and R-744, as well as combinations of refrigerants including fluorinated substances.

6.8.2 Vehicle thermal management and mobile air conditioning

There is a growing need for vehicle thermal management beyond comfort cooling and heating applications. At least one original equipment manufacturer has a keen interest in HC-290 secondary loop systems, and an industry group is understood to be conducting a risk assessment for potential submission to the United States Environmental Protection Agency (EPA). In China, however, there is still a wide adoption of HFC-134a heat pump systems in electrical passenger vehicles and partial adoption in electrical commercial vehicles. The SAE Thermal Management Refrigerant (TMR) Cooperative Research Program (CRP) still has ongoing work regarding refrigerant evaluation for HPs in electric vehicles.

CO₂ refrigerant HP systems have been put into operational deployment and use in high-speed railway lines and multiple metro systems in China while various new refrigerant blends are appearing for light-duty aftermarket servicing in various regions.

The EU public transportation segment (bus and rail) is uncertain about its refrigerant choices for cooling, awaiting the EU Commission report which is due 2027.

6.9 Not-in-kind (non-vapour compression) technologies

None of the assessed Not-in-Kind (NIK) technologies is capable of replacing mechanical vapour compression (MVC) for comfort cooling or heating applications. Most NIK technologies, except absorption and adsorption systems, have remained at the emerging or R&D stage, with limited commercial deployment and application mainly in niche or industrial segments. Caloric solid-state technologies continue to attract strong research interest, but key limitations, including fatigue, hysteresis losses, high fields and pressures, and manufacturability, remain unresolved, preventing commercial adoption.

6.10 Energy efficiency

In November 2025, at COP30 in Belém, Brazil, the United Nations Environment Programme (UNEP) launched the second edition of its flagship report, Global Cooling Watch 2025. The report issued a stark warning that under a business-as-usual scenario, driven by rising incomes and extreme heat, global cooling demand could more than triple from 22 TW in 2022 to 68 TW by 2050. This trajectory would nearly double cooling-related emissions to an estimated 7.2 billion tons of CO_{2e} by 2050 (UNEP, 2025).

To counter this, UNEP codified a "Sustainable Cooling Pathway." By aggressively combining passive cooling, low-energy solutions, high-efficiency equipment, and a rapid HFC phase-down, this pathway could reduce projected 2050 emissions by 64% (a reduction of 2.6 billion tons of CO_{2e}). The report also noted that by late 2025, 134 countries had officially incorporated cooling into their Nationally Determined Contributions (NDCs) or National Adaptation Plans (NAPs) (UNEP, 2025).

MEPS and corresponding energy labels remain the primary regulatory instruments to permanently remove inefficient RACHP equipment from the market. Recent global tracking highlights a pivot from isolated national policies to regional frameworks addressing efficiency equity.

CLASP's World's Best MEPS tracking data suggests that state-of-the-art room air conditioner technology has the technical potential to achieve a Cooling Seasonal Performance Factor (CSPF) of 8.5 to 9.0 W-h/W-h which is substantially better than regulatory baselines. The International Energy Agency (IEA) stipulates that to keep 2050 net-zero targets viable, global appliance efficiency must improve by 30% to 40% globally by 2030 (IEA, 2025a; CLASP, 2025a)² and this would be driven by progressively more stringent and national MEPS.

ExCom Decisions 94/60 and 95/87 were designed to transform RACHP manufacturing into higher energy efficiency products with the goal of upgrading MEPS in the countries implementing these decisions to at least U4E levels by the end of the 3-year implementation period which allows for the harmonisation of energy levels across regions. Further incentives through future ExCom Decisions could drive EE higher and critically enhance regional and national economies by reducing the requirement to build energy production capacity.

6.10.1 Regional progress

Africa: the Federal Government of Nigeria formally approved and enforced new MEPS for air conditioners in 2025. This stands as a critical regional milestone to elevate efficiency floors and curb energy demand in West Africa (IEA, 2025b).

Latin America and the Caribbean (LAC): A February 2026 analysis by CLASP revealed that the environmental dumping of obsolete, climate-harming room ACs remains widespread in the LAC region. Without stringent, harmonized MEPS, markets with weak regulations are flooded with inefficient, high-GWP units that have been regulated out of major economies. This data is currently being leveraged to advocate for tighter regional MEPS integration (CLASP, 2026).

EU: At the 10th Global Energy Efficiency Conference (June 2025) and leading into COP30, the EC pledged to strengthen sector-specific standards. The EU is linking MEPS directly to its broader Electrification Strategy, which relies on high-efficiency heating and cooling to reduce overall electricity demand from electrification by 10–20% (EC, 2025).

China issued revised MEPS for refrigerators (GB 12021.2-2025), effective 1 June 2026. The new standard raises minimum thresholds for Grade 5 (Total Energy Efficiency Index, TEEI: 90%) to Grade 1+ (TEEI: 40%), setting “a globally leading benchmark for refrigerator energy performance”. The policy is projected to reduce cumulative CO₂ emissions by 370 million tons by 2040^[1]³

In India, the Bureau of Energy Efficiency (BEE) adopted stringent efficiency standards for room AC effective 1 January 2026, with further revisions planned for 2028 that “will put India’s standards at global best levels”.^[2] The policy advances the India Cooling Action Plan (ICAP) target of a 20–25% reduction in cooling demand by 2037–38 through efficient appliances and sustainable refrigerants. Reproduced without change below is Table 3.2(g) as per the Gazette Notification dated 18 July 2024 implemented from 1 January 2026 for split type AC which forms the majority of market.

Table 3.2(g) – Split Type Air Conditioners

From 1 st January, 2026 to 31 st December, 2028		
Indian Seasonal Energy Efficiency Ratio (kWh/kWh)		
Star Level	Minimum	Maximum
1 Star	3.5	3.79
2 Star	3.8	4.29
3 Star	4.3	4.99
4 Star	5.0	5.59
5 Star	5.6	”

Singapore and Malaysia have updated their MEPS for room air conditioners to align with the Association of Southeast Asian Nations (ASEAN) regional roadmap, setting a benchmark for ambition.[3] The Philippines concluded the Accelerating Air Conditioning Transformation through Enhanced Energy Performance Standards (ACTMEPS) project for upgrading standards and labelling systems in January 2026, with agreed ASEAN harmonised MEPS.3. Vietnam is considering raising MEPS for room AC, being the fastest-growing residential AC market in ASEAN.[4]

The International Energy Agency’s (IEA) Energy Efficiency 2025 report states that global energy efficiency improved by 1.8% in 2025, up from approximately 1% in 2024[5] Cooling remains the fastest-growing source of electricity demand in buildings, with annual growth exceeding 4% since 2000. Consumers purchasing efficient air conditioners in 2025 saved up to 30% in energy costs while paying similar upfront prices.

6.10.2 Technology Trends and Market Data

The primary technological shift defining the RACHP market is the phasing down of fixed-speed compressors in favour of variable-speed, inverter-driven technologies, designed concurrently with lower GWP refrigerants. High-efficiency inverter RACs can halve energy consumption compared to conventional fixed-speed units, driving substantial gains in seasonal efficiency metrics (seasonal energy efficiency ratio (SEER)/cooling seasonal performance factor (CSPF)) (IEA, 2025a; CLASP, 2025b).

However, equipment efficiency alone is no longer sufficient to mitigate the grid strain caused by skyrocketing cooling demand. The integration of Demand Response (DR) technology into RACs allows grid operators to subtly adjust cooling loads during peak heat events and is becoming transitioning from a niche feature to a vital requirement for power infrastructure resilience to avoid outages (CLASP, 2025c).

6.10.3 References

- CLASP. (2025a). World's Best MEPS: Tracking Leaders in Appliance Energy Efficiency Standards. CLASP. <https://www.clasp.ngo/tools/worlds-best-meps/>
- CLASP. (2025b). Doubling Energy Efficiency with Appliances. CLASP. (Published September 2025). <https://www.clasp.ngo/wp-content/uploads/2025/09/Doubling-Energy-Efficiency-with-Appliances.pdf>
- CLASP. (2025c). Response-Enabled Room Air Conditioners: A Call to Action on Scaling Demand. CLASP. (Published June 18, 2025). <https://www.clasp.ngo/appliances/air-conditioners/>
- CLASP. (2026). Pathways to Prevent the Environmental Dumping of Climate-Harming Room Air Conditioners in Latin America & the Caribbean. CLASP. (Published February 25, 2026). <https://www.clasp.ngo/appliances/air-conditioners/>
- European Commission. (2025). New impetus for energy efficiency. European Union. https://energy.ec.europa.eu/topics/energy-efficiency/new-impetus-energy-efficiency_en
- IEA. (2025a). Appliances – Energy Efficiency Policy Toolkit 2025. International Energy Agency, Paris. <https://www.iea.org/reports/energy-efficiency-policy-toolkit-2025/appliances>
- IEA. (2025b). Minimum Energy Performance Standards (MEPS) for air conditioners – Nigeria. International Energy Agency, Paris. <https://www.iea.org/policies/25933-minimum-energy-performance-standards-meps-for-air-conditioners>
- UNEP. (2025). Global Cooling Watch 2025: Implementing a sustainable pathway to zero-emission cooling. United Nations Environment Programme. (Launched November 11, 2025 at COP30). <https://www.unep.org/resources/global-cooling-watch-2025>

^[1] <https://cprc-clasp.ngo/updates/china-raised-minimum-energy-performance-standards-refrigerators>

^[2] https://www.clasp.ngo/about/insights/india-raises-ac-efficiency-amid-growing-demand/#_ftnref1

^[3] <https://www.green-cooling-initiative.org/fr/actualite-publications-et-evenements/actualite/news-detail/2026/02/05/windows-of-opportunity-act-meps-project-ends-in-the-philippines>

^[4] <https://refindustry.com/news/news-events/philippines-concludes-actmeps-project-on-air-conditioner-energy-standards/>

^[5] 7. IEA. Energy Efficiency 2025. November 2025. <https://www.iea.org>

6.11 Decision XXXVI/2 Life-cycle refrigerant management (LRM)

This section responds to Decision XXXVI/2 which requested the TEAP “to include updated relevant information on life-cycle refrigerant management in its 2025 and subsequent progress reports, including the 2026 quadrennial assessment report, taking into account discussions at the Thirty-Sixth Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer.”

RACHP servicing continues to be a critical issue in achieving ozone protection and climate mitigation. Regardless of factory specifications, real-world performance of RACHP equipment depends on the technician on the ground. Effective installation and proactive servicing enhance system efficiency, safety, and longevity. Rigorous refrigerant management directly reducing emissions, energy use, and lifecycle costs.

However, the sector faces a deepening skills gap. A chronic shortage of trained technicians has been exacerbated by the retirement of experienced technicians, together with insufficient training programmes and slow entry of new professionals, especially in developing and rapidly urbanising regions. Urgent upskilling is an immediate necessity to prevent a rollback of climate gains.

The transition to lower GWP, flammable refrigerants (A2Ls like HFC-32 and A3s like HC-290) is now mainstream. Safe handling requires specialised training in plume dispersion, ventilation, and leak detection, plus access to calibrated, explosion-proof tools. Mandatory standards exist, but enforcement is uneven. Without these measures, the risk of accidents increases, potentially undermining confidence in lower GWP technologies.

Technological complexity is increasing. Heat pump adoption, electrification, IoT, and digitalisation have turned equipment into data-rich assets. Technicians must now interpret real-time sensor data, shifting from reactive calls to predictive maintenance. These demand retraining of legacy staff and a hybrid curriculum for new entrants, blending thermodynamics with IT skills. A lifecycle approach is inseparable from digital competency. Better qualified technicians deserve recognition and reward, as well as incentivisation to recover refrigerant rather than release.

LRM has emerged as a powerful policy tool. Aligned with the Kigali Amendment, LRM mandates inventory tracking, leak prevention, reclamation, and destruction. Full implementation of LRM strategies could reduce projected 2050 refrigerant emissions by approximately 50% under a Kigali-compliant scenario. Yet on-the-ground reality in 2025 shows significant disparities. The EU, Japan, and the United States (nationally and at the state level) are implementing LRM policies, leak detection schedules, certification, refrigerant registries, but success depends on reverse supply chain capacity. New Zealand has introduced a mandatory product stewardship scheme for synthetic refrigerants and commissioned the Southern Hemisphere's first refrigerant destruction facility (using plasma arc technology). The weakest links are in developing economies and small island states: lack of reclamation centres, poor cylinder return logistics, and insufficient destruction facilities. Without parallel investment in technician training on proper recovery and contamination avoidance, even the best policies fail. The priority is clear: align regulatory mandates with tangible investments in training infrastructure and reverse logistics.

The RTOC Assessment Report 2026 (due to be finished by the end of 2026) includes a detailed and comprehensive chapter on RACHP servicing and LRM.

7 Per- and poly-fluoroalkyl substances (PFAS): Emerging policies and sector information¹

7.1 Background

TEAP provides in this chapter updated information important to the parties related to PFAS and considerations of the potential implications for sector transitions to alternatives from substances controlled under the Montreal Protocol. TEAP has brought these emerging technical and economic policy-relevant issues to the attention of parties in its 2022 Assessment² and 2023-2025 Progress Reports^{78, 79, 80}.

In public discourse, the term “PFAS” has become broadly equated with the term “forever chemicals” which incorrectly implies long-term adverse impacts⁸¹. There is a misconception that all PFAS and their breakdown products are persistent, bioaccumulative, toxins (PBT) which is incorrect⁸². Some long chain PFAS are PBTs. Two examples are perfluorooctanoic acid (PFOA) and its analogue perfluorooctane sulfonate (PFOS) which were widely used since the 1950s to make fluoropolymer coatings and products that resist heat, oil, stains, grease, and water and used commercially in food packaging, non-stick cookware, water-proof clothing, firefighting foams (military and civilian aircraft rescue and firefighting) etc⁸³. PFOA and PFOS have seven adjacent fully fluorinated carbon atoms and high solubility in water and can be toxic at very low concentrations. Both chemicals are found in concentrations that may be toxic in some surface and drinking water supplies around the world⁸⁴. PFOA and PFOS are examples of a larger group of fluorochemicals under scrutiny by regulators^{85,86} and are prohibited in many jurisdictions and under the Stockholm Convention⁸⁷. PFOA

⁷⁸ <https://ozone.unep.org/system/files/documents/TEAP-May2024-Progress-Report.pdf>

⁷⁹ <https://ozone.unep.org/system/files/documents/TEAP-May2025-Progress-Report-vol1.pdf>

⁸⁰ The Stockholm Convention controls Persistent Organic Pollutants (POPs), such as PFOA and PFOS. Stockholm defines POPs as organic chemicals that, once released remain intact for exceptionally long periods of time; become widely distributed throughout the environment; accumulate in the living organisms including humans, and are found at higher concentrations at higher levels in the food chain; and are toxic to both humans and wildlife. PFOA and PFOS are listed here. <https://www.pops.int/TheConvention/ThePOPs/AllPOPs/tabid/2509/Default.aspx>

⁸¹ Wee, S.Y., Aris, A.Z. Revisiting the “forever chemicals”, PFOA and PFOS exposure in drinking water. *npj Clean Water* **6**, 57 (2023). <https://doi.org/10.1038/s41545-023-00274-6>

⁸² Han *et al* Identifying priority PBT-like compounds from emerging PFAS by nontargeted analysis and machine learning models, *Environmental Pollution*, Volume 338, 2023, 122663, ISSN 0269-7491, <https://doi.org/10.1016/j.envpol.2023.122663>. <https://www.sciencedirect.com/science/article/abs/pii/S0269749123016652>

⁸³ ChemTalk The Chemistry of PFAS <https://chemistrytalk.org/the-chemistry-of-pfas/>

⁸⁴ Kurwadkar *et al* Per- and polyfluoroalkyl substances in water and wastewater: A critical review of their global occurrence and distribution *Science of the Total Environment* Vol 805 2022 <https://www.sciencedirect.com/science/article/pii/S0048969721060812>

⁸⁵ Zhaoyu J *et al* The occurrence, tissue distribution, and PBT potential of per- and polyfluoroalkyl substances in the freshwater organisms from the Yangtze river via nontarget analysis <https://www.sciencedirect.com/science/article/abs/pii/S0304389423011512>

⁸⁶ United States Environmental Protection Agency PFAS Can Be Found in Many Places <https://www.epa.gov/pfas/our-current-understanding-human-health-and-environmental-risks-pfas>

⁸⁷ The Stockholm Convention <https://www.pops.int/TheConvention/ThePOPs/AllPOPs/tabid/2509/Default.aspx>

and PFOS are not directly relevant to the Montreal Protocol, but they have driven broad regulations that could impact the availability of Montreal Protocol controlled substances and their alternatives.

Different regulatory approaches arise from the use of different PFAS definitions. Some use PFAS definitions which classify chemicals based on chemical structure rather than on impact on human health and the environment. Others focus on controlling PFAS with known PBT properties. As a result, PFAS regulatory approaches vary in different jurisdictions, ranging from a non-discriminatory ban of a broad range of chemicals, to specific controls of named PFAS of known toxicity (e.g., PFOA and PFOS) for specific consumer end-uses (e.g., food packaging, cosmetics). Some definitions of PFAS and associated regulations include Montreal Protocol controlled substances and their alternatives, while others do not. Jurisdictions that adopt broad bans may end up limiting alternatives available or planned as replacements for Montreal Protocol controlled substances e.g., 2-BTP to replace halon 1211 in portable fire extinguishers; e.g., HFOs to replace high GWP HFCs in RACHP.

7.2 Definitions and regulations

In various existing and emerging regulations, there are numerous different definitions of the scope of “PFAS”. Some of these definitions include various substances of importance to the Montreal Protocol, whilst other definitions do not include these substances. Examples include the following:

The Organization for Economic Cooperation and Development (OECD) has created a definition noting that

“The term “PFASs” does not inform whether a compound is harmful or not, but only communicates that the compounds under this term share the same trait for having a fully fluorinated methyl or methylene carbon moiety”

In 2021, OECD defined PFAS as:

A fluorinated substances that contain at least one fully fluorinated methyl or methylene carbon atom (without any H/Cl/Br/I atom attached to it), i.e. with a few noted exceptions, any chemical with at least a perfluorinated methyl group (–CF₃) or a perfluorinated methylene group (–CF₂–) is a PFAS⁸⁸

This definition includes TFA and many commercially used HFCs and HFOs but excludes several fluorinated gases such as HFC-32, HFC-23, CF₃I, HFC-152a, and HCFC-22.

The U.S. Environmental Protection Agency (EPA) [Roadmap PFAS definition excludes Montreal Protocol controlled substances and breakdown products. The EPA inventory reporting requirements](#) are undergoing a modification but may include controlled chemicals, The current requirement includes some refrigerants and excludes most new refrigerants.

In the United States, the state of Maine defines PFAS as “*containing a single fully fluorinated carbon*”, which includes commercially used HFCs and HFOs (excluding several fluorinated gases such as HFC-32, HFC-23, CF₃I, HFC-152a, HCFC-22), and TFA and fluoropolymers⁸⁹.

Another state, [Delaware](#)⁹⁰ defines PFAS based solely on five PBT PFAS (including PFOA and PFOS) controlled in drinking water. PFAS are defined as “*...per- and polyfluoroalkyl chemicals, substances, or compounds, which are substances with at least one per-fluorinated methyl group (-CF₃) or one*

⁸⁸ [Organization for Economic Cooperation and Development](#)

⁸⁹ Maine state code https://www.mainelegislature.org/legis/bills/bills_129th/billtexts/HP153601.asp

⁹⁰ [Delaware](#) <https://legis.delaware.gov/json/BillDetail/GeneratePdfEngrossment?engrossmentId=37035&docTypeId=6>

perfluorinated methylene group (-CF₂-), including parents, salts, and anionic forms. For purposes of this chapter, PFAS includes only those PFAS with established legally enforceable [maximum concentration level in water] MCLs..”

[West Virginia](#) defines PFAS as “Substances that are a group of man-made chemicals that contain at least 2 fully fluorinated carbon atoms, excluding gases and volatile liquids. “PFAS” includes perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA).”⁹¹ This definition does not include Montreal Protocol controlled substances or TFA.

The Interstate Technology & Regulatory Council (ITRC) provides nine PFAS definitions⁹², some of which include, while other exclude Montreal Protocol controlled chemicals and their decomposition products⁹³. The following paragraphs describe various PFAS regulations, some of which could lead to bans of chemicals of importance to the Montreal Protocol. It should be noted that many of these regulations are under development and the information presented here is subject to change.

7.2.1 United Nations Stockholm Convention

The Stockholm Convention on Persistent Organic Pollutants (POPs) aims to eliminate or restrict the production and use of POPs. Some jurisdictions, e.g., China and Japan, restrict certain PFAS that are specifically listed under the Stockholm Convention, i.e., perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA), and perfluorohexane sulfonate (PFHxS). Other PFAS are not restricted in China and Japan. No Montreal Protocol controlled chemicals, alternatives or decomposition chemicals are included in these bans. Regardless of definitions, scientific assessment of individual PFAS chemicals show major differences in toxicity, environmental impacts, and breakdown products. Regulations based solely on PFAS definitions by chemical structures alone could result in indiscriminate bans of chemicals that are not PBTs, and have very different risk profiles from PFOA and PFOS.

7.2.2 European Economic Area

Some proposed and enacted PFAS policies are emerging that may ban several alternatives to ODS and high-GWP controlled substances, thereby eliminating many GWP alternatives that would otherwise support the implementation of the Montreal Protocol.

ECHA’s RAC adopted its final opinion on March 2, 2026, evaluating risks of PFAS to human health and the environment. The ECHA SEAC has finalized its *draft* opinion on the universal restriction proposal on all PFAS, with a public comment period open until May 26, 2026. The *draft* opinion recommends restricting the manufacture and use of PFAS in the EU.

After the comment period, adoption of the reports will conclude ECHA’s Committees’ scientific evaluation of the proposed restriction and the opinions will be formally submitted to the European Commission who could propose a restriction for discussion and vote in the REACH Committee, which is comprised of EU Member States.

⁹¹ West Virginia Code - <https://code.wvlegislature.gov/22-11C-2/>

⁹² Interstate Technology & Regulatory Council Per- and Polyfluoroalkyl Substances Chemistry, Terminology, and Acronyms ITRC - <https://pfas-1.itrcweb.org/2-2-chemistry-terminology-and-acronyms/>

⁹³ <https://pfas-1.itrcweb.org/2-2-chemistry-terminology-and-acronyms/>

7.2.3 *Canada*

Canada has banned PFOS and has proposed to manage risk to achieve environmental and human health objectives, for the class of PFAS, excluding fluoropolymers under Canada Environmental Protection Agency (CEPA).⁹⁴ Montreal Protocol controlled chemicals and their substitutes are proposed to potentially be included in a future rulemaking. Polymers are proposed to be excluded.^{95,96}

7.2.4 *United States*

The EPA has continued to implement their risk-based approach delineated in the "PFAS Strategic Roadmap: EPA's Commitments to Action 2021-2024"⁹⁷. Some of the actions EPA has undertaken include evaluating the toxicity of approximately 2500 chemicals in groups based on their chemical make-up, mandating toxicity testing for commercial chemicals to represent each group, where no data is available, enacting drinking water standards for 6 chemicals and requiring funding for pollution, and building an inventory by requiring retroactively reporting of import and production of PFAS chemicals.

At the subnational level in the United States, some states are considering or enacting policies requiring reporting and bans on PFAS chemicals with a definition and scope that is broad enough to include substances controlled under the Montreal Protocol, largely focused on consumer uses.

- Maine has now provided an extension of its legislative ban⁹⁸ until 2040 for the use of all PFAS chemicals in heating, ventilation, air conditioning, and refrigeration equipment and refrigerants, aerosols, foams, metered dose inhalers, and other substances controlled under the Montreal Protocol. Extensions past 2040 could be allowed.
- Minnesota has enacted the same legislation as Maine with an earlier ban in 2032 unless a "currently unavoidable use" exemption is approved. It is, as yet, unclear whether Minnesota may make similar modifications to those made in Maine. Minnesota has proposed exempting chemicals encapsulated in equipment. This would exclude polymers and could exclude Montreal Protocol controlled chemicals.⁹⁹
- Other states have proposed nearly identical legislation to the state of Minnesota; but no other states currently have proposed or enacted PFAS legislation impacting substances controlled by the Montreal Protocol. Enacted state legislation bans the use of PFAS chemicals in cosmetics, children's toys, turf, clothing, food packaging, and other specific uses, where there is high potential for exposure to PFAS chemicals. These uses do not include products using chemicals controlled under the Montreal Protocol

⁹⁴ [Canada Environmental Protection Agency \(CEPA\) Risk management approach for per- and polyfluoroalkyl substances \(PFAS\), excluding fluoropolymers March 2025](#)

⁹⁶ Canada Gazette, Part I: Vol. 155 No. 17 – April 24, 2021 available at: <https://www.canada.ca/en/health-canada/services/chemical-substances/other-chemical-substances-interest/per-polyfluoroalkyl-substances.html>

⁹⁷ U.S EPA Strategic Roadmap: EPA's Commitments to Action, 2021 – 2024 available at: <https://www.epa.gov/pfas/pfas-strategic-roadmap-epas-commitments-action-2021-2024>.

⁹⁸ July 2021, Public Law c. 477, An Act to Stop Perfluoroalkyl and Polyfluoroalkyl Substances Pollution available at: <https://www.maine.gov/dep/spills/topics/pfas/PFAS-products/#:~:text=A%20retailer%20may%20not%20sell,products%20containing%20intentionally%20added%20PFAS>.

⁹⁹ Minnesota SF 2216 https://www.revisor.mn.gov/bills/bill.php?b=House&f=SF2216&ssn=0&y=2025&keyword_type=all&keyword=PFAS

- In April 2025, New Mexico enacted PFAS bans, specifically exempting Montreal Protocol controlled chemicals approved by EPA.¹⁰⁰

In the context of these ongoing national and subnational actions which may or may not restrict products using chemicals controlled under the Montreal Protocol, TEAP is providing below additional information related to current considerations with some exemplar sectors of use.

7.3 What are the potential impacts of broad PFAS regulations on the Montreal Protocol?

The different regulatory approaches to PFAS, especially those that have created uncertainty for companies working to transition from ODS and HFCs. This results in delays in investments in alternatives and associated technologies and reduces the availability of optimized solutions. The impact of these delays risks slowing the implementation of the Montreal Protocol and its Kigali Amendment objectives.

Montreal Protocol controlled substances and their alternatives, as well as certain fluorinated materials (e.g., polymers) used in foam (e.g., insulation), fire suppression (e.g., in aircraft), refrigerants used in RACHP, aerosols, medical aerosols (e.g., MDIs), solvents, electronic manufacturing, and magnesium production, may be affected by some proposed and enacted regulations that incorporate broad PFAS definitions, including:

- Fluoropolymers (e.g., PTFE/Teflon) are widely used in equipment (e.g., compressors, valves, seals) and products (e.g., MDIs). Any restrictions may negatively impact the use of all refrigerants (including CO₂, ammonia and propane), fire suppressants, foam blowing agents, aerosols etc.
- Some FCs that are needed to meet Montreal Protocol phase out and phase down obligations.
- TFA is a breakdown product of some HFCs (e.g., HFC-134a) and HFOs (e.g., HFO-1234yf) refrigerants and fire suppressants (e.g., 3,3,3-trifluoro-2-bromopropene (2-BTP)) used/proposed for use on civil aircraft and in-kind clean agents).

7.4 Fire suppression

The fire suppression sector spearheaded the concept of recovery/reuse/reclaim of previously produced ODS as an alternative to new production/consumption. This was accomplished by industry wide efforts to minimize the continued use of halons in new applications (i.e., use alternatives wherever possible), develop and implement servicing and end-of-life practices (i.e., lifecycle management). These activities minimize emissions and also maximize recovery, thus fostering a market for reclaimed halons that helps to ensure that the product is valuable, instead of a waste to be disposed of, or worse, intentionally vented. This has been remarkably successful. After 30 years since the production/consumption phase-out in non-A5 parties in 1994, users that need halons continue to be able to obtain them from the halon reclaim market.

Halons used in fire suppression are potent ODS, with halon 1301 having the highest ODP (10-17) of any chemical in use, and potent GHGs, but they are not currently within most of the various definitions of PFAS. While the halon sector invested in extensive research and development (R&D),

¹⁰⁰ New Mexico HB 212 exempts “.. substances or refrigerants listed as acceptable... by the Significant New Alternatives Policy program...”

the halons remain the most effective fire suppressants known. A few applications rely on the unique capabilities of halons, making the use of alternatives to retrofit these existing applications, technically and economically challenging. These applications are termed “enduring uses” because there are neither viable retrofit alternatives available today, nor any new agents under development for retrofit.

7.4.1 Background: Halon1301 fire protection systems in cargo compartments and in engines nacelles

Although the incidence of in-flight fires is low, the consequences in terms of loss of life are potentially devastating, and the use of halon to help guard against such events has been extensive. Halon 1301 fire protection systems in cargo compartments and in engines nacelles not only do not have alternatives for retrofit, but they also still do not have alternatives to halon for new aircraft designs in spite of R&D in civil aviation continuing for over 30 years. This is not a recent development. The FSTOC (HTOC) 2002 Assessment report stated:

“Aviation applications of halons are amongst the most demanding uses of the agents and require every one of their beneficial characteristics...”

7.4.1.1 Airplane design timelines

The development of new airplane designs takes over 10 years. Fire protection systems are intrinsic to design and the extinguishing agent and equipment is highly specified. Therefore, any decision to use a certain fire suppressant for installed systems must be taken early during a new aircraft design. Once the new design or type is certified, the duration of manufacture of an aircraft type easily can be 20 years or more. Civil aircraft have a working lifetime of 20-30 years from the date of manufacture. This means that a specified fire extinguishing agent e.g., halon 1301, may need to be available for in excess of 60 years (>10 + >30 + >20), following a decision to use that agent. In the case of cargo compartments and engines nacelles, in the absence of alternatives, halon 1301 will need to be supplied for the life of these aircraft.

7.4.1.2 Alternatives to Halon

Major in-kind halon alternatives in fire suppression are the lower GWP fluoroketone (FK)-5-1-12, and 2-BTP, and high-GWP HFC-236fa, and HFC-227ea. Under the broader definitions of PFAS, all of these could be considered as PFAS. In contrast, some current fire suppression agents, such as halons and high-GWP HFC-23 that are controlled under the Montreal Protocol, would not be considered PFAS under most definitions.

7.4.1.3 Existing ICAO mandates

Under decisions of the parties, the FSTOC coordinated with the ICAO to mandate that halon 1301 cannot be used in cargo compartments of new aircraft designs after 2024. In addition, ICAO has a mandate to stop using halon 1211 on production of all aircraft as of 2018, but unlike the EU, has no retrofit date.

- **Portable extinguishers:** The current alternative to halon 1211 in portable extinguishers on aircraft is 2-BTP, a PFAS under most definitions. It is relatively easy to replace halon 1211 in extinguishers as they are considered as equipment and not a permanently installed system. 2-BTP and its hardware have been approved for use on civil aircraft, which enabled ICAO to mandate the replacement of halon 1211 portable fire extinguishers in new and in-production aircraft as of 2018.

- Cargo compartments and engine nacelles: these are fixed systems, intrinsic to the structure of the aircraft. A 2-BTP/CO₂ blend has been in R&D to replace halon 1301 in cargo compartments and is the only candidate at this time.

7.4.2 *Impacts of possible PFAS regulations on civil aviation*

Owing to reported uncertainty and apprehension surrounding long-term PFAS viability, the following impacts are happening now, with Montreal Protocol controlled fire suppressants, based on current and proposed regulations. Although the EU PFAS proposal provides for a 12-year derogation for fire suppression to allow time for the development of non-PFAS alternatives, the path to market for new fire extinguishing agents and systems is laborious (Wickham, 2002) and typically takes significantly longer than 10 years to identify and implement a new fire suppressant. The process involves various authorities and organizations, including health and environmental authorities, standard-making organizations, and certification bodies, both nationally and internationally. This lengthy and expensive process is often repeated country-by-country to meet different national standards to ensure both fire protection performance and environmental/ health safety. This must be accomplished so that the new agent is available, before it can be considered in new designs of aircraft.

Note: *The following update simply reports what civil aviation representatives recently reported to the FSTOC. This does not mean that the FSTOC endorses or supports these courses of action.*

ICAO Resolution A42-11 removed the 2024 mandate to not use halon 1301 in cargo bays of entirely new aircraft designs. This has removed some of the pressure on having to have suitable alternatives in the near future. This is exacerbated by the designation of 2-BTP as a PFAS under many existing / proposed regulations. Civil aviation is now quite concerned that the leading cargo compartment alternative, a 50%-50% blend of CO₂ and 2-BTP is not viable for the long term.

As a result of their intention to continue to use halon 1301 for the next generation of new aircraft designs, civil aviation representatives also stated that they intend to request that an EUN for halon 1301 be submitted to ensure long-term halon 1301 supply (i.e., at least 60 years) is available to meet their increasing demand for newly produced aircraft and support of the existing global fleet. Further, the fact that there are other enduring uses of halon 1301 that rely on the same available bank of halon 1301, means an EUN for halon 1301 could come from the other sectors to support their legacy systems as well. It is also possible that one or more of these enduring uses could propose to revert back to halon 1301 for new systems.

It is important to note that in 1993 and 1994, the then HTOC, evaluated the first of the EUNs submitted by parties in accordance with decision IV/25, and found the following, **which the FSTOC believes remains valid in the near term:**

*“The Halons Technical Options Committee reviewed all of the submitted nominations for consumption/production exemption. In general, it appears that for almost all of the nominations, alternative technologies now exist, particularly for new installations. **As well there were no nominations that could satisfy the requirement that halons are not available in sufficient quantity and quality from existing stocks of banked or recycled halons.**” (emphasis added)*

7.4.3 *Impacts in other fire protection applications*

In addition to the above, the FSTOC is aware of at least three additional development or implementation activities that have been impacted owing to apprehension about long-term production or use from the proposed or adopted PFAS regulations.

1. The withdrawal of a potential halon and high-GWP HFC replacement, HB-55, which is a blend of HCFO-1233zd(E) and FK-5-1-12, from further development, is reported at least in-part owing to PFAS concerns.
2. The nuclear industry is still installing reclaimed HFC-227ea in certain fire protection locations in lieu of transitioning to the lower GWP FK-5-1-12 owing to concerns surrounding the long-term viability (50+ years) of the use and supply of newly produced PFAS.
3. In the Middle East and Egypt, where some uncertainty arising from the ongoing PFAS fire suppression system supplier and their production concerns, has led to continued or even an increased use of HFC-227ea, thus slowing down the progress towards the use of FK5112 as a lower GWP alternative. This includes parties intending to meet their Kigali Amendment obligations in part by transitioning to FK5112.

Considering all of the above, the shortcomings of using a broad or indiscriminate definition of to classify certain chemicals as PFAS become apparent. Many of the fire suppression agents that are included in some of the definitions of PFAS are not persistent, bioaccumulative or toxic, in contrast to PFOS and PFOA.

The fire suppression sector is aware of the consequences of using PFOS and PFOA in firefighting foams. While these foams were very effective and saved countless lives and assets, their persistence, bioaccumulation and toxicity made their continued widespread use unsustainable. However, there are a few applications where their unique fire suppression capabilities are still needed and allowed based on the evaluation of fire risk together with environmental, safety and health risks.

The potential loss of 2-BTP as a replacement to halons may lead to very long-term continued use of halons with impacts on the ozone layer.

These two situations illustrate the need for a careful, risk-based assessment of chemicals, especially those relevant to the Montreal Protocol.

7.5 Foams

This section summarises the impact of possible PFAS bans on the foam insulation sector.

Foams reduce energy load in buildings and in the refrigeration cold chain. Foams also meet non-insulating performance requirements (e.g., structural performance) in other uses. The ODS phaseout and HFC phasedown have driven the search for economically optimized alternative FBAs with similar or better performance. Significant progress has been made in the transitions in most sectors and many parties.

However, some companies and other stakeholders have reported that they are delaying decisions regarding selection of fluorinated alternatives because of concerns about how these alternatives might be limited as a result of proposed regulations. In the EU, the 2024 F-Gas regulation cites 1st January 2033 as the phase-out date for the use of F-Gases in foams unless there are justified safety reasons for allowing continued use. There will be a further regarding the decision the practicality of this date following a formal review of alternatives by the European Commission in the period from 2028-2030. It is understood that current PFAS Restriction proposals give precedence to this process. If mainstream uses of F-gases are limited in Europe, there could be broader implications for investment in HFOs and HCFOs going forward.

There is no perfect FBA. There are advantages and disadvantages for every option, which vary for each end-use of foams and for different foam manufacturing methods and location. FBAs acceptable in one application to meet foam structural or insulation requirements may not be acceptable for other uses. The number of FBA blends is increasing as manufacturers work to reduce costs while still

achieving desired performance. Reducing available alternatives will make the already complex FBA selection process more challenging.

7.6 Medical and Chemical

Controlled substances and their technically and economically feasible alternatives that are used in aerosols, pressurised metered-dose inhalers (pMDIs), solvents, electronics manufacturing, and magnesium production, could be impacted by broad-ranging definitions of PFAS and associated possible restrictions.

Propellants HFC-134a, HFC-227ea, and HFO-1234ze(E), that are currently used, under development and investment, could be impacted. In addition to regular aerosols, pMDIs used to treat respiratory diseases would be affected by a PFAS ban.

The reported¹⁰¹ estimated global consumption of HFC propellants used in inhalers and other aerosols was relatively small at about 56,000 tonnes in 2021 (pMDIs: 10,100 tonnes HFC-134a, 600 tonnes HFC-227ea; aerosols: 15,000 tonnes HFC-134a, 30,000 tonnes HFC-152a).

Two pharmaceutical-grade lower GWP propellants, HFC-152a and HFO-1234ze(E), are now available. The choice of lower GWP propellant for pMDI reformulation has provided a dilemma for manufacturers. It is possible that inhaler performance for a specific drug/pMDI might be optimal with only one of the two propellants.

In terms of environmental impact, inhalers containing HFC-152a have about 10%¹⁰² of the carbon footprint of HFC-134a and are not considered a PFAS. HFC-152a, HFC-134a, and HFC-227ea are listed as Annex F HFC controlled substances subject to the Kigali phase-down requirements of the Montreal Protocol.

HFO-1234ze(E), which has almost zero GWP (< 1% of HFC-134a or HFC-152a), could be included in some PFAS definitions and subject to regulation, some potentially leading to bans. HFC-134a and HFC-227ea could also be included in some PFAS definitions.

Under the new F-gas Regulation (EU) 2024/573, the pMDI sector is brought into scope of the HFC phase-down from 2025, transitioning from its previous exemption. The Regulation establishes a quota-based system that applies to virgin HFCs, including HFC-152a used in medical applications, while exempting HFOs (HFO-1234ze(E)), non-fluorinated alternatives, and recycled or reclaimed refrigerants.

In parallel, under the EU REACH PFAS restriction process, SEAC did not conduct sector-specific assessments for several use sectors including other medical applications. This means that medical propellants were not reviewed in detail. As a result, SEAC has stated in their draft opinion, it cannot conclude on the appropriateness of proposed derogations for these sectors, recommending time-limited derogations pending further evaluation, and effectively leaving it to regulators to conduct a full assessment and make final decisions for pMDIs containing HFO-1234ze(E) and other medical applications.

Having two propellants available as options for manufacturers provides more patient options in the transition from high-GWP pMDIs. The timeline for development of pMDIs with new propellants is

¹⁰¹ UNEP, 2022, *2022 Assessment Report of the Chemical and Medical Technical Options Committee*, December 2022.

¹⁰² Panigone, S., Sandri, F., Ferri, R., Volpato, A., Nudo, E., Nicolini, G., Environmental impact of inhalers for respiratory diseases: decreasing the carbon footprint while preserving patient-tailored treatment, *BMJ Open Respiratory Research*, 2020, 7(1), e000571. <https://doi.org/10.1136/bmjresp-2020-000571>.

about 8–10 years, noting that the extensive search already for new propellants identified only HFO-1234ze(E) and HFC-152a when evaluating options to transition from existing HFC pMDIs. DPIs, SMIs, and nebulisers provide suitable options for many but not all patients. Industry and the healthcare community are concerned for the patients that rely on pMDIs for their asthma and chronic obstructive pulmonary disease treatment and about ensuring an uninterrupted global supply of essential medicine that is effective, affordable, and accessible.

Around half of global pMDIs are manufactured in Europe. The proposed EU PFAS regulation to ban categories of products has created uncertainty, impacting multi-million-dollar investments in drug development and creating industry concern about the future of existing products, manufacturing, and plans to transition to lower GWP alternatives. Transition is already beginning to lower GWP pMDI propellants but there is uncertainty as to which lower GWP propellants might be available long-term. There are almost 100 pMDI manufacturers worldwide and over one billion patients, whose health requires protection. Both manufacturers and patients will need to transition to lower GWP pMDIs because of HFCs being phased down.

Several industries with specialist chemical uses are also concerned about potentially closing off options where there are currently few alternatives with more suitable properties, such as in electronics manufacturing, magnesium production, and precision cleaning for aerospace and military uses, where the remaining options could be the continued use of, or reversion to, substances with higher GWP or worse toxicological profile.

7.7 Refrigeration, air conditioning and heat pumps

This section summarises the potential impacts of proposed restrictions on PFAS on the RACHP sector.

7.7.1 Refrigerants used in RACHP equipment

The RACHP sector accounts for approximately 90% of the global HFC supply subject to phase down under the Kigali Amendment to the Montreal Protocol. Consequently, refrigerant selection and transition pathways within this sector are central to achieving global climate objectives.

Alternatives to high-GWP HFC and HCFC refrigerants currently include HCs, ammonia (NH₃), CO₂, pure HFOs and HCFOs, as well as blends of lower GWP HFCs with HFOs or HCFOs and with CO₂ or HCs. Each of these alternatives presents a distinct set of advantages and limitations, and no single refrigerant solution is universally applicable across all RACHP applications.

Depending on the specific definition adopted, broad-ranging PFAS restrictions could encompass many fluorinated refrigerants currently used or proposed for RACHP applications. With the exception of HFC-32—which is excluded from proposed PFAS definitions—nearly all commonly used HFC and HFO refrigerants could potentially be affected. This includes both legacy high-GWP refrigerants such as HFC-134a, R-404A, and R-410A, as well as lower GWP alternatives including HFOs and HFC-HFO blends, even in cases where such alternatives do not degrade into significant quantities of TFA.

Refrigerant selection in RACHP systems is inherently application specific and depends on a wide range of technical, economic, and regulatory factors. These include, but are not limited to: market sector (residential, commercial, industrial), equipment location (indoor or outdoor), ambient temperature conditions, refrigerant charge size, flammability and toxicity classification, cost and availability, system efficiency and capacity requirements, applicable safety standards and building

codes, and the availability of a sufficiently trained workforce for installation, servicing, and maintenance.

Non-fluorinated refrigerants can be used safely and effectively in many applications; however, their use is constrained in certain situations by factors such as flammability (e.g., HCs), toxicity (e.g., ammonia), high operating pressures (e.g., CO₂), or performance limitations in specific climates or capacity ranges. These constraints are particularly relevant for medium- and large capacity systems, densely occupied buildings, retrofit applications, and certain geographic regions.

If broad PFAS restrictions were enacted across the RACHP sector without appropriate exemptions or transitional measures, the range of available refrigerant options would be further constrained. This could:

- Slow the uptake of lower GWP refrigerants, which is essential to meeting Kigali phase-down targets;
- Limit achievable energy efficiency in certain RACHP system categories, particularly medium capacity systems where alternatives are already limited; and
- Delay the deployment of heat pumps, which are a key technology for decarbonising space and water heating.

Collectively, these effects could result in higher overall greenhouse gas emissions, either through continued reliance on higher GWP refrigerants, reduced system efficiency, or slower electrification of heating.

7.7.2 Fluoropolymers used in RACHP equipment

In addition to refrigerants, certain fluoropolymers used in RACHP equipment may fall within the scope of PFAS definitions, depending on the regulatory framework adopted. These materials are widely used in RACHP systems due to their unique and highly favourable properties, including chemical inertness, thermal stability across a wide temperature range, low friction and wear, resistance to refrigerants and lubricants, and long-term durability over extended equipment lifecycles.

Fluoropolymers are used in a wide range of RACHP components, including but not limited to: bearings, seals, gaskets, valve components, compressor parts, coatings, wiring insulation, and elements within motors and electronics. They are also critical in high temperature and high-pressure safety devices, thermostats, compressor controllers, variable-speed drives, leak detection components, and other control and protection systems.

A ban or severe restriction on fluoropolymers would therefore have far-reaching implications for RACHP equipment design and manufacture, irrespective of the specific refrigerant used. Systems operating with hydrocarbons, CO₂, or ammonia would be affected to a similar extent as those using fluorocarbon refrigerants, as the reliance on fluoropolymer materials is largely independent of refrigerant choice.

Substituting fluoropolymers with alternative materials would present significant technical challenges. In many cases, no direct substitutes currently offer equivalent performance across the full range of operating conditions encountered in RACHP applications. Redesigning equipment to accommodate alternative materials would require substantial research, testing, requalification, and recertification, with associated impacts on cost, development timelines, and product reliability.

As a result, broad PFAS restrictions that include fluoropolymers could significantly disrupt RACHP equipment supply chains, slow innovation, and delay the deployment of both low-GWP refrigerants and high-efficiency RACHP technologies.

7.8 A focus for the 2026 quadrennial reports of the panels

Under Decision XXXV/3, Potential areas of focus for the 2026 quadrennial reports of the Environmental Effects Assessment Panel, the Scientific Assessment Panel and the Technology and Economic Assessment Panel, parties requested TEAP as well as the other panels to include in their assessment information on PFAS.

TEAP has been requested to assess and evaluate the *“potential impacts of evolving policies and regulations in relation to the management of controlled substances and their alternatives and breakdown products, in particular per- and polyfluoroalkyl substances, on the implementation of the Montreal Protocol and the selection of alternatives in relevant sectors.”*

EEAP has been requested *“to assess the effects and accumulation of breakdown products from controlled substances and their alternatives, in particular any substances that are very persistent in the environment, such as perfluoro- and polyfluoroalkyl substances, including trifluoroacetic acid, in ground and surface waters and in other relevant sinks.”*

SAP has been requested by parties to include in its assessment *“[early] identification and quantification of any substances that could be of concern for the ozone layer and relevant for the implementation of the Montreal Protocol and the objectives of the Vienna Convention for the Protection of the Ozone Layer, including other halogenated gases, in particular those with high global warming potential, breakdown products of controlled substances and their alternatives that are very persistent, such as PFAS substances, including trifluoroacetic acid, N₂O and very short-lived substances such as dichloromethane, and their main sources of emissions.”*

EEAP had published its 2024 Update Assessment which reported on several peer-reviewed papers and a government report related to TFA, including soil measurements in China, groundwater study in Denmark, a German report with TFA ocean samples, and data from a Netherlands monitoring programme for the River Rhine. It concluded that *“the risk to humans from chronic exposures to TFA in surface waters remains de minimis at current concentrations of TFA.”*

TEAP is coordinating with EEAP and SAP on the scope of information on this topic to be covered by each panel’s assessment for 2026.

8 TEAP organizational matters and Decision XXXV/20 – Options for the organization of the TEAP and its /TOCs

8.1 Introduction

Decision XXXV/20 requested that TEAP “in its progress report prepared ahead of the 47th meeting of the Open Ended Working Group, provide options on the organization of the Panel and its Technical Options Committees, considering the Panel’s terms of reference established in decision XXIV/8, and informed by consultation with the Technical Options Committees’ co-chairs and members, and by their experiences with operating, on a trial basis, with new ways of organizing their work.”

TEAP conducted the relevant analysis and presented its conclusions at the 47th OEWG. Given the substantial work in the period 2025-2026, when TEAP needed near-term stability to deliver the required outputs, the panel recommended retaining the current structure for TEAP and its TOCs and asked parties to consider any future changes to come into force as of 2027.

At an informal group meeting held during the 37th MOP in Nairobi (November 2025), parties requested TEAP to further elaborate on possible options for reorganisation of the TEAP and its TOCs in its 2026 Progress Report. TEAP reconvened the Working Group that prepared its response to Decision XXXV/20 (contained in the TEAP May 2025 Progress Report) and presents some further analysis in the following sections for the consideration of the parties. The preferred options presented for the TOCs reflect the current practicalities of managing near-term anticipated changes within the committees over the next few years (i.e., normal attrition, lack of support for participation, recruitment of new members) as well as gaining more experience, for at least the largest two TOCs, with working through subcommittees structures. These options can be revisited in the future as the needs of parties evolve.

8.2 Assumptions and approach for 2027 and beyond

TEAP proposed options for its organization based on the anticipated workload and scope, striving to improve gender balance and regional distribution while maintaining the required expertise. Currently, TEAP is composed by 21 members: three TEAP co-chairs, 12 TOC co-chairs and six senior experts; 48% from A5 parties; six female and 15 male.

When analysing proposed options, TEAP has found challenges for ensuring a manageable workload as well as maintaining an independent, consensus-based approach, which are becoming more critical with:

- The juncture of the ODS phase-out and HFC phase-down regimes,
- The anticipated attrition of membership and relevant expertise, and
- The lack of support limiting some members’ participation in face-to-face meetings.

To address these challenges to the long-term viability of TEAP and its TOCs, the panel will need the support of the parties to find sustainable solutions.

8.3 Further considerations for preferred future TOCs configurations

8.3.1 FTOC

The FTOC has been an integral part of the Montreal Protocol since shortly after its inception, providing regular updates through progress and quadrennial assessment reports, including technical information on alternatives specific to sectors and applications, the latest technical research, market availability and limitations to supply, safety and environmental research and standards updates for both energy efficiency and safety, and emissions modelling and global bank estimates.

FTOC currently consists of 19 volunteer members and continues to seek members with knowledge of under-represented regions and sectors. Recent retirements have left a gap in FBA production experts, which FTOC hopes to fill this year. Gaps are outlined in the Matrix of Needed Expertise in this report.

FTOC consistently works to maintain strong member engagement, relationships and development (even for future leaders) through regular monthly or biweekly virtual meetings. The committee is challenged, as are other committees, with ensuring in-person attendance due to travel funding and necessary time for travel, meetings and reports, especially for non-A5 members and entrepreneurs that own companies. FTOC hopes that alternating regions hosting in-person meetings might assist with balancing attendance.

FTOC believes it is structured and sized appropriately with sufficient expertise to support parties through the remaining transitions of the Montreal Protocol. Once FBA transitions are complete, alternate structures might be considered, such as reducing the size of the committee. In-person meetings might be reduced to alternate years, provided ongoing work on assessments reports can continue to be supported to ensure consensus.

8.3.2 FSTOC

The FSTOC and its predecessor the HTOC has been an integral part of the Montreal Protocol since shortly after its inception. In the decades that have followed, the FSTOC has been not only the conduit between industry/organizations and the parties, but the primary guiding source for phaseout, phasedown, banking, and emissions modelling in the fire suppression sector. With guidance from the FSTOC, the fire suppression sector has set the standard for banking and responsible use. The FSTOC continues to provide up-to-date reporting to the parties through the following efforts/activities:

- Emissions modelling and global bank estimates (and regional/sector imbalances).
- Global recycling/reclamation/destruction activities and costs
- Transboundary and regulatory impediments
- Sector use, end-users, and legacy applications
- Technical information on alternatives
- Market availability and impacts from regulations and R&D
- Safety and Environmental aspects/concerns
- Evolving research and development, testing, and standards development
- Fire safety of all agents listed under the Montreal Protocol
- Educational workshops and meetings, including NOUs

Background and Details

The FSTOC, formerly the Halons TOC (HTOC), is one of the original TOCs, providing its first assessment report in 1989. Since then, the FSTOC has evolved to meet the changing needs of the parties. The FSTOC is instrumental in providing guidance in the management of global supplies of halons. The then FSTOC/HTOC helped craft Decision IV/25 on Essential Uses and provided the first

evaluation of EUNs; the parties denied both EUNs based on the recommendations of the FSTOC. The FSTOC continues to provide the most up to date information on alternatives to halons and HCFC fire suppressants, particularly for HCFC-123 used as a clean agent alternative to halon 1211, and since 2016, for high-GWP fire suppressants, under the Kigali Amendment. This guidance and information have assisted parties in forming control structures that have made the phase-out of halons a model for others. The FSTOC continues to stay current in alternatives research, development, and implementation, and barriers thereto, and continues to apprise the parties of changes, impediments, and new concerns every year.

The FSTOC developed and was instrumental in implementing the first agent lifecycle management (ALM) of global supplies of halons, particularly halon 1301. The FSTOC provided parties and commercial enterprises with sound recommendations that have resulted in no additional EUNs being submitted because of the global ALM of halons. Since production ended in 1994 in non-A5 and 2010 in A5 parties, there has been and remains sufficient quantity and quality of halons so that no EUNs have been submitted or could meet that criterion in Decision IV/25. This is particularly important for halon 1301, as there remain 1) legacy uses (enduring) that need to be maintained and 2) existing and future civil aircraft which require new systems as well as maintenance. Both the legacy uses and the aircraft uses are being supplied from existing, previously produced, global supplies and will require halon 1301 for many years to come.

The FSTOC continues to monitor, estimate, and report on emissions and global supplies of halons. Since Decision XXVI/7 in 2014, the FSTOC has maintained the ability to estimate the run-out date for halon 1301 given that there is a need to continue to support enduring uses and new installations of halon 1301 on civil aircraft. A new run-out date for halon 1301 has been developed and included in the FSTOC response to Decision XXXVII/4. Most importantly, the FSTOC believes that there is sufficient evidence that a significant portion of halon 1301 emissions derived from atmospheric concentration measurements, come from feedstock production and use, and not from fire suppression activities. This remains very important to continue to estimate halon 1301 emissions (losses from the global bank) and the resulting global bank of halon 1301 that may be available to support on-going, enduring uses.

Tasks that the FSTOC continues to provide for the parties can be summarised as follows:

- Produce the quadrennial assessment report and the quintennial report specific to HFCs on the status of the availability, suitability, and barriers to implement alternatives to halons, HCFCs, and high-GWP fire suppressants.
- Monitor and update estimates for the run-out date of available halon 1301 for civil aviation and all other enduring uses. Continue to work with the Ozone Secretariat and the relevant ICAO technical committees and working groups to improve civil aviation data, priorities, and future needs for halon 1301 in civil aviation.
- Continue to monitor and estimate emissions from halon 1301 fire suppression uses and the resulting available global bank of halon 1301. This will be important should an EUN be submitted.
- Continue to estimate emissions and the global bank of HFC-227ea in fire suppression.
- Monitor and report on relevant issues related to the global exchange of halons, HCFCs, and high-GWP fire suppressants resulting from parties applying the Basel Convention, local conditions, plans to destroy otherwise reclaimable halons and HCFC-123, and the impact on global supplies.

- Cross-cutting issues with other TOCs and the other panels, e.g., fire protection issues surrounding the increasing use of flammable refrigerants, and the impacts of existing and future PFAS regulations.

Options for future configuration

The FSTOC has two co-chairs and seventeen members of which four members are women and eight are from A5 parties. The current membership reflects wide expertise in regional and global fire suppression and includes FSTOC members on key standards-making technical committees, members involved in each use sector, and members in the reclamation, banking, and destruction fields. All in all, the FSTOC consists of a cadre of experts with current, extensive knowledge of the information needed to report to parties. The FSTOC co-chairs continuously seek to ensure geographical balance and gender balance. The FSTOC typically meets face-to-face once a year for four to five days. This is complemented by virtual meetings generally once a month, set to accommodate widely varying time zones.

TEAP anticipates that the expertise and coverage of relevant issues for the FSTOC will remain for 2027 and beyond. FSTOC co-chairs will continue to seek new members for succession planning, balance, and to maintain or improve global coverage.

Previously, the FSTOC provided two options for parties' consideration. In light of the changes that have occurred in the fire suppression sector since 2022, and the real possibility that civil aviation or other enduring uses will submit EUNs in the future, the FSTOC believes that the current configuration updated with new/replacement members (while also trying to find a potential A5 co-chair, who can be supported for their time and for travel) is the best future configuration to meet the current and future needs of the parties. Should the parties choose to seek a reduction in FSTOC membership, the FSTOC believes that it would not be able to cover all future needs of the parties.

8.3.3 MBTOC

MBTOC was established in 1993 to address issues related to MB phase-out, particularly technically and economically feasible alternatives to MB that could be adopted in both A5 and non-A5 parties to replace this fumigant. MBTOC addresses both controlled and exempted (QPS) uses of MB and has been instrumental in providing the parties with reliable and updated information on a wide range of issues relating to both controlled and exempted MB uses including:

- Research developments;
- Issues related to the adoption and adaptation of alternatives to MB (chemical and non-chemical) such as registration or availability that may impact the sustainability of the phase-out achieved for both controlled and exempted uses;
- Specific issues relating to A5 and non A5 Parties that may impact the successful adoption of alternatives;
- MB consumption and production trends for both controlled and exempted use on a global and regional basis; providing clarity for classification of uses (QPS or non-QPS)
- MB emissions; and bottom-up evaluation of emission budgets and potential gains by strategies to minimize emissions (e.g. recapture);

MBTOC has effectively contributed to the present situation where global MB consumption for controlled uses is virtually phased-out and the CUN process apparently finalized, although there is concern that use is still occurring for some controlled uses outside of Montreal Protocol regulations.

In addition to controlled uses, QPS applications still amount to about ~8,000 to 10,000 tonnes of MB per year. The Protocol specifically excluded QPS from control measures in 1992 because the Parties at the time estimated that there were no alternatives to MB that gave the same level of protection for the diverse range of treatments carried out with this fumigant. Since then, MBTOC and the QPS Task Forces have conducted several reviews for the Parties which demonstrate that feasible alternatives are available for about 35% of the uses of MB for QPS especially for the preshipment uses which do not require the same level of pest control for quarantine situations. MBTOC notes that many parties have phased out or significantly reduced use of MB for QPS beyond controls agreed under the Montreal Protocol. This has been predominantly due to hazards associated with MB use and emissions on human health and safety. Identifying the effective alternatives and strategies which have enabled these parties to achieve the standards of pest control required for international trade and biosecurity is another important role of MBTOC.

Tasks that the MBTOC undertakes can be summarised as follows:

- Produce a sound and relevant quadrennial Assessment Report on current uses of MB and alternatives for both controlled (non-QPS) and exempted (QPS) uses, with updated data and analysis on production and consumption, efforts to achieve phase-out and emissions;
- Provide technical guidance to the Parties on the development, availability, technical and economic feasibility and adoption of alternatives for MB reduction and phase-out.
- Follow emerging issues related to MB, such as illegal imports/ trade, issues impacting compliance and reporting, and any factors that might challenge sustainability of the phase-out achieved.
- Follow issues outside the protocol that may impact MB use e.g. the Basel Convention, the International Plant Protection Convention (IPPC) or the Chemical Review Committee (CRC) of the Rotterdam Convention.
- Cross-cutting issues with other TOCs or the other panels (e.g. food security as per the RTome Declaration).
- Follow findings or developments related to ODS not yet controlled under the Protocol and which are relevant to MBTOC's expertise, for example nitrous oxide (N₂O).

8.3.3.1 Future configuration

MBTOC currently has 16 members including two co-chairs (one A5, one non-A5). Current membership reflects wide expertise, with MBTOC members being active as researchers, academic faculty, technical consultants, commercial fumigators, trainers and speakers in parties and regions around the globe, who keep permanently abreast of new developments and trends. MBTOC co-chairs continuously seek to ensure geographical balance and gender balance. MBTOC typically meets face-to-face once a year for four days (in the past, there were two meeting per year, of five days each). This is complemented by virtual meetings around once a month, in spite of widely varying time zones.

TEAP anticipates that MBTOC will continue its coverage of these areas for parties in 2027 and beyond. After considering various scenarios for the anticipated workload, the committee considers that maintaining MBTOC membership at about 15 - 20 including two co-chairs (one A5, one non-A5), to ensure continuity of expertise and preserve institutional memory is the best and preferred. The committee's focus will be on QPS and emissions but expertise in controlled uses will be retained.

Parties will remain informed of latest developments in relation to MB, allowing TEAP to respond to tasks/ requests from parties or in a timely, efficient manner. MBTOC will be able to assess CUNs appropriately if they arise. This gives a clear signal to parties from TEAP that MB continues to be

important, and the work is not finished. Further, TEAP will be able to address broader cross-cutting issues and/or emerging issues, for example topics related to food security and safety as related to the Rome Declaration.

With this structure, new members of MBTOC can be recruited and mentored to provide issues on QPS uses when required, enabling continuation of members with knowledge of the Montreal Protocol process.

8.3.4 MCTOC

Medical and Chemicals Technical Options Committee (MCTOC) was established in 2016 by a decision of parties in 2015 to merge the former Chemicals Technical Options Committee (CTOC) and the Medical Technical Options Committee (MTOC). The MTOC activity had declined with the completion of the CFC phase-out for pMDIs and parties no longer making use of Essential Use Exemptions after their transitions. This merger aimed to maintain and consolidate expertise in both fields, enabling more efficient evaluations and guidance.

MCTOC has 39 members, including three co-chairs. In 2026, three members were added to strengthen global balance and expertise in medical and chemical technologies.

The MCTOC maintains expertise in the following areas:

- Fundamental scientific understanding of chemical properties, manufacturing processes, application standards, and emissions management related to controlled and other fluorinated substances.
- Expertise in the use of chemicals in various industries, including aerosols, solvents, semiconductor uses and medical applications such as pMDIs.
- Knowledge of end-of-life (EOL) management, including destruction technologies, recycling, reclamation, and lifecycle management (LCM).
- Specialized expertise in chlorinated compounds, including CTC and VSLS, covering their emissions, lifecycle management, regulatory challenges, and environmental impacts on ozone depletion and climate change.

MCTOC members provide coverage across various regions, including North America, Europe, Asia, Africa, South America, and Australia. The committee emphasizes a balanced representation to address regional nuances in chemical and medical technology applications.

MCTOC assesses the use of ODS and HFC in the medical and chemical related applications, namely, chemical production and feedstock uses, including emissions of controlled substances, very short-lived substances, process agents, solvent uses, semiconductor and other electronics manufacturing, magnesium production, laboratory and analytical uses, end-of-life management and destruction technologies, aerosols and pressurised metered dose inhalers. MCTOC also offers guidance on alternatives and technologies that can help protect the ozone layer and mitigate climate change impacts. Recently MCTOC has led on Reports on unexpected emissions of controlled substances (e.g., CFC-11, HFC-23).

Expected workload - 2027 and beyond

The workload for 2027 and beyond is expected to remain at the same level or possibly higher as compared to prior years. This includes contributing to sector updates in the annual TEAP Progress report, preparing the quadrennial and quintennial assessments, and other reports based on standing decisions covering the topics listed below. Any new decisions related to these topics as well as emerging topics relevant to the scope of work of MCTOC would also need to be taken into account in its workload for this period.

Production, Including Feedstock (Decision VII/30 and XXXVI/5)

As emissive uses are controlled, production and feedstock use emissions are becoming more important to parties. MCTOC has worked through a number of issues in our reports in recent years. HFC-23 emissions is an on-going issue, and MCTOC will continue to monitor and report as necessary.

CTC (Decision XXXV/9)

Production of CTC has increased in recent years, due mainly to growing demand for CTC use as feedstock to HFCs and HFOs/HCFOs and to perchloroethylene. This trend is likely to continue due to expected increasing demand for HFO/HCFOs. MCTOC will continue to collaborate with SAP in estimating emissions and sources.

VSLs (Decision XXXVI/4)

VSLs are chlorinated hydrocarbons with very short atmospheric lifetimes. They are ODS, but with very low ODP, and are not yet controlled under the Montreal Protocol. Chlorinated VSLs have a small, but growing, contribution to total tropospheric chlorine, assessed at 4% in 2020. The VSLs contribution remains small compared to emissions from other sources such as EOL, but MCTOC will continue to monitor and report if requested by the parties concerned.

Process Agents (Decision XXIII/7 and XXXI/6)

Process agents are controlled substances used to facilitate or inhibit specific chemical reactions. The use of process agents is often in long-standing processes where transitioning to alternatives can be challenging. The current state remains largely unchanged, with manufacture using process agents undergoing gradual changes over time.

Solvents

HCFOs and HFOs are available as HFC and HCFC alternatives. The major trend in the development of solvents is the introduction of substances with unsaturated molecules, and thus short atmospheric lifetimes. However, potential PFAS regulations may affect not only HFOs and HCFOs, but also many other alternatives. As a result, the number of available alternatives may be significantly reduced.

***n*-Propyl bromide (Decision XXX/15)**

n-Propyl bromide is used as an electrical cleaning agent, degreaser, or carrier solvent, as an intermediate in chemical manufacture, in spray adhesives, dry cleaning, insulation for building and construction material, and as a refrigerant flushing agent. *n*-Propyl bromide is not a controlled substance under the Montreal Protocol. Due to the presence of bromine in the molecule, however, there are concerns regarding its use based both on its potential for ozone depletion and its toxicity. *n*-Propyl bromide may also contribute to photochemical smog and is regulated as a volatile organic compound.

Semiconductor and other electronics manufacturing

Global consumption of HFCs (HFC-23, HFC-32, HFC-41) for electronics manufacturing has increased significantly over the last decade, and this trend is expected to continue with increasing semiconductor production.

HFC emissions from electronics manufacturing mainly consist of the unutilised portion of the process gas. Some facilities have implemented emissions control technologies that significantly reduce emissions of HFCs and other fluorinated gases during semiconductor manufacturing.

Magnesium Production

Cover gases are used in magnesium production, casting processes, and recycling to prevent oxidation and combustion of molten magnesium.

Sulphur hexafluoride (SF₆) is the most widely used cover gas. Several gases with lower GWPs such as HFC-134a are used as alternatives to SF₆. The use of HFC-134a is declining among Annex I countries and MCTOC expects this trend to continue.

Laboratory and analytical uses (Decision XXIII/6 and XXXI/5)

Laboratory and analytical uses of controlled substances include equipment calibration, extraction solvents, diluents, or carriers for chemical analysis, and biochemical research. There have been no significant changes recently, but MCTOC will continue to monitor and report.

End-of-life management and destruction technologies (Decision XXX/15)

The EOL management of controlled substances requires the recovery, recycling, reclamation, reuse, and destruction of these substances. In non-A5 parties, these substances are present in large quantities and will reach EOL in the next decade. In A5 parties, the quantity is rapidly increasing due to the uptake of HFC-containing equipment and is expected to dominate global quantities by the early 2030s. The certification and review of destruction technologies are also being considered.

HFCs not listed in Annex F of the Montreal Protocol (Decision XXIX/12).

There are HFCs not listed as controlled substances in Annex F, and MCTOC provides information on the consumption and production of HFCs that have a GWP equal to or greater than the lowest GWP of those listed in Annex F. Since the AR4 GWP values for substances not listed in Annex F are not available, the AR6 GWP values must be used.

HCFC availability (Decision XXX/2)

The focus remains on maintaining stocks to supply on-going needs during (A5) and post (non-A5) phase out. Important on-going aerosol and solvent uses.

Aerosols

Some on-going HCFC aerosols to be revisited in 2026. Transition from HFC to HFO propellants for VOC control needs to be considered, e.g., if PFAS regulations that impact HFC-134a and HFOs could impact range of choices of propellants for aerosols production. Need to consider HFO uses that could slow transition from HFCs if HFOs availability becomes limited.

Inhalers for Asthma and COPD (Decision XXXVI/6)

There are two common types of highly portable inhalation devices for the delivery of respiratory drugs: (pressurised) metered dose inhaler (pMDI) and the dry powder inhaler (DPI) in single- or

multi-dose. The clinical guidelines for asthma and COPD are beginning to change from salbutamol pMDIs to controller medications. All controllers have both pMDI and DPI formulations.

There are now ~70 pharmaceutical companies manufacturing pMDIs worldwide, almost all pMDIs. Pharmaceutical companies replaced CFCs with HFCs propellants in pMDIs (HFC-134a and to a lesser extent HFC-227ea) With the Kigali Amendment, the production and consumption of these HFCs (HFC-134a, HFC-227ea) will be phased down. All currently available HFC pMDIs have a much greater carbon footprint than DPIs. Life cycle assessments consistently demonstrate that the large majority (88–98%) of the carbon footprint of pMDIs is due to propellant release during use or end of life. DPIs are propellant-free inhalers and consequently have far smaller carbon footprints.

Intensive efforts by the pharmaceutical industry in both non-A5 and A5 parties are starting to develop and transition to “green” pMDIs. Two lower GWP chemicals are under development as potential propellants for pMDIs (pharmaceutical grade HFC-152a and HFO-1234ze(E)) as replacements for HFC-134a and HFC-227ea. Propellant supply chain will be critical as overall HFC volumes decline. One company worldwide produces almost all pharmaceutical grade HFCs and they have indicated they will cease supply of HFC-134a in ~2030. Maintaining a sufficient and affordable supply of propellants for pMDIs during transition to lower GWP propellants will be important for patient safety both in non-A5 but especially in A5 parties,

MCTOC will continue to monitor this sector of use and expects the transition to lower GWP inhalers to occur over the next decade, and to take place in parallel in non-A5 and A5 parties. It should occur more quickly than the 20 years for CFC MDIs phaseout because the larger number of MDI manufacturers with alternatives is providing commercial competition and more options for patients, and because there is a complete range of DPI alternatives which are suitable for most patients.

Others (Decision XXXVI/3)

MCTOC continues to monitor and report on emerging issues relevant to chemicals (e.g., PFAS, TFA, CFC-11, HFC-23) in coordination with the other panels, as appropriate.

New use of HFC: A few miscellaneous uses popped up in recent years — e.g., laser dermatology use of HFCs, use of HFCs in the separation of natural products (e.g., medical cannabis).

8.3.4.1 Options for future configuration

MCTOC’s preferred option appears below (Table 8.1). At this stage, other options are likely to be premature, for example during the transition from high-GWP HFCs to lower-GWP. Broad expertise on HFCs and HFOs is currently required especially regarding the manufacture and supply of bulk propellant. MCTOC considers that other configuration options could be considered in future if it becomes clear that the two subgroups could operate independently with the available expertise and without difficulty or loss of technical balance.

Table 8.1. Preferred option for future configuration of MCTOC for 2027 and beyond

Option	Pros	Cons
<p>Restructure MCTOC with 4 co-chairs and about 40 members in 2 formal subcommittees: (1) Aerosols/Medical and (2) Chemicals</p>	<p>Specialization: Having sub-groups with 4 specialist co-chairs enables specific focus on relevant sectors and their technical issues</p> <p>Management: More efficient /improved productivity, with advantage of additional co-chair to share management workload and augment specialist leadership.</p> <p>Membership: Ensures the retention of specialized and cross-cutting knowledge and expertise.</p> <p>Single overarching committee enables joint review of cross-cutting issues.</p> <p>While the overall committee membership numbers may not align with the TOR, the sub-committee membership numbers would align and address the intent of the TOR for the manageability of the committees and its individual sub-committee.</p>	<p>Management Complexity: Managing a large TOC with diverse and separate technical issues is complex and time-consuming,</p> <p>Expertise Distribution: The large group may lead to dilution of expertise and loss of focus</p> <p>Membership for each specialist technical area is limited by large committee size</p> <p>Co-Chair Coordination and Leadership: Dividing into two subgroups would require appropriate management by the co-chairs to facilitate the necessary collaboration between the groups. Strong leadership would be essential to address technical issues effectively and ensure constructive cooperation.</p>

8.3.5 RTOC

The RTOC was established in 1989 under the Montreal Protocol. Its purpose is to address challenges related to the phase-out of CFCs and HCFCs in the RACHP sector. The RTOC provides comprehensive information on technically and economically feasible alternatives to these substances, ensuring their adoption by both A5 and non-A5 parties.

The following list outlines some of the expertise currently represented in the RTOC, as well as additional expertise required for the next assessment:

- Refrigerants – Properties, Regulations, Standards, Manufacturing, Supply Chain, Reclamation and destruction
- Sealed Systems Refrigeration – Design, Manufacturing, Servicing, Supply Chain
- Supermarket Refrigeration – Design, Manufacturing, Servicing, Supply Chain
- Industrial Refrigeration – Design, Manufacturing, Servicing, Supply Chain for food, pharmaceuticals and other industrial processes

- Transport Refrigeration – Design, Manufacturing, Servicing, Supply Chain for food and pharmaceuticals
- Mobile AC/HP – Design, Manufacturing, Servicing, Supply Chain, Mobile Comfort Related Standards, vehicle thermal systems design and management
- AC/HP and Central AC/HP – Design, Manufacturing, Servicing, Supply Chain
- Residential and Commercial Building Comfort Related Standards
- Building Loads and Systems Analysis, Systems Innovation and
- EE - Design Options, Test Standards, Regulations/MEPS
- LRM – all aspect of Lifecycle Refrigerant Management
- Sustainability – Regulations, Emissions, Social/Environmental Impacts, Lifecycle analysis: energy, environmental, and economic
- Modelling – Equipment, refrigerant loss and Refrigerant Inventory
- Montreal Protocol - HPMP – Kigali Amendment - KIP, Manufacturing conversion and servicing practices including refrigerant management to meet HPMP and KIP

Tasks that the RTOC undertakes can be generally summarised as follows:

- Produce comprehensive quadrennial assessment reports on current uses of alternatives to CFC/HCFC and HFC, with updated data and analysis on equipment by application and efforts to achieve phase-out and elimination of emissions;
- Report and update annually on the technologies that help in eliminating or reducing consumption
- Provide technical guidance to the Parties on the development, availability, and adoption of alternatives and any issues that they deem to be relevant in relation to HFC reduction and CFC/HCFC phase-out.
- Report on the latest developments in EE and its co-benefits.
- LRM as it applies to the RACHP sector; and how it relates to other sector practices and needs.
- Track and report on the impact of PFAS related regulations (and uncertainties) on the RACHP sector.

RTOC expects to continue to receive requests and deliver reports to parties on the impacts of the following key global trends and drivers on Montreal Protocol controlled substances use, EE, etc. in the RACHP sector:

- Kigali Amendment implementation (RACHP is ~ 80% of controlled substances consumption)
- New and potential regulations on the horizon – PFAS, EE, LRM
- Global growth in air conditioning – projected to triple by 2050 (Global Cooling Watch 2023 | UNEP - UN Environment Programme), due to the growth in economies as well as changing

climate

- Growth in heat pumps usage, especially in non-Article 5 parties and China
- Growth in emerging market segments such as, decarbonization of all heating processes, data centre cooling, high temperature heat pumps
- Growth in alternative technologies to current vapor compression cycle-based systems
- Growth in cold chain due to global economic growth and increasing focus on food waste
- Potential future interest in retrofitting existing systems to lower GWP refrigerant options
- Need for an open-source TEAP/RTOC model of production and consumption of MP controlled substances
- Growth in world population, affecting all the above
- Growth in economies around the world, leading to a greater global demand for comfort cooling (and heating) as well as cold chain benefits.
- Continuous modernization in the age of Artificial Intelligence (AI) and its impact in all industries including RACHP (growth in Data Centres), including Digitalization.

8.3.5.1 Options for future configuration

The current structure of the RTOC—comprising a single committee of approximately 40 members and four co-chairs, supported by subcommittees—is functioning very effectively. It fosters strong collaboration and consistently delivers high-quality outputs. The co-chairs have established a regular virtual meeting cadence, with weekly meetings for co-chairs and monthly meetings for the full membership, which supports steady progress and active participation. Notably, all RTOC reports are produced entirely by the membership, with the co-chairs providing editorial guidance and coordination support.

TEAP anticipates that RTOC will continue its coverage of a broad range of areas in the RACHP sector. RTOC requires extensive expertise across the Cold Chain, Comfort Cooling and Heating, and other applications, necessitating a wide range of expert resources. Considering various scenarios for the anticipated workload and coverage of issues for parties in 2027 and beyond, TEAP provides below the preferred option for RTOC’s future configuration in the table below:

Preferred Option	Pros	Cons
<p>Restructure RTOC to focus on cross-cutting aspects and general topics relevant to the RACHP sector while continuing with two application subcommittees on (1) Comfort Cooling and Heating and (2) Cold Chain and Other Applications.</p> <p>The RTOC would continue to have ~40 members with four co-chairs.</p>	<p>Enables joint consideration and consensus on all cross-cutting issues e.g. EE, LRM, PFAS, Safety standards, etc.</p> <p>Allows technical subgroups to meet on refrigeration/cold chain and ACHP space cooling</p> <p>RTOC maintains ability to respond to tasks and requests from parties in a timely and efficient manner</p> <p>RTOC maintains expertise in applications and equipment while strengthening its knowledge of the cross-cutting topics relevant to the RACHP sector</p> <p>Support succession planning and recruitment efforts</p> <p>Streamlines function with least disruption.</p> <p>Allows for membership to flex between all the required areas of expertise seamlessly.</p>	<p>Management Complexity: Managing a large TOC with diverse and separate technical issues is complex and time-consuming</p> <p>Expertise Distribution: The large group may lead to dilution of expertise and loss of focus</p> <p>Co-Chair Coordination and Leadership: Dividing into two subgroups would require appropriate management by the co-chairs to facilitate the necessary collaboration between the groups. Strong leadership would be essential to address technical issues effectively and ensure constructive cooperation.</p>

This option maintains a single committee structure dedicated to common areas relevant to all segments of RACHP (topics that change often and substantially during the year), with two subgroups focusing on specific applications of RACHP: (1) Comfort Cooling and Heating, and (2) Cold Chain and other applications (topics that do not change significantly during the year but do from year to year). The single committee structure enables collaboration amongst all the sector technical experts to deliver the most accurate and timely responses and reports, while avoiding duplicated effort. Recruitment of future experts to the committee is likely to be improved due to the ability of volunteers to contribute to all the relevant industry topics of their choosing as well as giving them an opportunity to learn from the other experts. The single RTOC structure also enables seamless shifts in expertise required between refrigerants, applications, equipment and the various cross-cutting topics. This option is viewed as the most effective committee structure for RTOC beyond 2027.

8.4 Organizational matters

Parties have relied on the TEAP and its TOC experts in all areas of production, consumption and end-use. Our experts are unpaid volunteers. Today, over 150 experts serve on the TEAP and its TOCs. In producing their quadrennial assessment report for parties, TEAP and TOC members have documented the successes and challenges of the Protocol, sector by sector. These volunteer experts provide objective, policy-neutral, technical and economic review of issues relevant to the Montreal Protocol. In addition to responses to specific decisions of parties, the TEAP annual progress report shapes a major part of the agenda and discussions in the OEWG and MOP. TEAP members can contribute up to 50% of their working time.

Expertise is the priority consideration for TEAP and TOCs and they have generally been successful in recruiting and retaining the balance of voluntary expertise needed to address the issues facing parties. Co-chairs of the TEAP and each TOC continually strive to maintain and strengthen the relevant expertise within its membership while making every effort to also reach the goals of a representative geographical distribution, equal number of A5 and non-A5 experts, and gender balance. TEAP and its TOCs are stepping up their efforts to recruit active new members to meet gaps in expertise. Task Forces on specific Decisions have enabled new experts to familiarise themselves with the process and work commitment and allows TEAP to consider their capability and suitability for TEAP/TOC membership.

The mission of TEAP and its TOCs has evolved as the ODS phase-out and more recently the HFC phase-down have progressed. Accordingly, the membership has also evolved over the years to meet the issues faced by TOCs and the expertise needed to address these. As the tenth anniversary of the Kigali Amendment draws closer, it becomes even more timely to review the work and structure of the TEAP. The challenges to both retain and recruit volunteer experts on the TOCs continues as TOC co-chairs consider future workload. TEAP considers this to be at least as great a challenge as TEAP/TOC organization and structure.

TEAP and its TOCs are being challenged by a number of issues as it strives to maintain its expertise, and gender/geographical balance:

- Balancing the need for new experts while maintaining the same level of independent technical and economic expertise for our work for parties becomes challenging in ensuring new experts are educated in TEAP's TOR, annual disclosure and conflict of interest requirements, process for consensus, and processes for developing, reviewing, and presenting reports.
- The overlap of the ODS phaseout and HFC phasedown regimes have significantly expanded the scope of discussions and decisions that need to be taken by parties under the Montreal Protocol. As a result, TEAP's workload has expanded substantially not only to respond to standing decisions but also to new decisions, all within the same timeframes required for OEWG and MOP documents.
- Some TOCs have experienced substantial attrition of key members through retirement and loss of support for their participation, with increasing loss of expertise for those TOCs.
- TEAP and TOC volunteers are increasingly facing lack of financial support for many non-A5 experts for travel and subsistence. Some parties who do nominate experts do not provide travel costs. Some experts from both A5 and nonA5 parties who work for companies find that those companies are now unwilling to provide travel support and/or time off to attend meetings. Addressing the funding of travel and subsistence of TEAP/TOC volunteers independent of A5/non-A5 status is critical to the consensus-based process of TEAP's work.

TEAP/TOCs pattern of working has changed towards on-line working. This has benefits in terms of cost, organization and continuous working, but consensus requires mutual respect and trust – and it is hard to develop and maintain that essential culture without meeting face to face, especially for new members. TEAP/TOCs on-line meetings are necessarily shorter to enable participation by members in different time-zones. On-line and hybrid meetings also make it harder to get a full debate of issues, and full participation in consensus. Annual face to face meetings remain an essential part of TEAP/TOC function and consensus, and in preparing reports in a timely manner for the OEWG and MOP.

Continuing the legacy and support provided by the TEAP and its TOCs to parties under the Protocol requires a pool of experts to serve on the panel and its committees in the future, who have the capacity, support, and time to understand the work and TOR. Recruitment of new experts is becoming critical to maintaining an independent and consensus-based process for TEAP's development of its

reports. To address these challenges to the long-term viability of TEAP and its TOCs, the panel will need the support of the parties to find sustainable solutions.

Annex 1 - TEAP reports 2026-2027

Year	Issue	Request by parties to TEAP	Report anticipated to be produced
2026	Progress update		
	Technical progress update by TEAP and its TOCs	Decision IV/13 – Report annually to OEWG on technical progress in reducing the use and emissions of controlled substances and assess the use of alternatives, particularly their direct and indirect global-warming effects	2026 progress report
		Decision XI/17 – Report on any important new developments	
	Procedures relevant to nominations to the TEAP and its TOCs	Decision XXXI/8 – Provide, as part of its annual progress report, a summary outlining the procedures that the Panel and its technical options committees have undertaken to ensure adherence to the Panel’s terms of reference through clear and transparent procedures, including full consultations with the focal points, in line with the terms of reference, regarding: (a) nomination processes, taking into account the matrix of needed expertise and already available expertise; (b) proposed nominations and appointment decisions; (c) termination of appointments; and (d) replacements	2026 progress report
	Thematic reports		
	Critical-use nominations	Decision IX/6 – Review nominations for critical use exemption of methyl bromide and make recommendations based on the criteria established in the decision (and other relevant decisions)	2026 progress report (only upon submission of nominations)
	Essential-use nominations	Decision IV/25 – Review any submitted nominations and make recommendations in accordance with the criteria established in the decision	2026 progress report (only upon submission of nominations)
	Laboratory and analytical uses	Decision XXXI/5 – Report in the TEAP quadrennial report on any progress made by parties in reducing their production and consumption of ozone depleting substances for laboratory and analytical uses, on any new	2026 progress report (only if new compelling information)

Year	Issue	Request by parties to TEAP	Report anticipated to be produced
		alternatives to those uses, and on laboratory standards that can be performed without such substances, on the understanding that, should new compelling information become available, including opportunities for significant reductions in production and consumption, that information should be reported in its annual progress report	becomes available)
	Process agents	Decision XXXI/6 – Report in the TEAP quadrennial reports on any progress made by parties in reducing their use and emissions of controlled substances as process agents and on any new alternatives to such uses, including new production processes and emissions-reduction techniques, on the understanding that should new compelling information become available, that information should be reported in its annual progress report	2026 quadrennial assessment report
	Process agents; destruction technologies; laboratory and analytical uses; n-propyl bromide; possible new substances ^a	Review only if the specific conditions set out in decision XXX/15 are met ^b	
	Life-cycle refrigerant management	Decision XXXVI/2 , paragraph 1– Include updated relevant information on life-cycle refrigerant management in its 2025 and subsequent progress reports, including the 2026 quadrennial assessment report, taking into account discussions at MOP36	2026 progress report and 2026 quadrennial assessment report
	MDIs with low-GWP propellants	Decision XXXVI/6 , paragraph 3 – Continue to provide in the TEAP annual progress reports updated information on low-GWP MDI propellants and to complement the TEAP 2026 quadrennial assessment report with timely information, including on the availability, technical feasibility, economic viability, safety and market penetration of those propellants in parties operating under paragraph 1 of Article 5 of the Montreal Protocol on Substances that Deplete the Ozone Layer and in parties not so doing	2026 progress report
	Emissions of the HFC-23	Decision XXXVII/2 , paragraph 1– TEAP and SAP to provide an update on emissions of HFC-23 to the 38th MOP, taking into account the information submitted by parties in response to Decision XXXVI/3 and pursuant to paragraph 2 of this decision and including	Report on HFC-23 emissions

Year	Issue	Request by parties to TEAP	Report anticipated to be produced
		the following: (a) Additional analysis of the discrepancy between reported emissions and those derived from atmospheric measurements, including the methodologies applied; (b) A description of the information and data sources used, identifying any gaps or limitations; (c) Additional information on methodologies adopted by parties for estimating and reporting	
	Halons 1301 and other fire suppressors	Decision XXXVII/4 , paragraph 1– The Ozone Secretariat to liaise with the secretariat of the International Civil Aviation Organization (ICAO) on the matter of fire suppression agents controlled under the Montreal Protocol and facilitate the exchange of information between the TEAP, through its Fire Suppression Technical Options Committee, and the relevant ICAO technical committees and working groups in order to allow the Panel to: (a) Better assess the future use of and need for halons in civil aviation, making use of, among other things, available data on the locations of the maintenance, repair and overhaul operations authorized to service halons, data on future fleet evolution and estimates regarding aircraft in operation with different types of halon fire protection systems (b) Submit a report on halon availability and the global distribution of halon banks, based on the above-mentioned activities, to the parties in advance of the 48th OEWG meeting	2026 progress report
	Options for the organization of the TEAP and its technical options committees (TOCs)	Decision XXXV/20 , To provide in the TEAP progress report prepared ahead of the 47th OEWG meeting, options on the organization of the Panel and its technical options committees, considering the Panel’s terms of reference established in decision XXIV/8 and informed by consultation with the technical options committees co-chairs and members, and by their experiences with operating, on a trial basis, with new ways of organizing their work	2026 progress report (request at MOP37 for additional information by the TEAP co-chairs)
Periodic assessments			
	Replenishment study for 2027–2029	Expected decision at the 37th MOP, in 2025, and potential additional guidance by OEWG (48th meeting) in 2026 – Prepare a report on the appropriate level of the 2027–2029 replenishment of the Multilateral Fund	Replenishment task force report (2027–2029) Supplement to the replenishment task force report

Year	Issue	Request by parties to TEAP	Report anticipated to be produced
	Quadrennial assessment	Decision XXXV/3 - Prepare the TEAP 2026 quadrennial assessment	TEAP and TOCs 2026 quadrennial assessment reports (6)
	HFCs not listed in Annex F of the Montreal Protocol	Decision XXIX/12 – Provide in the quadrennial reports of the assessment panels to be presented to the 35th MOP, in 2023, and every four years thereafter, information on the consumption and production of HFCs not listed in Annex F of the Protocol that have global warming potential no less than the lowest global warming potential of the HFCs listed in Annex F	2026 quadrennial assessment report
	HCFC availability	Decision XXX/2 – Provide in its quadrennial reports to be presented to the 35th MOP, in 2023, and to the 39th MOP, in 2027, information on the availability of Annex C, group I, substances, including amounts available from recovery, recycling and reclamation, and best available information on country-level and total known stocks, as well as the availability of alternative options for the applications described in Article 2F, paragraphs 6 (a) and 6 (b)	2026 quadrennial assessment report
	Laboratory and analytical uses	Decision XXXI/5 – Report in the TEAP quadrennial report on any progress made by parties in reducing their production and consumption of ozone depleting substances for laboratory and analytical uses, on any new alternatives to those uses, and on laboratory standards that can be performed without such substances, on the understanding that, should new compelling information become available, including opportunities for significant reductions in production and consumption, that information should be reported in its annual progress report	2026 quadrennial assessment report
	Life-cycle refrigerant management	Decision XXXVI/2 , paragraph 1– Include updated relevant information on life-cycle refrigerant management in its 2025 and subsequent progress reports, including the 2026 quadrennial assessment report, taking into account discussions at MOP36	2026 quadrennial assessment report
	Additional information on very short-lived substances (VSLS)	Decision XXXVI/4 , paragraph 1– TEAP and SAP to include the requested information, in their 2026 assessment report, for consideration by OEWG49.	2026 quadrennial assessment report

Year	Issue	Request by parties to TEAP	Report anticipated to be produced
	Developments regarding metered-dose inhalers with low-global-warming-potential propellants	Decision XXXVI/6 , paragraph 3 – Provide updated information, in its annual progress report, on low-GWP metered-dose inhaler propellants, and to complement its 2026 quadrennial assessment report with timely information including on their availability, technical feasibility, economic viability, safety and market penetration in parties operating under paragraph 1 of Article 5 of the Montreal Protocol and those not so doing	2026 quadrennial assessment report
	Report of the TEAP prepared pursuant to decision XXVIII/2, paragraph 5	Decision XXXVI/10 , provide in its 2026 quadrennial assessment report an update by sector and subsector on low- and lower-GWP alternatives to HFCs for use in Article 5, group 2 parties to prepare for the hydrofluorocarbon freeze, including the following: (a) Challenges and barriers in terms of availability, accessibility and adoption; (b) Standards for alternative refrigerants and for equipment, taking into consideration the capacity of equipment in different countries; (c) Market structure, including supply chain issues; (d) Options for addressing the challenges and barriers to the adoption of alternatives identified in subparagraph (a) above; (e) Information on the cost of adoption of alternatives, in the context of the information provided under subparagraphs (a) to (d) above.	2026 quadrennial assessment report
Indicative number of expected reports in 2026:			10

Year	Issue	Request by parties to TEAP	Report produced
2027	Progress updates		
	Technical progress update by TEAP and its TOCs	Decision IV/13 – Report annually to OEWG on technical progress in reducing the use and emissions of controlled substances and assess the use of alternatives, particularly their direct and indirect global-warming effects	2027 progress report
	Decision XI/17 – Report on any important new developments		

Procedures relevant to nominations to the TEAP and its TOCs	Decision XXXI/8 – Provide, as part of its annual progress report, a summary outlining the procedures that the Panel and its technical options committees have undertaken to ensure adherence to the Panel’s terms of reference through clear and transparent procedures, including full consultations with the focal points, in line with the terms of reference, regarding: (a) nomination processes, taking into account the matrix of needed expertise and already available expertise; (b) proposed nominations and appointment decisions; (c) termination of appointments; and (d) replacements	2027 progress report
Thematic reports		
Critical-use nominations	Decision IX/6 – Review nominations for critical use exemption of methyl bromide and make recommendations based on the criteria established in the decision (and other relevant decisions)	2027 progress report (only upon submission of nominations)
Essential-use nominations	Decision IV/25 – Review any submitted nominations and make recommendations in accordance with the criteria established in the decision	2027 progress report (only upon submission of nominations)
Laboratory and analytical uses	Decision XXXI/5 – Report in the TEAP quadrennial report on any progress made by parties in reducing their production and consumption of ozone depleting substances for laboratory and analytical uses, on any new alternatives to those uses, and on laboratory standards that can be performed without such substances, on the understanding that, should new compelling information become available, including opportunities for significant reductions in production and consumption, that information should be reported in its annual progress report	TEAP 2027 progress report (only if new compelling information becomes available)
Process agents	Decision XXXI/6 – Report in the TEAP quadrennial reports on any progress made by parties in reducing their use and emissions of controlled substances as process agents and on any new alternatives to such uses, including new production processes and emissions-reduction techniques, on the understanding that should new compelling information become available, that information should be reported in its annual progress report	TEAP 2027 progress report (only if new compelling information becomes available)

	Process agents; destruction technologies; laboratory and analytical uses; n-propyl bromide; possible new substances ^a	Review only if the specific conditions set out in decision XXX/15 are met ^b	
	Life-cycle refrigerant management	Decision XXXVI/2 , paragraph 1– Include updated relevant information on life-cycle refrigerant management in its 2025 and subsequent progress reports, including the 2026 quadrennial assessment report, taking into account discussions at MOP36	2027 progress report
	Metered-dose inhalers (MDI's) with low-global-warming-potential (GWP) propellants	Decision XXXVI/6 , paragraph 3 – To continue to provide in the TEAP annual progress reports updated information on low-GWP metered-dose inhaler propellants and to complement the TEAP 2026 quadrennial assessment report with timely information, including on the availability, technical feasibility, economic viability, safety and market penetration of those propellants in parties operating under paragraph 1 of Article 5 of the Montreal Protocol on Substances that Deplete the Ozone Layer and in parties not so doing	2027 Progress report
	Study on quantities of and options for used and unwanted controlled substances under the Montreal Protocol, including those at their end of life	Decision XXXVII/3 , paragraph 1 – Prepare, for consideration by the 39th MOP, a comprehensive report that includes: (a) An estimate of the quantity at the global level of used and unwanted refrigerants containing controlled substances, taking into account the national inventories developed pursuant to decision 91/66 of the Executive Committee of the MLF and other sources of information, and taking into account the uncertainties in obtaining the information relating to used and unwanted refrigerants as well as end-of-life equipment; (b) Identification of existing destruction and reclamation facilities that can accept used refrigerants from other countries, and the conditions associated with exporting used refrigerants for disposal at such facilities, taking into account any legislative barriers to transboundary movements; (c) Estimates of the potential benefits in terms of avoided ozone depleting-potential tonnes and carbon-dioxide-equivalent tonnes associated with the reclamation and destruction of used and unwanted refrigerants	Report on quantities of and options for used and unwanted controlled substances under the Montreal Protocol, including those at their end of life

	Halon 1301	Decision XXXVII/4 , paragraph 4 – Parties to submit, on a voluntary basis, to the Ozone Secretariat, by 31 March 2026, available information regarding the development of alternatives suitable for use as substitutes in fire suppression, and to request the Secretariat to forward the information received to the TEAP for its consideration and for inclusion, at the latest, in the TEAP 2027 progress report	2027 progress report
Periodic assessments			
	Quadrennial assessment	Decision XXXV/3 - Prepare the assessment panels' synthesis report	2027 quadrennial assessment synthesis report
	Review related to the Kigali Amendment to the Montreal Protocol	Decision XXVIII/2 , paragraph 4 – Conduct periodic reviews of alternatives to HFCs in 2022 and every five years thereafter, and provide technological and economic assessments of the latest available and emerging alternatives to HFCs (second review)	Report on review of alternatives to HFCs
Indicative number of expected reports in 2027:			4

Annex 2 - TEAP and TOC membership and administration

The disclosure of interest (DOI) of each member can be found on the Ozone Secretariat website at: <https://ozone.unep.org/science/assessment/teap>. The disclosures are normally updated at the time of TEAP’s annual meeting (normally in April/ May). TEAP’s Terms of Reference (TOR) (2.3) as approved by the Parties in Decision XXIV/8 specify that

“... the Meeting of the Parties shall appoint the members of TEAP for a period of no more than four years...and may re-appoint Members of the Panel upon nomination by the relevant party for additional periods of up to four years each.”. TEAP member appointments end as of 31 December of the final year of appointment, as indicated in the following tables.

TEAP’s TOR (2.5) specifies that *“TOC members are appointed by the TOC co-chairs, in consultation with TEAP, for a period of no more than four years...[and] may be re-appointed following the procedure for nominations for additional periods of up to four years each.”* New appointments to a TOC start from the date of appointment by TOC co-chairs and end as of 31st December of the final year of appointment, up to four years.

A4.1 Technology and Economic Assessment Panel (TEAP) 2026

TEAP is presently composed of three co-chairs, the co-chairs of the Technical Options Committees and six senior experts as indicated in Table A4.1 below.

Table A4-1 TEAP Membership at May 2026

	Co-chairs	Affiliation	Country	Appointed through
1	Bella Maranion	U.S. Environmental Protection Agency	US	2028
2	Marta Pizano	Independent Expert	Colombia	2026*, 2029
3	Ashley Woodcock	Manchester University NHS Foundation Trust	UK	2026*
	Senior Experts	Affiliation	Country	Appointed through
4	Suely Machado Carvalho	Independent Expert	Brazil	2026*
5	Sukumar Devotta	Independent Expert	India	2026*
6	Bassam Elassaad	Independent Expert	Lebanon	2026*
7	Ray Gluckman	Gluckman Consulting	UK	2026*
8	Marco Gonzalez	Independent Expert	Costa Rica	2026*
9	Shiqiu Zhang	College of Environmental Sci. & Eng., Peking University	PRC	2026*
	TOC Chairs	Affiliation	Country	Appointed through
10	Omar Abdelaziz	The American University in Cairo	Egypt	2027
11	Paulo Altoé	Independent Expert	Brazil	2028
12	Adam Chattaway	Collins Aerospace	UK	2028
14	Takeshi Eriguchi	AGC Inc.	JP	2027
15	Roberto Peixoto	Maua Institute (IMT), Sao Paulo	Brazil	2027
16	Fabio Polonara	Università Politecnica delle Marche	Italy	2026*
17	Ian Porter	La Trobe University	Australia	2027
18	Rajan Rajendran	Independent Expert	US	2027
19	Helen Tope	Independent Consultant, Planet Futures	Australia	2029
20	Daniel P. Verdonik	Jensen Hughes Inc	US	2028

21	Helen Walter-Terrinoni	Trane Technologies	US	2029
22	Jianjun Zhang	Zhejiang Chemical Industry Research Institute	PRC	2027

* Indicates members whose terms expire at the end of 2026. See comments under TEAP and TOCs for consistency.

A4.2 TEAP Flexible and Rigid Foams Technical Options Committee (FTOC)

Flexible and Rigid Foams Technical Options Committee members currently have expertise in: producing and handling FBA; foam formulation; foam production (XPS, spray foam, appliance etc.) and life cycle analysis; emissions and banks modelling; certification testing for foams; regulations related to foams; global foam markets including forecasting future production; historical knowledge of foams, FBAs, regulations, and the Montreal Protocol; the building envelope and reducing energy demand from buildings; appliance design and production for EE.

Table A4-2 FTOC Membership at May 2026

	Co-chairs	Affiliation	Country	Appointed through
1	Paulo Altoé	Independent Expert	Brazil	2028
2	Helen Walter-Terrinoni	Trane Technologies	US	2029
	Members	Affiliation	Country	Appointed through
3	Paul Ashford	Anthesis Group	UK	2029
4	Roy Chowdhury	Foam Supplies	Australia	2029
5	Gwyn Davis	Kingspan Group	UK	2029
6	Cecilia Girotti	Dow Italia S.r.l.	Italy	2026*
7	Ilhan Karaağaç	Kingspan Group	Turkey	2029
8	Shpresa Kotaji	Huntsman Corporation	Belgium	2027
9	Lisa Massaro Kustuck	Dupont	US	2026
10	Simon Lee	Independent Expert	UK	2027
11	Jorge Lemus	Productos Eiffel	Mexico	2028
12	Boxun Leng	Wanhua Chemical	China	2028
13	Yehia Lotfi	Technocom	Egypt	2028
14	Smita Mohanty	LARM CIPET Bhubaneswar	India	2028
15	Sascha Rulhoff	H-C-S Group	Germany	2026*
16	Enshan Sheng	Huntsman Corporation	Singapore	2026*
17	Hendro Utama Tjugito	PT Intimas Chemindo	Indonesia	2027
18	Koichi Wada	Japan Urethane Industry Institute	Japan	2028
19	Ernest Wysong	Natural Polymers LLC	US	2027

* Indicates members whose terms expire at the end of the current year

A4.3 TEAP Fire Suppression Technical Options Committee (FSTOC)

The parties renamed the Halons TOC as to the Fire Suppression TOC in 2022 in recognition that the committee had an increased scope beyond halons. This includes assessing current and potential HFC alternatives needed to implement the Kigali Amendment and potential ramifications of the increased reliance on flammable refrigerants.

Table A4-3 FSTOC Membership at May 2026

	Co-chairs	Affiliation	Country	Appointed through
1	Adam Chattaway	Collins Aerospace	UK	2028
	Daniel P. Verdonik	Jensen Hughes, Inc.	USA	2028
	Members	Affiliation	Country	Appointed through
3	Jamal Alfenzaie	Independent Expert	Kuwait	2026*
4	Johan Åqvist	FMV	Sweden	2027
5	Ali Azam	Independent Expert	Bangladesh	2028
6	Carl Chapell	Hilcorp Alaska LLC	USA	2028
7	Michelle M. Collins	Independent Expert - EECO International	USA	2026*
8	Khaled Effat	Modern Systems Engineering	Egypt	2029
9	Alan Elder	Johnson Controls International	UK	2027
10	Laura Green	Alyeska Pipeline Service Company	USA	2028
11	Elvira Nigido	A-Gas Australia	Australia	2028
12	Emma Palumbo	Safety Hi-tech srl	Italy	2026*
13	Erik Pedersen	Independent Expert	Denmark	2028
14	Inderpal Singh Kanwal	CFEES, DRDO	India	2027
15	R.P. Singh	CFEES, DRDO	India	2028
16	Sidney de Brito Teixeira	Embraer	Brazil	2028
17	Mitsuru Yagi	Nohmi Bosai Ltd & Fire and Environment Prot. Network	Japan	2028
18	Yu Bohong	Shanghai Waysmos	China	2028
19	Zouheir Yakine	FirePro Engineering	Morocco	2028
20	Xiaomeng Zhou	Civil Aviation University of China	China	2026*
	Consulting Experts	Affiliation	Country	One-year renewable terms
1	Thomas Cortina	Halon Alternatives Research Corporation	USA	2026*
2	Joshua R. Fritsch	United States Army	USA	2026*
4	Steve McCormick	Huntington Ingalls Industries	USA	2026*
5	John G. Owens	Independent Consultant	USA	2026*
6	John J. O’Sullivan	Bureau Veritas	UK	2026*

* Indicates members whose terms expire at the end of 2025

A.4.4 TEAP Methyl Bromide Technical Options Committee (MBTOC)

The Methyl Bromide Technical Options Committee brings together expertise on controlled and exempted (QPS) uses of methyl bromide and their technically and economically feasible alternatives. Members are experts on the control and management of soil-borne pests and pathogens attacking various crops where methyl bromide is used or was used in the past; pest control in a variety of stored commodities and structures; and alternatives for controlling quarantine pests and pathogens. Members have research, regulatory and commercial experience.

Table A4-4 MBTOC Membership at May 2026

	Co-chairs	Affiliation	Country	Appointed through
1	Marta Pizano	Independent Expert	Colombia	2029
2	Ian Porter	La Trobe University	Australia	2027
	Members	Affiliation	Country	Appointed through
3	Jonathan Banks	Independent Expert	Australia	2026*
4	Mohamed Besri	Inst. Agron. et Vétérinaire Hassan II	Morocco	2029
5	Fred Bergwerff	Oxyflow BV	Netherlands	2029
6	Aocheng Cao	Chinese Academy of Agric. Sciences	China	2026*
7	Guillermo Castellá	Independent Expert	Uruguay	2026*
8	Kang Fenfen	Plant and Foodstuffs Insp. Centre Tiajin Customs District	China	2026*
9	Ayze Ozdem	Plant Protection Central Res. Inst.	Turkey	2026*
10	Ken Glassey	MAFF – NZ	New Zealand	2026*
11	Eduardo Gonzalez	Fumigator	Philippines	2026*
12	Takashi Misumi	MAFF – Japan	Japan	2026*
13	Christoph Reichmuth	Honorary Professor – Humboldt Univ	Germany	2026*
14	Alejandro Valeiro	Nat. Institute for Ag. Technology	Argentina	2026*
15	Tim Widmer	USDA	US	2029
	Consulting expert	Affiliation	Country	Appointed through
16	Matt Hall	Draslovka LLC	Australia	2026*

* Indicates members whose terms expire at the end of the 2026.

A4.5 TEAP Medical and Chemicals Technical Options Committee (MCTOC)

The Medical and Chemicals Technical Options Committee brings together expertise in production, by-production, and feedstock uses of controlled substances, solvent and process agent applications, electronics manufacturing, magnesium production, laboratory and analytical uses, end-of-life management, disposal and destruction of controlled substances, metered dose inhalers and their alternatives, and aerosols. Members are experts in asthma and chronic obstructive pulmonary disease and their treatment, pharmaceutical manufacturing and markets, aerosols manufacturing and markets, chemicals manufacturing and markets, laboratory and analytical procedures, end-of-life management, banks, disposal and destruction. Members have academic, research, clinical, regulatory, laboratory, industrial, business, consulting, and commercial experience.

Table A4-5 MCTOC Membership as of May 2026

	Co-chairs	Affiliation	Country	Appointed through
1	Takeshi Eriguchi	AGC Inc.	Japan	2027
2	Helen Tope	Independent Consultant, Planet Futures	Australia	2029
3	Jianjun Zhang	Zhejiang Chemical Industry Research Institute	China	2027
	Members	Affiliation	Country	Appointed through
4	Emmanuel Addo-Yobo	Kwame Nkrumah University of Science and Technology	Ghana	2026*
5	Fatima Al-Shatti	Consultant to the International Ozone Committee of Kuwait Public Authority of Environment	Kuwait	2026*
6	Paul Atkins	Inhaled Delivery Solutions LLC	USA	2026*
7	William Auriemma	Diversified CPC International	USA	2029
8	Christian Sekomo Birame	National Industrial Research and Development Agency (NIRDA)	Rwanda	2027
9	Steve Burns	AstraZeneca	UK	2029
10	Nick Campbell	Independent Expert	UK	2026*
11	Andrea Casazza	Chiesi Farmaceutici	Italy	2028
12	Nee Sun (Robert) Choong Kwet Yive	Independent Expert	Mauritius	2026*
13	Rick Cooke	Man-West Environmental Group Ltd.	Canada	2029
14	Şerife Erçel	ERCEL Engineering and Environmental Technologies Industry and Trade Limited Company	Turkey	2029
15	Maureen George	Columbia University School of Nursing	USA	2029
16	Susan Holmes	Independent Expert, Sue Holmes CMC Consulting LLC	USA	2028
17	Jianxin Hu	Peking University	China	2026*
18	Junjie Hu	Ministry of Ecology and Environment (MEE)	China	2028
19	Ryan Hulse	Solstice	USA	2028
20	Patsy Jeffery	Cipla Ltd	India	2028
21	Fang Jin	Guangzhou Medical University	China	2028
22	Rabinder Kaul	Independent Expert	India	2027
23	Javaid Khan	The Aga Khan University	Pakistan	2026*
24	Markus Laubscher	Orbia Fluor & Energy Materials	Germany	2029
25	Andrew Lindley	Independent Consultant	UK	2028
26	Tim Noakes	Koura	UK	2026*
27	John G. Owens	Independent Expert	USA	2028
28	Sheng Peng	Chemours	US	2028
29	Maximilian Plank	GlaxoSmithKline	Australia	2029
30	John Pritchard	Independent Expert, Inspiring Strategies	UK	2026*

31	Rabbur Reza	Beximco Pharmaceuticals	Bangladesh	2026*
32	Bettina Schreck	Independent Expert	Argentina	2028
33	Peter Sleigh	Independent Expert	UK	2027
34	Kristine Whorlow	Independent Expert	Australia	2026*
35	Alex Wilkinson	East and North Hertfordshire NHS Trust	UK	2029
36	Gerallt Williams	Independent Expert	UK	2028
37	Ashley Woodcock	Manchester University NHS Foundation Trust	UK	2027
38	Arzu Yorgancıoğlu	Respiratory Medicine at Celal Bayar University, Medical Faculty, Department of Pulmonology	Turkey	2029
39	Lifei Zhang	National Research Center for Environmental Analysis and Measurement	China	2026*

* Indicates members whose terms expire at the end of 2026.

A4.6 TEAP Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee (RTOC)

The RTOC brings together expertise on Refrigeration, Air Conditioning and Heat Pumps (RACHP) sectors. Members are experts of: refrigerants, domestic refrigeration, commercial refrigeration, industrial refrigeration and HP systems, transport refrigeration, air-to-air conditioners and HPs, water and space heating HPs, chillers, vehicle air conditioning, EE and sustainability applied to refrigeration systems, not-in-kind technologies, high-ambient-temperatures applications, modelling of RACHP systems. Members have research, industry activities regulatory and commercial experience.

Table A4-6: RTOC Membership at May 2026

	Co-chairs	Affiliation	Party	Appointed through
1	Omar Abdelaziz	American Univ. in Cairo	Egypt	2027
2	Roberto Peixoto	Maua Institute (IMT)	Brazil	2027
3	Fabio Polonara	UNIVPM	Italy	2026*
4	Natarajan Rajendran	Five Rivers Research & Consulting	USA	2027
	Members	Affiliation	Party	Appointed through
5	Yosr Allouche	International Institute of Refrigeration	Tunisia	2026*
6	Jitendra Bhambure	Independent Expert	India	2026*
7	Maria C. Britto Bacellar	Johnson Controls, JCI	Brazil	2026*
8	Feng Cao	Xi'an Jiaotong University	China	2026*
9	Ana Maria Carreño	CLASP	Colombia	2026*
10	Radim Čermák	Thermo King	Czech Republic	2026*
11	Yu Chen	TRANSICOLD	USA	2026*
12	Daniel Colbourne	Re-phridge Consultancy	UK	2026*

13	Sukumar Devotta	Independent Expert	India	2026*
14	Hilde Dhont	Daikin Europe	Belgium	2026*
15	Gabrielle Dreyfus	IGSD	USA	2026*
16	Bassam Elassaad	Independent Expert	Lebanon	2026*
17	Kylie Farrelley	Refrigerant Reclaim Australia	Australia	2026*
18	Qiang Gao	Sanhua Group	China	2026*
19	Ray Gluckman	Gluckman Consulting Ltd	UK	2026*
20	Samir Hamed	Petra Industries	Jordan	2026*
21	Herlin Herlianka	Independent Expert	Indonesia	2026*
22	Yuky Kamioka	Daikin Industries Ltd	Japan	2026*
23	Michael Kauffeld	Karlsruhe Univ.of Applied Sciences	Germany	2026*
24	Mary Koban	Chemours	USA	2026*
25	Juergen Kohler	University of Braunschweig	Germany	2026*
26	Lambert Kuijpers	A/gent b.v. Env. Cons	Netherlands	2026*
27	Steve Kujak	TRANE.	USA	2026*
28	Richard Lawton	Cambridge CRT	UK	2026*
29	Tingxun Li	Guangzhou Sun Yat Sen U.	China	2026*
30	Carloandrea Malvicino	Stellantis	Italy	2026*
31	Akio Miyara	Saga University	Japan	2026*
32	Petter Nekså	SINTEF Energy Res.	Norway	2026*
33	Mr.Tetsuji Okada	JRAIA	Japan	2026*
34	Pallav Purohit	Int. Inst. for Appl. Syst. Analysis	India	2026*
35	Tao Ren	Qingdao Haier Air Con. Electr.	China	2026*
36	Giorgio Rusignuolo	UTC Carrier	USA	2026*
37	Madi Sakande	New Cold System Bologna	Burkina Faso	2026*
38	Leyla Sayin	Centre for Sustainable Cooling, University of Birmingham	Turkey	2026*
39	Andrea Voigt	Danfoss	Germany	2026*
40	Asbjørn L. Vonsild	Vonsild Consulting	Denmark	2026*
41	Christian M. Wisniewski	US EPA	USA	2026*
42	Samuel Yana Motta	ORNL	Peru	2026*

* Indicates members whose terms expire at the end of 2026

Annex 3 - Matrix of needed expertise

As required by the TEAP TOR an update of the matrix of needed expertise on the TEAP and its TOCs is provided below valid as of May 2026.

To facilitate the submission of appropriate nominations by the parties, the TEAP TOR require the TEAP and its TOCs to draw up guidelines for the nomination of experts by the parties. Section 2.9 of the TOR states that “*the TEAP/TOCs will publicize a matrix of expertise available, and the expertise needed in the TEAP/TOCs so as to facilitate submission of appropriate nominations by the parties*”. The matrix must include the need for geographic and expertise balance and provide consistent information on expertise that is available and required. The matrix would include the name and affiliation, and the specific expertise required including on different alternatives. The TEAP/TOCs, acting through their respective co-chairs, shall ensure that the matrix is updated at least once a year and shall publish the matrix on the Secretariat website and in the Panel’s annual progress reports. The TEAP/TOCs shall also ensure that the information in the matrix is clear, sufficient and consistent as far as is appropriate between the TEAP and TOCs and balanced to allow a full understanding of needed expertise.”

The matrix of needed expertise is the basis for facilitating the nomination by parties of appropriate experts to the TEAP and its TOCs and TSBs. Nominations are typically made through a simple communication to the TEAP or TOC or the Ozone Secretariat accompanied by the curriculum vitae of the nominee. In annex C to its report issued in May 2012 pursuant to decision XXIII/10, the TEAP had proposed a draft standardized nomination form for detailed information about a nominee, such as education and other qualifications, employment history, publications, awards, memberships, language knowledge and references. Consultation among the parties and TEAP and its TOCs and TSBs on potential nominations are helpful to ensure the appropriate experts are considered. In the case of nominations or renominations for membership in a committee, the committee co-chairs consult with the Panel co-chairs and the relevant national focal points. Nominations for committee membership and appointments to a committee can be made at any time. Section 3.5 of the TOR states that once appointed, “TEAP/TOCs/TSBs members function on a personal basis as experts, irrespective of the source of their nominations and accept no instruction from, nor function as representatives of Governments, industries, nongovernmental organizations (NGOs) or other organizations.”

As explained in Chapter 8 on options for TEAP and TOC reorganization, TEAP does not intend to introduce substantial changes to the membership of its TOC in the period 2025-2026 since the 2026 Assessment Report preparation is currently under way. Nevertheless, some TOCs have identified a need for additional expertise as seen in Table A5-1 below. Nominations from parties to meet the gaps in expertise identified in the matrix would be very helpful to TEAP.

Table A5-1: Matrix of needed expertise for the TEAP

Body	Required Expertise	A5/ Non-A5
Fire Suppression Technical Options Committee	Use of HFCs and alternatives	Central and /or South America, Middle East and southern Africa (2)
	Use of halons and alternatives in merchant shipping and recovery from shipbreaking	Pakistan

	Nuclear power plants	A5 and non-A5
	Civil aviation, (especially maintenance, repair and overhaul (MRO) activities)	A5 and non-A5
	Halon and HFC recycling	A5
	Halon 1301 feedstock use and emissions	A5 and non-A5
Foam Technical Options Committee	Extruded Polystyrene (XPS) production in India and China Polyurethane system house technical experts – particularly from Southern Africa, South Korea, the Middle East, Latin American parties, especially experts within small- and medium-sized enterprises (SMEs) FBA production, chemistry, and supply chains	A5 or non-A5
Methyl Bromide Technical Options Committee	Members with expertise on MB alternatives used to effectively treat quarantine pests affecting import and export of agricultural commodities globally	A5 or non-A5
Medical and Chemicals Technical Options Committee	Aerosols and pMDI manufacturing	A5 (Africa, China, South America), non-A5
	CTC and VSLS global manufacturing and use	A5 or non-A5
	Semiconductor and other electronics manufacturing	East Asia, non-A5
	End-of-life management and destruction technologies	A5 and non-A5
Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee	No additional expertise needed	
Senior Experts	No additional expertise needed	

Annex 4 - TEAP Nomination Form

For reference the standard nomination form can be found below or at:

https://ozone.unep.org/sites/default/files/assessment_panels/teap-nomination-form-2022.docx.

TEAP: Nomination Form

This form is to be completed by:

Parties nominating experts to the TEAP, Technical Options Committees (TOCs), or Temporary Subsidiary Bodies (TSBs)

Please provide a CV detailing the candidate's previous, relevant employment beginning with the most current one. Experience and expertise relevant to the Montreal Protocol are particularly important and a list of relevant publications is useful (do not provide copies of publications)

Position Nominated for:

Expert Information

Please provide full names rather than only acronyms or initials

Title: Ms. Mr. Other: _____
 Professor Dr

Name (underline family name):

Employer / Organization:

Job Title:

Email:

Web Site:

Nationality/ies:

Applicant profile

Main Countries or Regions
Worked or Experience in
(with relevance to Montreal
Protocol)

Employment History and/or Relevant Experience

Please provide a short
summary of the applicants'

Publications

Please give a list of relevant publications (do not attach) (No need to fill this section if already provided with CV)

English Proficiency and computer skills

All meetings, correspondence and report writing are conducted in English so good command of English is essential. If English is not your mother tongue [native language] please describe briefly your proficiency to speak, read, and write in English. Basic computer literacy (Word, Excel, Power Point) for

References

Please provide names of two persons who have worked with you on issues relevant to the Montreal

Confirmation and Agreement

I hereby confirm that the above information is correct and agree for review by the TEAP. I have no objection to this information being made publicly available. I also confirm that, if appointed, I will review and agree to abide by TEAP's terms of reference, its code of conduct, operational procedures, and relevant decisions of the Parties as per Decision XXIV/8: <https://ozone.unep.org/node/1953>

Signature: _____ Date: _____

Confirmation by Nominating Government

This section must be completed by the national focal point of the relevant party.

Government: _____

Name of Government Representative: _____

Signature: _____ Date: _____

To be completed by the national focal point in the case of nomination by the party:

Has the matrix of needed expertise of TEAP been consulted?

<https://ozone.unep.org/science/assessment/teap/teap-expertise-required>

Yes No

Has TEAP been consulted on this nomination?

Yes No

PLEASE RETURN COMPLETED FORM TO: THE OZONE SECRETARIAT

ADDITIONAL INFORMATION - Expectations for members of TEAP, TOCs and TSBs

Work done for TEAP, its TOCs and TSBs is on a voluntary basis and does not receive any remuneration [funding for their time]. Members from A 5 parties may be funded for their travel (flight) and per diem (UN DSA) only to relevant meetings, based on needed participation and availability of funding. Members are expected to attend meetings, engage in discussions, and devote time to the preparation of reports including finding and reviewing information to respond to the tasks set out by the Parties, drafting and formatting reports or sections of reports, reviewing reports and preparing presentations. TOC members attend at least annual meetings of that TOC. TOC co-chairs also attend the annual TEAP meeting, and typically two meetings per year of the Montreal Protocol. TSB members attend meetings of the TSB and may be asked to attend up to two meetings of the Montreal Protocol, based on needed participation and availability of funding.

All meetings, correspondence and report writing are conducted in English so good ability to read English plus good command of spoken and written English are essential.

Basic computer literacy (Word, Excel, Power Point) for drafting and editing products is required. Advanced computer/ document formatting skills are an asset.

All appointed members of TEAP, TOCs or TSBs should provide a “Declaration of Interest” prior to a meeting and at least once a year. The DOIs are posted at the Ozone Secretariat website.

In submitting a CV to support a nomination, Parties may wish to provide a short summary of the applicants' expertise and skills, as they relate to the position for which he/she is being nominated, including the main countries or regions worked or experience in (with relevance to Montreal Protocol). Also please indicate if the nomination is in response to a specific category listed in the Matrix of Expertise published by TEAP

<https://ozone.unep.org/science/assessment/teap/teap-expertise-required>

Once appointed, members of TEAP, TOCs or TSBs provide a "Declaration of Interest" (DOI) at least once a year and prior to the group's first meeting. Members provide updated DOIs within 30 days of any changes. The DOIs are posted on the Ozone Secretariat website.

Members review and agree to abide by TEAP's terms of reference, its code of conduct, operational procedures, and relevant decisions of the Parties as per Decision XXIV/8:

<https://ozone.unep.org/node/1953>