MONTREAL PROTOCOL

ON SUBSTANCES THAT DEPLETE

THE OZONE LAYER

REPORT OF THE
TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL

MAY 2019

VOLUME 1: PROGRESS REPORT

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United Nations Environment Programme (UNEP)
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Foreword

The May 2019 TEAP Report

The 2019 TEAP Report consists of four volumes:

Volume 1: *TEAP 2019 Progress Report*
TOC Progress Reports
TEAP administrative issues and lists of TEAP and TOC members at May 2019
Matrix of expertise
Volume 2: *MBTOC Interim CUN Assessment Report – May 2019*
Volume 3: *Decision XXX/3 Tazsk Force Report on Unexpected Emissions of CFC-11*
Volume 4: *Decision XXX/5 Task Force Report on Access of A5 Parties to Energy-Efficient Technologies in RACPH sectors*

This is Volume 1

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MAY 2019 PROGRESS REPORT
TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL

VOLUME 1

TABLE OF CONTENTS

1 Introduction

This is volume 1 of 4 of the May 2019 Technology and Economic Assessment Panel (TEAP) Report and contains Progress Reports from the five Technical Options Committees (TOCs) composing the TEAP: Flexible and Rigid Foams TOC (FTOC), Halons TOC (HTOC), Methyl Bromide TOC (MBTOC), Medical and Chemicals TOC (MCTOC) and Refrigeration, Air Conditioning and Heat Pumps TOC (RTOC).

The TEAP and TOC membership lists, as at 31st May 2019, which includes each member's term of appointment, expertise brought together by the TOCs and a matrix of needed expertise for the TEAP and its TOCs appear in annexes at the end of this document. Specific organisational issues relating to each TOC and to TEAP are also discussed in Chapter 7 and in the relevant annexes.

The TEAP and its TOCs only recently completed and published their quadrennial Assessment Reports. Therefore, the following chapters present progress and developments identified by TOCs as of December 2018, after submission of the Assessment Reports.

TEAP would like to express its sincere gratitude for the voluntary service of the TOC members and their contributions to the work of completing the 2018 Assessment Reports. We look forward to future contributions of both continuing and new members to the TOCs.

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2 Flexible and Rigid Foams TOC (FTOC) Progress Report

2.1. Introduction

- The FTOC continues to explore possible causes of the unexpected emissions of CFC-11 with focus on possible scenarios related to the foam sector. More detail is available in the 2019 Task Force Report on Unexpected Emissions of CFC-11. Highlighted below are some of the preliminary findngs and continuing areas of focus for foams on this issue:

    - It seems unlikely that the unexpected emissions have resulted from the traditional handling of foams at end-of-life alone unless there has been a significant change in those processes resulting in emissions from appliances and construction for very large volumes of foams. FTOC continues to examine foam disposal practices.
    - Although technically feasible, the FTOC questions the economic incentive to replace methylene chloride with CFC-11 in flexible foams, given methylene chloride's very low cost. The FTOC continues to explore the possibility that some enterprises are using CFC-11 to reduce volatile organic compound emissions from flexible foams as restricted in some parties or to limit the use of methylene chloride owing to toxicity concerns.
    - Further investigation is warranted into the use of CFC-11 in rigid polyurethane (PU) foams and in premixed polyol systems for PU rigid foams as it is technically feasible and more economically advantageous than reverting to the use of CFC-11 in flexible foams as postulated above. However, it seems unlikely that multi-national or other large system houses or foam producers would risk their reputations[1] by knowingly using CFC-11. Some of the volumes of CFC-11 emissions noted would require the usage of CFC-11 to extend beyond the likely use within smaller or local system houses. Concerns related to conversion of enterprises in the spray foam sector and small and medium enterprises (SMEs) have created the most challenging issues that might drive the further use and release of CFC-11. Whether or not this actually has resulted in any usage of previously banned blowing agents on a significant basis has not been confirmed.
    - It is important to note that any scenario where significant CFC-11 is used in rigid foams would require significant production and would increase the foam banks because most of the CFC-11 stays in the foam and only a percentage is emitted during the blowing of the foam.
    - There is a gap between the projected emissions from foams in banks (including landfills) based on emission rates found in the literature and the derived atmospheric emissions, even in regions where CFC-11 has not likely been used in decades (<1.5% vs 3-4%). It is possible that further processing of foams before disposal through shredding and crushing of foams accounts for at least some of that difference. The FTOC proposes continued investigation into the gap between literature data related to release rates as well as re-use and disposal of foams containing CFC-11.

- New foam blowing agent manufacturing capacity is now producing HCFO-1224yd(Z) in Japan and significant quantities of HCFO-1233zd(E) in China.
- A5 parties face combined challenges in phasing out hydrochlorofluorocarbons (HCFCs) at the same time as avoiding high global warming potential (GWP) HFC blowing agents, which are themselves subject to phasedown. However,

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[1] Use of CFC-11 may have local legal consequences and shipping foams or polyol blends containing CFC-11 may breach customs restrictions

- HPMPs continue to drive transitions in foams.
- In general, HCFCs are ~ 20-30 % of the cost of high GWP HFCs. Hydrofluor-olefin / hydrochlorofluoro-olefin HFO/HCFO blown foams remain more expensive than HFC foams due to the total cost of blowing agent and required additives.
- For most A5 parties, import of ODS itself is controlled or under license, but polyols containing HCFC-141b can be imported without controls. To counter this, some A5 parties have implemented regulations that would ban or restrict import of CFC and HCFC-containing polyol systems.
- Decisions on transition for some segments (e.g. spray foam and extruded polystyrene [XPS]) may be delayed because the cost of transition remains a barrier for some applications and regions, especially where performance goals are demanding, pending further optimization of the transition process.
- Although additional capacity is now producing significant volumes of low GWP alternatives, communication between regulators, producers and users will be needed to ensure smooth transitions.

2.2. Global Markets for Foams

- Total global production of polymeric foams continues to grow (3.2% per year) at a slightly lower rate than noted last year (4.0%), from an estimated 25.4 million tonnes in 2018 to 29.8million tonnes by 2023. Production of foams used for insulation is expected to grow in line with global construction and continued development of refrigerated food processing, transportation and storage (cold chain).

Estimated Global Polymeric Foam Production 2018-2023 (tonnes & CAGR[1]%)			
	2018	**2023**	**CAGR**
Polyurethane (PU)	**(tonnes)**	**(tonnes)**	**%**
Rigid	5597600	6,831,808	4.1%
Flexible	7591140	9,100,541	3.7%
Total Polyurethane Foam	**13188740**	**15,932,349**	**3.9%**
Polystyrene (PS)			
Expanded Polystyrene (EPS)	8,775,250	9,890,000	2.4%
Extruded Polystyrene (XPS)	1,785,000	1,850,000	0.7%
Total Polystyrene Foam	**10,560,250**	**11,740,000**	**2.1%**
Other foams (phenolic, ENR, etc)	1,701,700	2,150,000	4.8%
Total Foams	**25,450,690**	**29,822,349**	**3.2%**

[1] Compound Annual Growth Rate
[2] Sources: Market & Market, IAL Consultants, Industry Report

The market size of polymer foam is projected to grow at a Compound Annual Growth Rate of 3.2% from 2018 to 2023 in volume from just over 25.4 million tonnes to 29.8 million tonnes. The rate of growth is estimated to be slowing due to lower economic growth.[2]

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[2] Market & Market Global Polymeric Foam Report 2017-2022

2.3. Global Drivers for Foams

The increasing level of urbanisation and growth of the middle class remain the main drivers of the global polymeric foam market. Demand is driven by its wide range of end-use industries, building & construction, the cold chain, furniture & bedding, packaging and automotive industries. Urbanisation is one of the key factors in the growth of the commercial refrigeration equipment market due in part to an increasing consumption of meat and chilled foods. Although most major countries have a high penetration of refrigerators and freezers, replacement is being driven by demand for large models, greater energy efficiency as well as connectivity through the internet.

Polyurethane (PU), extruded polystyrene (XPS), expanded polystyrene (EPS) and phenolic foams contribute to reducing energy consumption in buildings, while XPS and PU rigid foams are the main foam types used within the cold chain. The relative demand for each type of foam depends upon end-use, cost, availability and performance. XPS is preferred for insulating perimeters, facades, and flat roofs as it offers good mechanical properties such as high compressive strength and water-repellent surface texture. It is also used as a load-bearing insulation material in civil engineering due to its lightweight nature. EPS has many applications in construction and packaging; however, the oscillating prices of raw materials and stringent environmental regulations might hamper the global growth in demand. Conversely, the growing demand for recycled polystyrene products across the world is projected to provide new growth opportunities in the future.

The main drivers for thermal insulation are legislation and building standards to reduce heat loss. The EU and North America are currently leading proponents of building codes to improve energy efficiency in the construction industry. Emerging countries are also trying to increase energy efficiency through the use of thermal insulation, to reduce the stress on power supplies. However, regulations concerning the flammability of polymeric foams in inhabited buildings, has limited their use, especially in China and may limit future growth in other regions of the world.

New applications for polymeric foams continue to grow in areas as diverse as wind turbine blades and acoustic and thermal insulation for electric vehicles. However, legislation concerning disposal and recycling of post- consumer polymeric foam and concerns about exposure to isocyanates are increasingly important and may slow demand growth in the longer term.

2.4. Drivers Impacting Blowing Agent Choice

For **Article 5 parties,** a growing number of foam producers are required by regulation to transition to zero ozone depletion potential (ODP) blowing agents. In some parties, use of HCFCs is limited to applications where hydrocarbons (HCs) are not suitable, such as spray foam. In others, HCFCs are still widely used. Some parties are working to limit imported CFC-11 and HCFC 141b pre-blended polyol and manufacture of foam using ODSs. Globally, the production phase down controlling the availability and increasing price of HCFCs may drive the selection of foam blowing agents.

2.5. Additional Blowing Agents in Current Use

HFOs/HCFOs provide an alternative to HCs which can eliminate or reduce the flammability for polyurethane, polyisocyanurate, phenolic, and extruded thermoplastic foam production eliminating the capital investment required to address safety when using HCs as a blowing agent. In addition, the use of HFOs/HCFOs often results in improved foam insulating values compared to HC blown foams. There have been significant improvements in the development and availability of additives, co-blowing agents, equipment and formulations enabling the successful commercialization of foams containing low GWP blowing agents. The transition to HFOs/HCFOs amongst PU foam SMEs is currently slowed by both their greater expense and limited, but improving, supply of some HFO/HCFOs in A5 parties. HFO/HCFOs are sometimes commercially blended with other blowing agents to reduce costs in both A5 and non-A5 parties.

Manufacturers of HFO/HCFOs have significantly increased capacity of some of the HFOs/HCFOs to meet the demand for low GWP blowing agents that is expected to result from the implementation of low GWP regulations. Continued coordination could be helpful to ensure that there is adequate supply as regulations are implemented.

HCFO-1224yd(Z) was commercialized in Japan. Its boiling point is 15C and it's molecular weight is 149 (similar to HCFO-1233zd€.

Other Blowing Agents and Co-blowing Agents continue to be used in small quantities.

Iso PropylChloride (2-ChloroPropane) is blended with Iso Pentane generally for Phenolic Foam.

FA188 has been normally used and viewed technically as nucleating agent. However, based on the European Norm (EN13165), this material can be found in the cell gas after 6 months @ 70 Deg C in Polyisocyanurate (PIR) foam, then it is classified as a blowing agent, as well.

A patented chemical blowing agent (trade named CFA8) is being promoted to the polyurethane market by China's Butian New Materials and Technology Company. It is expected that other innovative chemical and physical blowing agents will be introduced over the next several years.

Blowing Agent Blends

The demand for HFOs/HCFOs will be influenced by the formulations that are developed. Significant work is on-going by system houses to reduce HFO/HCFO loading in final foam products. HFC/HCFO blends are increasingly in use (e.g. pentane blends for appliances). Equipment companies are developing in-line, multi component blending equipment to facilitate this (Table 1).

Within the framework of the Multilateral Fund demonstration project on discontinuous panel in Article 5 parties, whose results were reported in June of 2018[3] HFO based formulations with blowing agent reductions of 61 to 64 by weight were developed with a significant improvement of the cost/performance balance.

Please note that foam manufacturers may combine any blowing agents (e.g. methyl formate, pentanes, HCFCs, HFCs, HFOs, HCFOs, CO_2 etc.) in foams or in polyol blends in proprietary or commercially marketed blends.

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[3] *Demonstration project to validate the use of Hydro-Fluoro-Olefins (HFO) for discontinuous panels in Article 5 Parties through the development of cost-effective formulations*", UNDP report, submitted on behalf of the Government of Colombia at the 81st meeting of the Executive Committee of the Multilateral Fund, Canada, June 2018 (Decision 81/19).

Examples:

Component 1	Component 2	Component 3	Foam Type
Any HFC or HFO/ HCFO	HFC-152a, CO_2, butane, ethanol, DME, alcohols		XPS
Any HFC or HFO/ HCFO	pentanes, methyl formate, formic acid, trans DCE, water		PU
HFC-365mfc	HFC-227ea		PU and polyol blends
HFC-245fa	HFC-365mfc		PU
HFC-245fa	HFC-134a		PU
HFC-245fa	HFC-134a	pentane*	PU
HFO-1233zd(E)	cyclopentane		PU
HFO-1336mzzm(Z)	HFO-1336mzzm(E)		PU
HFO-1336mzzm(Z)	other pentanes		PU
HFO-1233zd(E)	other pentanes		PU
HFO-1233zd(E)	HFO-1234ze(E)		XPS & PU
HFO-1234ze(E)	DME		XPS
HFO-1234ze(E)	Ethanol		XPS
HFO-1234ze(E)	normal butane		XPS
HFO-1234ze(E)	isobutane		XPS
HFC-134a	HFC-152a		XPS
HFC-134a, HFC-134	HFC-152a		XPS
HFC-134a	HFC-134		PU
HCFC-142b	HCFC-22		XPS
HCFC-141b (temporary solution when HCFC-141b is short)	HFC-245fa		PU
HFC-245fa	trans 1,2-dichloroethylene		PU
Super-critical CO_2 (nucleation agent for flexible)	methlyal		flexible foams
Methylene Chloride	Water		flexible foams
2-Chloropropane	pentane		Phenolic
Pentane blends	combinations of iso, n, cyclo-pentanes		PU

For PU, all known blowing agents and blends plus water

For XPS, all known blowing agents and blends plus CO_2

*Pentanes could be any combination of pentane isomers iso, normal or cyclo-pentane

3 Halons TOC (HTOC) Progress Report

HTOC has recently submitted its quadrennial Assessment report for the period 2015-2018. Therefore, this short 2019 HTOC Progress report only updates progress and developments relevant to this sector since the completion of the 2018 Assessment report.

The International Civil Aviation Organization (ICAO) has changed their preparatory cycle for their triennial General Assembly meetings such that safety issues (such as halon replacement) must now be ready to be addressed one full year before the General Assembly. Therefore, halon issues will not be able to be addressed again until the 2022 General Assembly.

Despite over 25 years of research, the civil aviation industry has failed to find replacements that they deem acceptable for engine and cargo bays, but research is still on-going. Without significant reduction in halon 1301 dependency, it is likely that their demand will continue beyond the time when recycled halon is available. Parties may wish to consider liaising with their (civil aviation) airframe manufacturers and civil aviation regulatory bodies to urge the adoption of halon 1301 alternatives in cargo bays and engine nacelles and to determine all activities that can reduce emissions from these applications.

The informal working group established by ICAO for Decision XXIX/8 is continuing its work to better estimate halon emissions from civil aviation and will transition to activities for Decision XXX/7. In addition, the HTOC has developed an internal working group for Decision XXX/7 to continue to work with both the International Maritime Organisation (IMO) and ICAO.

Based on additional consultation with IMO staff, the lifetime of ships could be less than the 30 to 40 years estimated by the HTOC in its reports for Decision XXVI/7 and XXIX/8. If this turns out to be the case, the amount of halon 1301 from shipbreaking could be nearly already exhausted. The HTOC is actively seeking additional expertise in shipbreaking activities as listed in our matrix of needed expertise.

IMO, with HTOC support, updated the IMO Circular listing global halon banking and reception facilities for maritime access in late 2018. The IMO released a notice in January 2019 of the action to add the list of facilities to the IMO Global Integrated Shipping Information System (GISIS), a database which is available to all IMO Member States. The Member States will be able to update and maintain their entries in relation to halon recycling and reception facilities on the GISIS database

In February 2019, HTOC co-chairs briefed eight of the nine regional networks on ongoing issues to related to halons and on preparations for addressing HCFCs and high-GWP HFCs in the fire protection sector during the Second Global Inter-regional and Parallel Networks Meeting for National Ozone Officers sponsored by United Nations Environment OzonAction. HTOC plans to continue to liaise with each of the networks to improve awareness and institutional strengthening (capacity building) on current halon issues and to prepare for upcoming HCFC and HFC issues in the fire protection sector. HTOC is also seeking assistance in identifying additional members to fill in expertise gaps as listed in the HTOC matrix of needed expertise.

The HTOC is planning to develop a new technical note to address fire prevention aspects of fire protection in addition to its reports and technical notes on technical and economic aspects of alternatives to halons, HCFCs and high-GWP HFCs used in “active” fire suppression and extinguishment systems.

The European Commission has passed Commission Implementing Regulation (EU) 2019/133 in January 2019 amending Regulation (EU) 2015/640 as regards the introduction of new additional airworthiness specifications for large airplanes and large helicopters. This Regulation implements the ICAO requirements that lavatory waste receptacle extinguishers and portable fire extinguishers do not use halon for in-production aircraft as of 18 February 2020 and 18 May 2019, respectively.

4 Methyl Bromide TOC (MBTOC) Progress Report

4.1. Introduction

MBTOC has recently submitted its quadrennial Assessment Report for the period 2015-2018. Therefore, this short 2019 MBTOC Progress Report only addresses progress and developments relevant to methyl bromide production and consumption for both controlled and exempted uses occurring since then.

This report also includes a brief update on the collaboration between the International Plant Protection Convention (IPPC) and MBTOC and developments within that body, plus a report on an emergency use of MB. Some emerging challenges associated to MB use and phase-out are also discussed.

4.2. Update on alternatives for remaining critical uses

Technically and economically feasible chemical and non-chemical alternatives to MB have been found for virtually all soils, structure and commodity applications for which MB was used in the past including nearly all critical uses applied for since 2005. Comprehensive information is available on the adoption of key alternatives in the recent Assessment Report (MBTOC 2019).

However, in spite of active research and some promising results of late, progress in phasing out specific critical uses, such as for strawberry runners in Canada and Australia and to control some soil borne pathogens such as the false root-knot nematode (*Nacobbus)* on tomato in Argentina, is proving more difficult.

Assessment of critical uses from some A5 parties is proving difficult because research data from trials within the specific circumstances of their nominations may be limited.

In museums, churches, houses and other premises with plenty of wooden parts, where MB had been the chemical of choice to be used for disinfestation, the worldwide replacement of MB has occurred with alternatives, including inert gases or sulfuryl fluoride (SF) and heat.

The MBTOC 2018 Assessment Report (MBTOC, 2019) provides updated information on recent research related to alternatives to controlled uses of MB for which critical uses are still being requested, including tomatoes (for control of false root-knot nematodes), strawberry runners and fruit and structures (mills, houses). The full report can be downloaded at https://ozone.unep.org/science/assessment/teap

4.3. MB use for QPS purposes

Due to almost complete phase-out of MB for controlled uses, QPS (exempted) uses have become, by far, the main uses of MB. Detailed and updated analysis on consumption and production of MB for QPS purposes can be found in the MBTOC 2018 Assessment Report (see https://ozone.unep.org/science/assessment/teap).

Currently, nearly all the MB used for QPS is emitted to the atmosphere, and despite recapture systems being available for MB, they are not widely adopted. This is because they impose a cost for the user and thus are considered uneconomical (compared to venting directly to the atmosphere) or local policies are not in place to encourage or mandate their use.

Recapture systems are however being implemented due to other environmental and human safety concerns outside of Montreal Protocol regulations. For example, the New Zealand

Environmental Protection Agency (EPA) requires mandatory recapture or destruction of all available methyl bromide left in the enclosures after QPS fumigation from October 2020. Recapture from ship holds is still under development as is recycling MB. Smaller recapture units utilizing activated carbon or liquids are being used for shipping container recapture. A destruction process for MB has also been approved by the Montreal Protocol, and this could provide further opportunity to reduce emissions. Overall, MBTOC estimates that there is scope for avoiding about 70% of current yearly emissions derived from QPS (about 8,500t) if recapture/destruction technologies were used.

The off gassing/venting of MB from QPS uses to the atmosphere is now the key reported contributor to the global anthropogenic concentrations of MB in the atmosphere, and these could be controlled. Any increase in use for QPS will thus offset any benefit gained by phasing out MB for controlled uses.

MBTOC further notes that recently, concerns over air quality and the risk to public health were causing authorities in North Carolina to impose greater regulations on MB use, including greatly reducing the levels of emissions. In 2018, the authorities withdrew a permit for a new facility to use MB for log fumigation for QPS uses and also imposed a review of all use of MB at existing facilities. Comments from authorities suggested that the review may require permit holders to capture and control a minimum of 90% of MB emissions; they further considered that feasible capture and control technologies exist and should be included in all permit applications (SELC, 2019). Even though this is outside the control measures of the Montreal Protocol, it is an action providing benefit to the ozone layer.

In spite of the above, it is important to note that parties are encouraged to minimize and replace MB for QPS whenever possible. Considering that MBTOC has identified opportunity for replacing 30 to 40% of QPS uses with immediately available alternatives, it is suggested that parties may wish to strengthen initiatives for controlling both use and emissions of MB from QPS uses to any extent possible.

Chemical alternatives currently under research in the QPS sector which continue to show promising potential include ethyl formate (EF) alone or combined with phosphine, CO_2 or N_2 (Yang *et al.* 2016; Jamieson *et al.* 2016; Grout and Stoltz, 2016) and ethanedinitrile (EDN) (Pranamornkith *et al.* 2014; Park *et al.* 2014; Bong-Su *et al*. 2015).

Promising non-chemical alternatives being adopted for QPS uses include irradiation, heat and cold treatment, bark removal and vacuum/controlled atmospheres (Hallman 2016, UNEP, 2016, MBTOC, 2019).

Treatment of durable and perishable agricultural products to comply with quarantine requirements can be achieved with physical options like cold and heat, or inert gases like nitrogen and carbon dioxide used with controlled (CA) or modified (MA) atmospheres with low residual oxygen. These are promising alternatives to MB already in use in some countries. These phytosanitary treatments can be harmonized for specific pest species, i.e. *Ceratitis capitate* and *Bactrocera dorsalis*, regardless of country of origin of marketed fruit hosts (Hallman et al., 2018, Dohino et al., 2017). However, phytosanitary treatments stablished for a specific pest species may not always be effective against other species (Follet *et al*., 2018).

The MBTOC 2018 Assessment Report also provides updated information in this respect (MBTOC, 2019).

4.4. International Plant Protection Convention (IPPC)

On the basis of a Memorandum of Understanding (MOU) subscribed between the International Plant Protection Convention (IPPC) and the Ozone Secretariat, MBTOC maintains regular communication with relevant bodies of IPPC dealing with phytosanitary measures and standards where MB is of interest, in particular the Commission on Phytosanitary Measures (CPM).

At its 13th Session (Rome, April 2018) the CPM conducted and adopted of a revision of ISPM (International Standard for Phytosanitary Measure) No. 15 dealing with treatment of wood packaging materials. This revision, which has become official in January 2019 (FAO, 2019a), includes sulfuryl fluoride as an additional valid treatment to MB or heat (including microwaves) to comply with this standard. Further information on this standard has been published at the IPPC portal in February 2019: *"Regulation of wood packaging material in international trade"* (FAO, 2019b).

More recently, the CPM-14 was held from 1 to 5 April 2019 also in Rome (FAO headquarters). Of interest to MBTOC work, the commission adopted ISPM 43 *"Requirements for the use of fumigation as a phytosanitary measure"* (FAO, 2019b). This standard "provides technical guidance for national plant protection organizations (NPPOs) on the application of fumigation as a phytosanitary measure" (FAO, 2019b). It also serves as a guide for NPPOs on the authorisation processes necessary for fumigation services. It does not consider specific treatments with specific fumigants.

The IPPC has now approved and published 26 international approved treatments in recent years for use on a combination of fresh produce, wood or pest specific treatments through the ongoing work of the Technical Panel on Phytosanitary Treatments

Complete texts of all ISPMs and their revisions are available on the International Phytosanitary Portal (IPP) at https://www.ippc.int/en/core-activities/standards-setting/ispms/

Other lists of quarantine treatments are available at:

https://www.eppo.int/RESOURCES/eppo_standards/pm10_phytosanitary_treatments

https://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/treatment.pdf

https://www.mpi.govt.nz/.../1555-approved-biosecurity-treatments-for-risk-goods
http://www.pps.go.jp/english/law/list2-2.html

In addition, the UN Assembly has proclaimed 2020 as the International Year of Plant Health, with the aim of "increasing awareness among the public and policy makers of the importance of healthy plants and the necessity to protect them in order to achieve Sustainable Development Goals". FAO will spearhead related activities through the IPPC secretariat. MBTOC will explore ways in which, through the MOU signed between the Ozone Secretariat and IPPC, it can have an active role in matters and activities of common interest.

4.5. Emerging challenges

4.5.1. Previously unrecorded uses of MB

The National Agency for Food and Drug Administration and Control (NAFDAC) of Nigeria announced in February 2019 a ban on methyl bromide as a pest control fumigant (NAFDAC, 2019; UNEP, 2019). NAFDAC is the government agency regulating chemicals in Nigeria but their specific use in phytosanitary treatment is the statutory responsibility of The Nigeria Agricultural Quarantine Service (NAQS) as the National Plant Protection Organization (NPPO) for Nigeria, operating under IPPC guidelines. NAQS has confirmed to MBTOC that MB use is still allowed for quarantine uses due to lack of suitable alternatives (i.e. to comply with ISPM

15) and where a specific request to treat export goods with MB is made by some countries (e.g. Mexico).

When accessing the Ozone Secretariat Data Centre, however, MBTOC finds that this party has not reported any controlled uses of MB since 2004 (when usage of 1.7 ODP tonnes was reported) and has never reported any QPS uses. On several occasions, MBTOC has indicated that parties continue to encounter difficulties in reporting MB, as well as differentiating the categories of MB uses (controlled and exempted). This may be one of those cases.

4.5.2. Treatment of waste with MB in China

During its annual meeting held in Qingdao, China (March 4-8, 2019), MBTOC visited a quarantine fumigation company. This single company (one of about 15 in the Shandong province alone) declared the use of about 100 tonnes of MB for "quarantine uses" in 2018, mainly comprising logs and used machinery (e.g., cars) (uses known to MBTOC), but also imported waste paper and plastic for recycling (a previously unknown use). The reported objective is controlling pests and potential vectors of diseases (e.g., insects, rodents). According to the company, the MB used for these purposes is 100% from domestically manufactured MB, and many other companies could be fumigating with MB to the same end.

Until recently, China was the main world player in international solid waste trade. The recycling activity has grown dramatically in China over the past two decades and China is presently importing more than 50% of the recyclable waste plastic and paper generated globally (although new restrictions now in place are significantly and increasingly reducing the quantities imported). When waste is imported into China, the Commodity Inspection or Quality Inspection officer examines goods before giving clearance. If fumigation is deemed necessary, an authorised fumigation service provider is called to apply the treatment; the consignee or the consigner may pay the charge (Sai Ling *et a*l., 2010; Men and Yoshida, 2012; Bamy *et al*., 2018).

The above raises questions for MBTOC, about the number of companies that may be fumigating waste with MB, and the quantities used in China. It is also not clear whether this use fits within the definitions of quarantine and pre-shipment as included under the Montreal Protocol. MBTOC has not assessed this kind of use in the past, but it is probable that alternatives are available and could be used. MBTOC is unclear if any alternatives are being used or considered for use. MBTOC also does not know if recycling/recapture is being used.

MBTOC is also concerned whether this use is being reported and included in totals reported under Article 7 to the Ozone secretariat every year.

Finally, some neighbouring countries in SE Asia (Thailand, India, Vietnam) are increasingly participating in global waste recycling trade (NYT, 2019). MBTOC is also unclear whether this waste is fumigated with MB and if so, whether it is reported. Parties may wish to address this issue through reaching out to the relevant officials in all parties.

As this use appears to involve a large volume of MB, which is directly emitted to the atmosphere, MBTOC suggests parties may wish to consider investigating this use, whether alternatives are available, and how to minimise emissions of MB.

4.5.3. Sustainability of alternative fumigants

The volatile nature of fumigants facilitates their emission from the soil into the atmosphere, where their toxicity may have impact on human health and negative impacts on the environment. For this reason, and despite their importance in replacing MB, some key alternative fumigants are under scrutiny from regulatory authorities in many countries for either concerns over continued registration or tightening of regulations to use technologies which reduce their emissions during use (Ashworth et al, 2018; López-Fernández et al, 2016; Mirmohseni et al, 2012 & 2013; Yates et al 2018). This is for example the case of 1,3-D and chloropicrin, which are highly effective for pre-plant pest control and are widely used in the production of high-value crops such as strawberries, ornamentals, fruit tree vegetables and others.

According to the California Department of Pesticide Registration (CDPR, 2017), 1,3-D was the fumigant with the highest preplant soil use use in California, US from 2011 to 2015. These fumigants have already been banned in the European Union (although strawberry growers in Spain can still use 1,3-D under special permits). China is considering a ban on use of chloropicrin use in 2022 (China Daily, 2017) but it has been a key alternative adopted to replace MB in China and globally.

Sulfuryl fluoride is another alternative fumigant for pest control, which has been widely adopted and registered around the world for treatment of of structures such as flower mills, as well as stored durables such as dried fruit and nuts, grains and flours. It was also recently approved as a treatment to comply with ISPM-15 for treatment of wood packaging materials in international trade. However, SF has a very high GWP of 4780 (Miller *et. al.*, 2017); this factor may well restrict its use or see technologies introduced to reduce its emissions during use in the future. Like with MB, recapture systems could mitigate its negative impacts.

These issues also reveal that, although MB use has declined substantially, continued research is still urgently needed for better alternatives and recapture systems.

4.6. Emergency use reported by Israel

On 28 March 2019, Israel notified the Ozone Secretariat of using 100 kg (0.1 metric tonne) of MB, as an emergency measure as allowed under Decision IX/7, to control an infestation in the library of the Greek Orthodox Patriarchate in Jerusalem, with the common furniture beetle (*Anobium punctatum*). The library contains various ancient and valuable manuscripts decorated in gold and copper. Phosphine could not be used as it would damage the manuscripts (which cannot be moved) and sulfuryl fluoride is not registered in Israel.

MBTOC is aware of relevant recent research conducted in Israel with gases such as nitrogen and carbon dioxide, which can be used for efficient control of pests of grain and under the circumstances described (Berzolla *et al.*, 2011; Calderon and Barkai-Golan, 1990; Calderon and Navarro, 1980; Donahaye and Navarro, 1987; Donahaye *et al.*, 1996; Navarro, 1978; Navarro and Calderon, 1980). It is possible that the specific circumstances of the infested library make application of inert gases very difficult, but it is suggested that the party approach Prof. Dr. Shlomo Navarro (http://www.green-storage.co.il/about.html) and consider relevant studies conducted in Israel if this issue arises in the future. MBTOC experts stand ready to provide further information if required.

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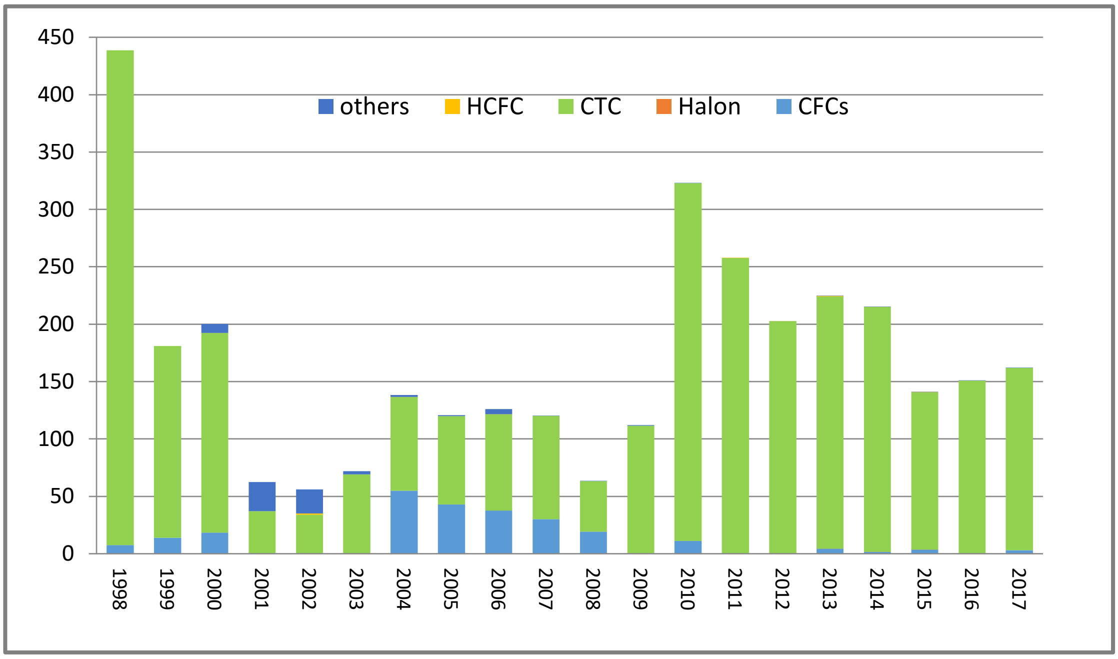
5 Medical and Chemicals TOC (MCTOC) Progress Report

5.1. Laboratory and analytical uses

In 2017, the total global production reported by the parties of ODS for laboratory and analytical uses (LAUs) was 162 tonnes, a slight increase compared with 2016. Only three ODS (CTC, CFC-113 and methyl bromide) were produced in 2017, with CTC remaining the dominant ODS of total global production. The production of ODS for LAUs reported by non-Article 5 parties in recent years shows a continuous decline (12 tonnes in 2017). The production of ODS for LAUs reported by Article 5 parties shows a slight increase in the three years to 2017 (150 tonnes in 2017). Small quantities of a wide range of ODS continue to be used for LAUs.

Figure 5.1 Global ODS production for LAU as reported by the parties (tonnes)



Note: "Others" includes Group V 1,1,1-trichloroethane (TCA) and Group VI methyl bromide (CH_3Br)

Decision XXX/15(4) requests TEAP *"...to provide a review of the laboratory and analytical uses of controlled substances if new compelling information becomes available indicating an opportunity for significant reductions in production and consumption*".

Since the publication of the MCTOC Assessment Report 2018, MCTOC has identified two new ASTM standard methods (D7678 and D8193) and one new draft standard in China that use cyclohexane or tetrachloroethylene as alternatives to ODS for oil analysis.

- ASTM D8193 - 18 (2018): Standard Test Method for Total Oil and Grease (TOG) and Total Petroleum Hydrocarbon (TPH) in Water and Wastewater with Solvent Extraction Using Non-Dispersive Mid-IR Transmission Spectroscopy (using cyclohexane).

- ASTM D7678 - 17 (2017): Standard Test Method for Total Oil and Grease (TOG) and Total Petroleum Hydrocarbons (TPH) in Water and Wastewater with Solvent Extraction using Mid-IR Laser Spectroscopy (using cyclohexane, cyclopentane).

- Stationary source emission-determination of oil fume and oil mist—Infrared spectrophotometric method (under review) (using tetrachloroethylene).

5.1.1. Status of CTC production authorised under essential use exemption for laboratory and analytical uses in China

Decision XXIII/6 specifies that after 31 December 2014, the use of carbon tetrachloride (CTC) for the testing of oil in water would only be allowed under an essential use exemption. In accordance with this Decision, parties authorised essential use exemptions for China for 80 tonnes, 70 tonnes, 65 tonnes, and 65 tonnes of CTC for 2015, 2016, 2017, and 2018 respectively. In 2017, China announced its commitment to phase out this use by 2019 and, accordingly, no essential use nomination was received. China stated in its reporting accounting framework that it produced and used the entire 65 tonnes CTC that was authorised by parties for 2018.

The oil in water test, which is a fundamental requirement in monitoring water quality in China, previously followed the national standard "*HJ 637-2012 Water quality- Determination of petroleum oil, animal and vegetable oils- Infrared photometric method*", using CTC as an extractant. A new standard *HJ 637-2018* replaces CTC with tetrachloroethylene as the extractant, which commenced on 1 January 2019.

5.2. Decision XXIX/7: Use of controlled substances as process agents

In Decision XXIX/7, parties decided,

1. *To update table A of decision X/14 as set out in the annex to the present decision;*

2. *To urge parties to update their information on the use of controlled substances as process agents and provide the Ozone Secretariat by 31 December 2017 with information on the implementation and development of emissions reduction techniques;*

3. *To request the Technology and Economic Assessment Panel to report to the forty-first meeting of the Open-ended Working Group of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer on the industrial application of any alternative technologies employed by parties that have already eliminated the use of controlled substances as process agents in the processes listed in table A, as updated in the annex to the present decision.*

China, the European Union, and the United States submitted information about their process agent uses in response to decision XXIX/7. MCTOC reviewed the information provided by parties and considered this and other available information in preparing its response.

Table 5.1 presents a summary of available information on the industrial application of alternative technologies employed by parties that have already eliminated the use of controlled substances as process agents in the processes listed in table A, as updated by Dcision XXIX/7.

Table 5.1 Available information on alternative technologies employed for process agent applications listed in Table A (as in decision XXIX/7)						
No.	**Process agent application Decision XXIX/7**	**Substance**	**Permitted Parties in Decision XXIX/7**	**Parties no longer requiring ODS for process agent application[1]**	**Reason for process agent application using ODS**	**Status of process agent use (including as reported by parties in 2017)**
1	Elimination of NCl_3 in chlor-alkali production	CTC	European Union, Israel, United States of America		CTC is used for quality of final product and safety in production, transport and use of liquid chlorine. At concentrations above approximately 3%, NCl_3 has a high explosion potential.	The European Union noted that NaClO has been introduced as the alternative and CTC is no longer used at one site. CTC use was expected to cease shortly at the other site in the European Union. In Europe, very few plants used CTC for elimination of NCl_3 in chlor-alkali production. The majority now use either very pure salt and water or NaClO to avoid the formation of NCl_3, or UV destruction in the gas phase. CTC phase out was initiated by other changes that were required.
2	Chlorine recovery by tail gas absorption in chlor-alkali production	CTC	European Union, United States of America	European Union	CTC is used as a process agent to separate the residual chlorine from the inert vapours present in the chlorine gas and recover it in a usable form. CTC is a practical solvent suitable for use in this type of gas recovery process.	This process agent application ceased in the European Union due to introduction of gas burners through which tail gas circulates. In Europe, very few plants used CTC for this purpose, and mainly because of the type of chlorine liquefaction process employed at those plants in the past. Today, chlor-alkali plants have reduced chlorine in the tail gas with compression/ condensation and as a result of the higher chlorine purity from the processes used. CTC phase

Table 5.1 Available information on alternative technologies employed for process agent applications listed in Table A (as in decision XXIX/7)						
No.	**Process agent application Decision XXIX/7**	**Substance**	**Permitted Parties in Decision XXIX/7**	**Parties no longer requiring ODS for process agent application[1]**	**Reason for process agent application using ODS**	**Status of process agent use (including as reported by parties in 2017)**
						out was initiated by other changes that were required.
3	Production of chlorinated rubber	CTC	European Union		Chemical inert solvent for high quality product for heavy duty anti-corrosives and adhesives.	The European Union noted that alternatives do not exist.
4	Production of chlorosulfonated polyolefin (CSM)	CTC	China		In China, this CTC-based process has been optimised to minimise CTC emissions. Chlorobenzene was evaluated as an alternative unsuccessfully due to energy consumption, chemical stability and in-plant safety.	The United States has previously eliminated this CTC use. Information is not available on how this was achieved.
5	Production of aramid polymer (PPTA)	CTC	European Union		CTC is used for the following reasons: to avoid side reactions during chlorination, which is crucial for the polymerisation; to reduce explosion and fire risks during chlorination; to reduce waste and increase yield by acting as a carrier for recycling of incomplete chlorination products; and to clean HCl emerging from the reactors (the cleaning solution is recycled). CTC is the only option that satisfies these safety, waste-reduction, and quality purposes under the various conditions of the process because: CTC is inert in all process steps; CTC prevents side reactions in the reactor;	The European Union noted that alternatives do not exist.

Table 5.1 Available information on alternative technologies employed for process agent applications listed in Table A (as in decision XXIX/7)						
No.	**Process agent application Decision XXIX/7**	**Substance**	**Permitted Parties in Decision XXIX/7**	**Parties no longer requiring ODS for process agent application[1]**	**Reason for process agent application using ODS**	**Status of process agent use (including as reported by parties in 2017)**
					CTC has the right vapour pressure to prevent explosions in the gas cap of the reactor; CTC is easy to recover and reuse; and CTC has a low solubility in HCl.	
6	Production of synthetic fibre sheet	CFC-11	United States of America		The use of CFC-11 is primarily due to safety, yield and cost, but also product quality. The unique process agent properties are: low toxicity; non-flammable; physico-chemical properties e.g., boiling point, critical temperature/pressure, solvency power (capability to enter polymer matrix), and control of solution viscosity and process operating pressures; chemical stability to high temperature and pressure; and non-corrosivity.	No information available.
7	Photochemical synthesis of perfluoropolyetherpolyperoxide precursors of Z-perfluoropolyethers and difunctional derivatives	CFC-12	European Union		CFC-12 is liquid at the reaction temperatures (–50 °C to –90 °C); it dissolves both reactants tetrafluoroethylene and oxygen (whose mixture would otherwise explode); is transparent and inert to UV radiation, apart from a minimal release of radicals that are responsible for initiation and regulation of the molecular weight in case of UV initiated synthesis. Should the breakdown be more than minimal,	Work is currently being undertaken on replacing CFC-12 with an alternative.

Table 5.1 Available information on alternative technologies employed for process agent applications listed in Table A (as in decision XXIX/7)						
No.	**Process agent application Decision XXIX/7**	**Substance**	**Permitted Parties in Decision XXIX/7**	**Parties no longer requiring ODS for process agent application[1]**	**Reason for process agent application using ODS**	**Status of process agent use (including as reported by parties in 2017)**
					degradation products would make it impossible to achieve commercial results.	
8	Preparation of perfluoropolyether diols with high functionality[1]	CFC-113	European Union	European Union	The perfluoropolyether diols are obtained from the reduction of the perfluoropolyether diacylfluorides. The solvent has to be chemically inert to the chemical reduction, and to dissolve the raw materials and products.	HFE-7100 is now used.
9	Production of cyclodime	CTC	European Union		The CTC is used in this process because it is the only solvent compatible with the raw materials; it is very stable, non-reactive, and non-flammable. Evaluation of numerous other solvents under process conditions has led to unsatisfactory results. Only, chloroform seemed to be a potential alternative solvent. However, due to the different behaviour of this solvent (volatility, reactivity), chloroform resulted in other process safety and hygiene issues, major loss of yield, and greater solvent consumption. Moreover, a large part of the plant would have to be re-designed and re-built in other materials compatible with chloroform.	The European Union noted that alternatives do not exist.

Table 5.1 Available information on alternative technologies employed for process agent applications listed in Table A (as in decision XXIX/7)						
No.	**Process agent application Decision XXIX/7**	**Substance**	**Permitted Parties in Decision XXIX/7**	**Parties no longer requiring ODS for process agent application[1]**	**Reason for process agent application using ODS**	**Status of process agent use (including as reported by parties in 2017)**
					For these reasons, this would be a less safe and uneconomical solution.	
10	Bromination of a styrenic polymer	BCM	United States of America		This process uses bromochloromethane (BCM) as an inert solvent in the bromination of styrenic polymer. The 2002 TEAP Report indicated that BCM was used as a solvent for its inertness, for safety reasons, and for waste reduction. Brominated styrenic polymers are useful as flame retardants for thermoplastic polymers.	No information available.
11	Production of high modulus polyethylene fibre	CFC-113	United States of America		The interaction of the spinning solvent with the fibre plays an important role in the unusual strength of the end product. 'hundreds of non-ODS materials' had been tested as replacements for CFC-113, but none had been able to achieve the technical performance of CFC-113 in respect of flammability, boiling point, toxicity, compatibility with materials of construction, economy, and recoverability while retaining required product properties and performance.	No information available.

1. In 2018, MCTOC recommended that parties may wish to consider: removing the use of CFC-113 in the preparation of perfluoropolyether diols with high functionality from Table A of Decision XXIX/7; and removing the European Union (for chlorine recovery by tail gas absorption in chlor-alkali production) from Table A of Decision XXIX/7.

5.3. Decision XVII/6(4): Assessment of any new plant using controlled substances as process agents

Decision XVII/6(4) states, "*Where Parties install or commission new plant after 30 June 1999, using controlled substances as process agents, to request Parties to submit their applications to the Ozone Secretariat and the TEAP by 31 December 2006, and by 31 December every subsequent year or otherwise in a timely manner that allows the TEAP to conduct an appropriate analysis, for consideration subject to the criteria for essential uses under decision IV/25, in accordance with paragraph 7 of decision X/14;*". No applications were submitted by parties by 31 December 2018.

5.4. Use of controlled substances for chemical feedstock

Ozone-depleting substances (ODS) feedstocks are chemical building blocks that allow the cost-effective commercial synthesis of other chemicals. As raw materials, ODS feedstocks are converted to other products, except for *de minimus* residues and emissions of unconverted raw material. Emissions from the use of ODS feedstock consist of residual levels in the ultimate products, and fugitive leaks in the production, storage and/or transport processes. Significant investments and effort are spent to handle ODS feedstocks in a responsible, environmentally sensitive manner and, in most countries, are regulated through national pollution control measures. The definition of production under the Montreal Protocol excludes the amount of controlled substances used as feedstock.

Table 5.2 shows common feedstock applications, although the list is not exhaustive. Parties report amounts of ODS used as feedstock to the Ozone Secretariat, but they do not report how they are used. Processes are proprietary and there is no official source to define the manufacturing routes followed and their efficacy. The table provides some examples and is the product of the collective experience and knowledge of MCTOC members. Products included are both intermediates as well as final products, including fluoropolymers.

Table 5.2 Common feedstock applications of ozone-depleting substances (this list is not exhaustive)

Feedstock ODS	Product	Further conversion	Comments
CFC-113	Chlorotrifluoroethylene	Chlorotrifluoroethylene based polymers	Polymers include poly-chlorotrifluoroethylene (PCTFE), and poly-fluoroethylenevinyl ether (PFEVE).
CFC-113	Trifluoroacetic acid and pesticides		Production processes in China and India. CFC-113a is as an intermediate in this process.
CFC-113	HFC-134a and HFC-125		High-volume use. The sequence for production of these HFCs may begin with CFC-113, which is converted to CFC-113a and then to CFC-114a.
CFC-114, -114a	HFC-134a		The sequence for production of this HFC may begin with CFC-113, which is converted to CFC-113a and then to CFC-114a.
CTC	CFC-11 and CFC-12		Production and consumption of these CFCs has fallen to zero based on reported data.
CTC	With methanol to make Methyl Chloride and HCl	Methyl chloride in CMs plant converted to DCM and CFM	A method of recycling CTC into useful products rather than destruction operated in CMs plant complex
CTC	Perchloroethylene		High volume use.
CTC	With hydrogen to make Chloroform and methane as a by-product	Chloroform is used to make HCFC-22	A method of recycling CTC into useful products rather than destruction operated in CMs plant complex
CTC	Chlorocarbons including chloropropanes and chloropropenes	Feedstocks for production of HFC-245fa and some new HFOs.	HFOs are low-GWP fluorocarbons used in refrigeration, air conditioning and insulation and production is increasing.
CTC	Intermediates (DVAC)	Pyrethroid pesticides.	CCl_3 groups in molecules of intermediates become $=CCl_2$ groups in pyrethroids.
CTC	with 2-chloropropene - Intermediates	Production of HFC-365mfc	
CTC	with vinylidene chloride - Intermediates	Production of HFC-236fa	
CTC	with benzene to make triphenylchloromethane (trityl chloride)	Intermediate for dyes and pharmaceuticals such as antiviral drugs	Trityl chloride is an efficient tritylation agent.
CTC	With 1,3-dichloro-4-fluorobenzene to make 2,4-dichloro-5-fluorobenzoyl chloride (DCFBC)	intermediate for example in the synthesis of highly active antibacterial agent Ciprofloxacin	
CTC	With methyl 3,3-dimethyl-4-pentenoate to produce methyl 4,6,6,6-tetrachloro-3,3-dimethylhexanoate		

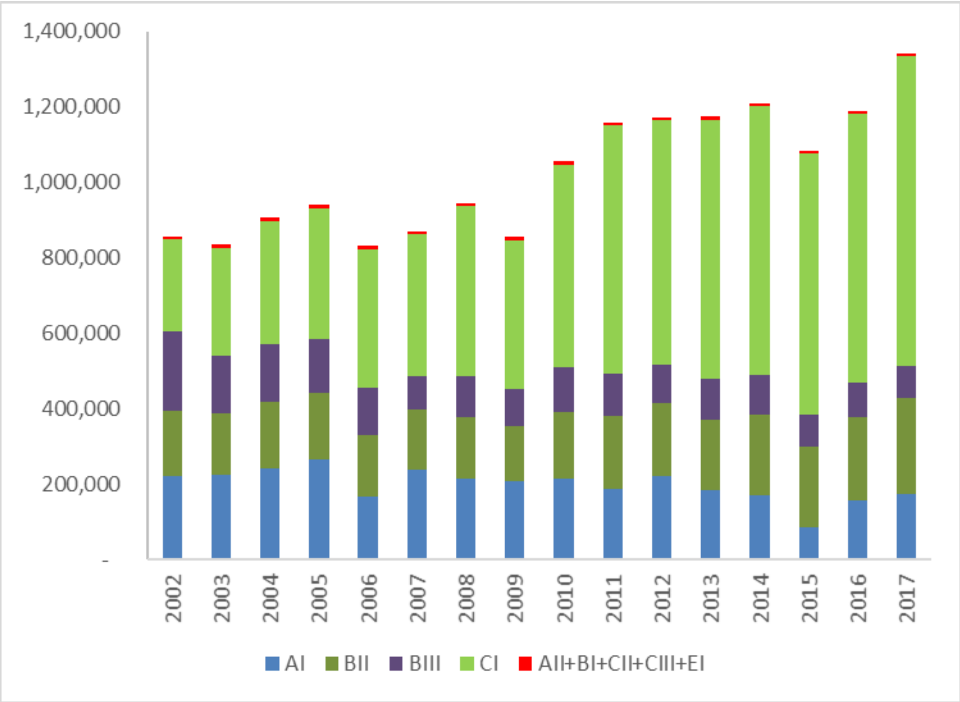
1,1,1-trichloroethane	HCFC-141b, -142b, and HFC-143a		Note that an alternative feedstock is 1,1-dichloroethylene (vinylidene chloride), which is not an ODS.
HCFC-21	HCFC-225		Product used as solvent.
HCFC-22	Tetrafluoroethylene	Polymerized to homopolymer (PTFE) and also co-polymers	Very high-volume use. Work has been done for decades to find an alternative commercial route, without success.
HCFC-123	HFC-125		
HCFC-123, HCFC-133a and Halon-1301	Production of pharmaceuticals, TFA and agrochemicals		
HCFC-124	HFC-125		
HCFC-141b	HFC-143a		
HCFC-142b	Vinylidene fluoride	Polymerized to poly-vinylidene fluoride or co-polymers.	Products are fluorinated elastomers and a fluororesin.

5.4.1. Recent and historical trends in ODS feedstock uses

Data have been provided to the MCTOC by the Ozone Secretariat on production, import and export of ODS used as feedstock for the year 2017. These also include quantities used as process agents because parties are required to report such consumption in a manner consistent to that for feedstock. For 2017, a total of 16 parties reported use of ODS as feedstock, while 11 of these parties were also producers of ODS for these uses. In 2016, 17 parties reported use of ODS as feedstock.

In 2017, total ODS production for feedstock uses was 1,341,844 tonnes (2016: 1,189,536 tonnes), representing a total of 501,966 ODP tonnes (2016: 438,712 ODP tonnes). Feedstock use in 2017 is the largest (in metric tonnes) since 1990.

Figure 5.2 Annual reported production (metric tonnes) of ODS for feedstock and process agent uses, categorised by Montreal Protocol Group, for the years 2002-2017[1]



The largest feedstock uses currently are HCFC-22 (47 percent of the total mass quantity), CTC (19 percent), and HCFC-142b (11 percent). The quantity of HCFCs, in total, used as feedstock has been growing since the record began in 1990, mainly as a consequence in the growth of fluoropolymers. HCFC-22 is used to produce tetrafluoroethylene (TFE), which can be both homo- and co-polymerized to make stable, chemically resistant fluoropolymers with many applications. Polyvinylidene fluoride is made from HCFC-142b. The growth in fluoropolymers can be expected to continue for the near future, offset to a small extent by reduced demand for HFCs with higher GWP, such as HFC-143a. Similarly, the increasing demand for HFCs with

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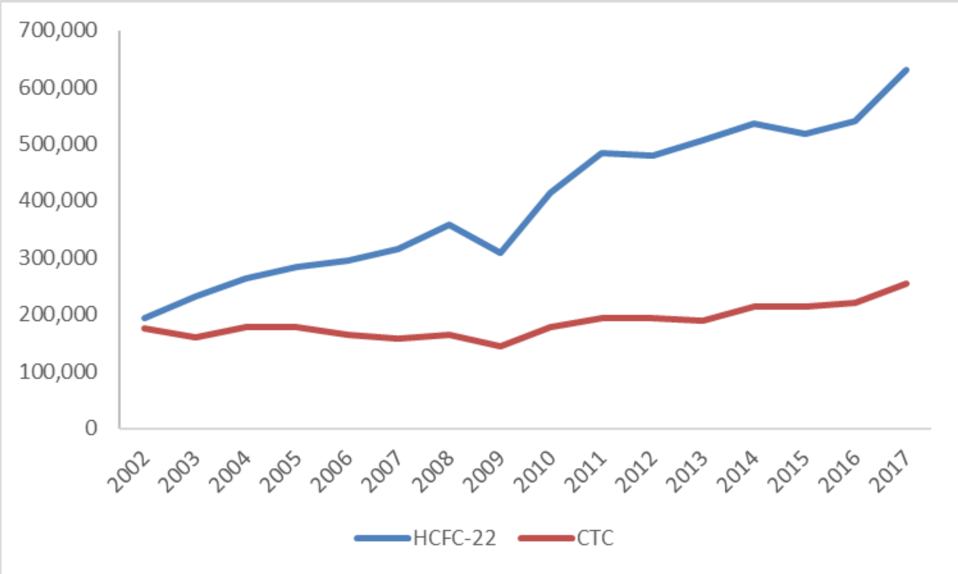
[1] Annex AI CFCs -11, -12, -113, -114, -115; Annex BII carbon tetrachloride; Annex BIII 1,1,1 trichloroethane; Annex CI HCFCs. Annex AII Halons -1211, -1301, -2402; Annex BI CFCs -13, -111, -112, -211, -212, -213, -214, -215, -216, -217; Annex CII HBFCs; Annex CIII bromochloromethane; and Annex EI methyl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

lower GWPs is thought to be responsible for the long-term reduction in use of 1,1,1-trichloroethane. CTC use is growing; CTC use had been growing at an average of 6,700 tonnes per year from a minimum in 2009, but then increased by 33,500 tonnes (15%) from 2016 to 2017 due to growing demand for low-GWP hydrofluoroolefins (HFOs) and perchloroethylene. Figure 5.2 shows the trends for HCFC-22 and CTC feedstock use.

Figure 5.3. Trends in annual use of HCFC-22 and CTC for feedstock for the years 2002-2017 (metric tonnes)



In China, according to a 2019 presentation[2], 68% of the CTC produced is converted to CH3Cl, CHCl3, and PCE inside the CMs plants and 32% is used as feedstock in the production of 11 non-ODS chemicals. A requirement in China is that all CMs plants should construct CTC-disposal unit in line with production capacity. In 2017, the use as feedstock for non-ODS chemicals (outside CMs plants) was 42,158 metric tonnes. More detail on CTC production and its uses as feedstock can be found in the *SPARC Report on the Mystery of Carbon Tetrachloride*.[3]

CFCs, mainly CFC-113, have shown a long-term decline in use. The reasons for this are complex – a reduction in the fluoropolymers produced from CFC-113 is possible, but unlikely in view of the increased demand for other fluoropolymers. However, changes in the production technology for HFCs can impact use of CFC-113, as can changes in the reporting of in-house production and inventories. In fact, CFC-113 use increased slightly in 2017 compared to 2016.

[2] CTC Production, Conversion Technology and Management in China, Chun-xi Li, College of Chemical Engineering, Beijing University of Chemical Technology. March 2019

[3] SPARC Report on the Mystery of Carbon Tetrachloride Q. Liang, P. A. Newman, S. Reimann SPARC Report No. 7, WCRP-13/2016.

Table 5.3 Amount of ODS used as feedstock in 2017

Substance	ODP	Tonnes	ODP Tonnes*
HCFC-22	0.055	630,024	34,651
Carbon tetrachloride	1.1	255,151	280,666
HCFC-142b	0.065	146,892	9,548
CFC-113	0.8	112,275	89,820
1,1,1-Trichloroethane (methyl chloroform)	0.1	86,244	8,624
CFC-114	1	60,442	60,442
HCFC-124	0.022	24,693	543
HCFC-141b	0.11	12,119	1,333
HCFC-123	0.02	6,052	121
Methyl bromide	0.6	3,311	1,987
Bromochloromethane	0.12	1,985	238
Halon 1301	10	1,380	13,798
HCFC-133	0.06	1,134	68
CFC-12	1	80	80
HBFC-22B1	0.74	60	45
CH_2FBr (HBFC-31B1)	0.73	3	2
Other		0.4	0.2
Total		1,341,844	501,966

* While ODP tonnes are included, it should be noted that ODP is not relevant to emissions. From the total amount of ODS used as feedstock, only an insignificant quantity will be released as emissions. This is discussed in the next section.

5.4.2. Estimated emissions of ODS feedstock and process agent uses

Emissions are not reported by parties, and the estimation of ODS emissions is also inexact. This issue was discussed in detail in the MCTOC 2018 Assessment Report.

In order to generate indicative estimations of ODS emissions, the IPCC emission factor of 0.5 percent[4] for HFC production has been applied as a surrogate emission factor uniformly across all Groups. Estimated indicative emissions associated with ODS feedstock and process agent uses can be calculated as 6,709 tonnes, or 2,510 ODP tonnes for 2017.

5.5. Solvent uses of ODS

Aerospace and military applications currently require small quantities of HCFCs globally, possibly less than about 50 tonnes annually. These applications might continue to require small quantities of HCFCs, potentially to service existing equipment (e.g. HCFC-122, -122a, -141b, -225), after 2020 in non-Article 5 parties. HCFC-225 is used in precision cleaning and cleanliness verification of sensitive equipment, such as oxygen systems, in aerospace applications. HCFO-1233zd(E) has been approved by NASA as an acceptable replacement for HCFC-225 solvent cleaning and verification sampling of propulsion oxygen systems and other associated applications at propulsion test facilities. HCFC-225 is also used as a solvent for

[4] The IPCC emission factor for HFC production is currently under review by the IPCC. If the IPCC revises its emission factor, then this will be used to provide an indicative estimate of ODS emissions from feedstock use. The European Union also reports its feedstock emissions in an annual report.

syringe/needle coating in Japan. HCFC-141b is used for this purpose in Article 5 parties. This solvent application coats silicone oil on the surface of the needle/syringe to reduce pain at injection. Non-ODS solvents are expected to replace HCFC-225 in Japan by the end of 2019. Alternatives are already used in Europe and the United States (e.g. HFEs). Topical creams are also available as pain relief for injections.

n-Propyl bromide is a very short-lived substance (VSLS) with a variable ODP depending on the distribution of emissions at the surface[5]. It is not a controlled substance under the Montreal Protocol. *n*-Propyl bromide is used in the manufacture of agricultural chemicals and pharmaceuticals, and also as a cleaning solvent for degreasing, precision cleaning, electronics, adhesives, and metal cleanings. Decision XXX/15(6) requests TEAP to "*provide information to the parties on n-propyl bromide if new compelling information is available*". Recent online summaries of a market research report estimate that global production of *n*-propyl bromide was 75,000 tonnes in 2015, which is three times larger than previously estimated by MCTOC. The recent report states that the United States is the dominant producer and exporter of *n*-propyl bromide. However, with strong growth in China and India, Asia is also assuming dominance as a producing and exporting region. In the last 15 years, United States' production and use of *n*-propyl bromide has increased nearly tenfold as a result of "*aggressive marketing of* n-*propyl bromide as a drop-in substitute for the carcinogenic chlorinated solvents TCE* [trichloroethylene] *and PCE* [perchloroethylene]*, and as an "acceptable" substitute for other more potent ozone depleting substances*".[6] The report mentions potential factors that might restrain future market growth of *n*-propyl bromide, such as toxicity, ozone-depleting potential, volatile organic content, and alternatives with superior characteristics.

5.6. Metered dose inhalers

The United Kingdom's National Institute for Health and Care Excellence has recently issued a Patient Decision Aid[7] that provides information to help people with asthma and their healthcare professionals discuss their options for inhaler devices. The aid, which is designed to enhance patient choice, includes summary information on different factors related to using inhalers and how they compare with each other, such as the relative carbon footprint of inhaler options and that metered dose inhalers with propellant have a higher carbon footprint than dry powder inhalers.

[5] The SAP Assessment 2018 [WMO, 2018] reports the ODP of *n*-propyl bromide in Appendix A as less than 0.17. The ODP is highly dependent on the distribution of surface emissions. In the tropics, convection can quickly carry very short-lived substances (VSLSs) into the lower stratosphere from the surface. Hence, VSLSs emitted in the tropical troposphere are quickly transported before oxidation or other losses can reduce their gas concentrations. Derived ODPs have been shown to be strongly dependent on region and season of substance emission, with the greatest values obtained for emissions in the Indian subcontinent (see WMO [2018], Appendix A, footnote O12). The Indian-subcontinent *n*-propyl bromide ODP is found to be 0.17, with a range of 0.079-0.29. It should be noted that an ODP is not considered to be the best metric for a VSLS because it is sensitive to the region of emissions, and it can also impact tropospheric ozone. See also Table 5-4 in WMO (2014). Personal communication with SAP, May 2019.

[6] Global N-Propyl Bromide Market Precise Scenario Covering Trends, Opportunities and Growth Forecast during 2018-2026, News Tech Markets, April 10, 2019. https://newstechmarkets.com/2019/04/10/global-n-propyl-bromide-market-precise-scenario-covering-trends-opportunities-and-growth-forecast-during-2018-2026/. Accessed April 2019; N-Propyl Bromide Market Forecast, Trend Analysis & Competition Tracking - Global Review 2018 to 2026, FactMR, publication date (on-going), https://www.factmr.com/report/589/n-propyl-bromide-market. Accessed April 2019.

[7] Available at https://www.nice.org.uk/guidance/ng80/resources/inhalers-for-asthma-patient-decision-aid-pdf-6727144573. Accessed April 2019.

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

RTOC has recently submitted its quadrennial Assessment Report for the period 2015-2018. Therefore, this short 2019 RTOC Progress Report updates recent progress and developments in RACHP sectors and provides some highlights from the 2018 RTOC Assessment Report by sectors.

6.1. Technical update

In April 2019 a proposal (known as a "final draft international standard", FDIS) to revise the product standard IEC 60335-2-89[11] was accepted for publication by IEC[12] SC 61C (Safety of refrigeration appliances for household and commercial use). This proposal includes an increase in charge limits for flammable refrigerants up to about 500 g for A3 and up to 1,200 g for A2 and A2L refrigerants.

Until now, the standard had limited the upper refrigerant charge in commercial appliances to 150 g, irrespective of the flammability type, i.e., A2L, A2 or A3. The FDIS is a major change, which means that flammable refrigerants can now be applied in RACHP equipment of higher capacity.

With this decision, charge sizes in excess of 150 g can be used, provided that the appliance passes a "surrounding concentration test", where a leak of refrigerant is simulated and the concentration of flammable refrigerant surrounding the appliance is measured until the release is exhausted.

Additional context on flammable refrigerants and safety standards can be found in the Decision XXVIII/4 TEAP Task Force Report on "Safety Standards for Flammable Low Global-Warming-Potential (GWP) Refrigerants" (available at: http://conf.montreal-protocol.org/meeting/oewg/oewg-39/presession/Background-Documents/TEAP-XXVIII_4-TF-Report-May%202017.pdf). The Ozone Secretariat, according to Decision XIX/11, updates information on related standards through a document, "Information on the tabular overview of safety standards for refrigeration, air-conditioning and heat-pump systems and appliances". (The document and the on-line tool overviewing the current situation of Safety Standards is available at:
http://conf.montreal-protocol.org/meeting/oewg/oewg-41/presession/SitePages/Home.aspx)

[11] IEC 60335-2-89: Household and similar electrical appliances — Safety — Part 2-89: Particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant unit or compressor

[12] IEC is an international standards organization that prepares and publishes International Standards for all electrical, electronic and related technologies. The IEC is made up of members, called national committees, and each NC represents its nation's electrotechnical interests in the IEC. This includes manufacturers, providers, distributors and vendors, consumers and users, all levels of governmental agencies, professional societies and trade associations as well as standards developers from national standards bodies.

6.2. Highlight of RACHP sectors

Below are brief sector highlights from the 2018 RTOC Assessment Report:

6.2.1. Refrigerants

- Since the publication of the RTOC 2014 Assessment Report, 35 new refrigerants have received a standard designation and safety classification and five are single-compound refrigerants.
- There is not a single "ideal" refrigerant. Refrigerant selection is a balanced result of several factors which include: suitability for the targeted use, availability, cost of the refrigerant and associated equipment and service, energy efficiency, safety, ease of use, and environmental issues.
- The HFC phase-down under the Kigali Amendment, as well as regional and national regulations, are driving the industry towards the use of low GWP refrigerants. Alternatives to high GWP refrigerants exist and new lower GWP refrigerants have been proposed, which creates a challenge to finding the best refrigerant for each application. Many of these newly introduced refrigerants are expected to play only an interim role in the phase-down process, as their GWP may still be high for the average future application.
- Refrigerants with low direct impact on climate change are often flammable and may have higher toxicity. In order to maintain the current safety levels new technologies are being developed and an increased level of training will be needed.

6.2.2. Domestic appliances

- HC-600a (predominantly) or HFC-134a continue to be the refrigerant options for new production and currently, more than 1 billion domestic refrigerators use HC-600a. None of the other new refrigerants has matured to become an energy-efficient and cost competitive alternative.

6.2.3. Commercial refrigeration

- Lower GWP HFC/HFO blends and non-halocarbon options like R-744, HC-290, HC-600a and R-717 are growing in use, especially as research and development continues into improving system performance; this trend will increase once new safety standards and codes go into effect in the next few years.

6.2.3. Industrial refrigeration and heat pump systems

- In larger industrial refrigeration plants, R-717 has been extensively used for more than 150 years. Current technological advances enable the use of low charge R-717 systems, as well as cascade systems using R-717 together with R-744, opening up new opportunities.

6.2.4. Transport refrigeration

- In some regions, a significant migration from R-404A to lower GWP has occurred since the last assessment. Today, R-404A has been completely replaced by R-452A in new truck and trailer equipment in Europe. This trend might extend across the rest of the world.

- R-744 and R-513A have been introduced in intermodal container applications. R-744 is being field tested on trucks and trailers.

6.2.5. Air-to-air air conditioners and heat pumps

- The phase out of HCFC-22 in non-Article 5 parties is essentially complete and is progressing in Article 5 parties.
- There is an almost continuous introduction of new refrigerants for use in air-to-air air conditioners and heat pumps, but few match or exceed the performance of HCFC-22 regardless of the GWP. Component and system optimisation can be a design challenge.
- Despite the reported low risk for certain applications, safety standards remain restrictive to several low GWP flammable refrigerants in certain product types, but are under revision for all refrigerants. There remains no large-scale shift to low GWP refrigerants as yet.

6.2.6. Water and space heating heat pumps

- Water and space heating heat pumps are a dynamic market with a number of options. Low GWP refrigerant HC-290 and the medium GWP refrigerant HFC-32 are commercially available, and other medium and low-GWP HFC blends may become commercially available. R-744 based water heating heat pumps have been mainly developed and commercialised in Japan, where around 6 million units have been installed since 2001. In Europe, commercial sized units are being installed for multi-family houses and hotels.

6.2.7. Chillers

- The phase-out of ozone depleting refrigerants in new chillers is nearly complete. HCFC-22 in new, small chillers has been phased out in non-Article 5 parties, but limited production continues in Article 5 parties.
- Since the HFCs in use today are considered to have a high GWP, there is global pressure to change to lower GWP refrigerants. Research for alternative refrigerants with lower GWP are nearly over and have yielded several acceptable alternatives.

6.2.8. Vehicle air conditioning

- At present, more than one refrigerant is used for new car and light truck air conditioning: HFC-134a will remain widely accepted world-wide while, due to regulations, the use of HFO-1234yf will continue expanding mainly in the US, Europe and Japan. R-744, currently available for very few car models, is expected to be considered as an option for electrified vehicles, when used at the same time for a heat pump function.

6.2.9. Energy efficiency and sustainability applied to refrigeration systems

- Industry and policymakers may consider the methods, tools and incentives described in the 2018 RTOC Assessment Report to stimulate and support improvements on energy efficiency and sustainability. A wider range of relevant environmental and social aspects is briefly described in this chapter while keeping focus on possible environmental impacts of refrigeration systems.
- Comprehensive sustainable selection criteria for refrigerants have been introduced. They address energy efficiency, impact on climate and hydrosphere, usage of renewable energy, and other options to reduce GHG emissions and consumption of natural

resources, adaptability for thermal energy storage, costs, technological development level, safety, flammability and liability.

6.2.10. Not-in-Kind technologies

- Not-In-Kind (NIK) technologies do not primarily use mechanical vapour compression (MVC) technology to produce air conditioning or refrigeration.
- These technologies can be classified as “widely commercially available”, “commercially available” or “emerging and R&D”. They are divided into three groups: (1) thermal, (2) solid-state, and (3) electro-mechanical technologies.
- Thermal technologies are predominantly available commercially; solid-state technologies are mostly available commercially with one technology in the R&D stage; electro-mechanical technologies are mostly in the R&D stage. The last ones are assumed to become the NIK technologies of the near future, with expected higher EERs compared to other NIK technologies.
- NIK technologies are expected to provide savings in operating costs. Their unique ability to use waste and renewable energy sources makes their application potentially highly energy efficient.

6.2.11. High ambient

- Research done at HAT conditions reveals viable low-GWP refrigerant alternatives that can be effectively used.
- There is more awareness of the challenges faced at HAT conditions in the design, implementation, and even servicing of equipment using low-GWP refrigerants that are capable of delivering a high level of energy efficiency.

6.2.12. Modelling

- The methodology used by the RTOC to model banks and emissions from the global sector transitions is described in significant detail for the first time in the 2018 RTOC Assessment Report.

7 Other TEAP matters

7.1 TEAP and TOCs organisation

As indicated in Annex 1, TEAP currently includes 19 members including 5 Senior Experts. In addition, almost 150 experts serve on its five TOCs. TEAP recognises and is grateful for the voluntary service of the TEAP and TOCs members, past and present, and their substantial contributions. to the successful protection of the ozone layer.

In TEAP's Decision XXIV/8 Task Force Report (May 2013), individual TOCs membership numbers in the 2014-2018 period were anticipated to remain the same or decrease from the 2013-2014 period due to anticipated attrition during the 2014 reappointment process; the exception to this was RTOC, which was predicted to retain or increase its previous membership numbers based on anticipated workload. Annex 1 of this report provides updated TOC membership lists, which include the start dates and current terms of appointment for all members. TEAP has re-assessed its skill mix in this Progess Report, with a view to re-focussing the TOCs on the continuing phaseout of ODS under the Montreal Protocol and the phasedown of HFCs under the Kigali Amendment going forward.

TEAP is taking a broad view of its work for parties going forward under these mandates, its current pool of experts, the potential loss of expertise through attrition or lack of support for some experts, the need for specific and cross-cutting expertise within TOCs and the TEAP itself. TEAP is working to identify appropriate expertise and find qualified candidates interested and available to serve in these positions. TEAP will communicate these needs through its matrix of needed expertise and communication with interested parties in order to manage an orderly transition, avoiding significant disruption to its work. TEAP seeks to discuss with parties how to engage experts in these areas, mindful of the need for geographical and gender balance.

In addition to the above update, TEAP takes the opportunity in this report to bring to the attention of the parties specific issues relevant to particular TOCs:

7.1.1 FTOC

The FTOC met in Vienna, Austria in March 2019. The FTOC is seeking additional experts to provide expertise in A5 extruded polystyrene production especially in India and China replacing experts that left the FTOC as they no longer work in the industry. FTOC also seeks polyurethane system house technical experts from southern Africa, the Middle East, India or Mexico (especially from small and medium enterprises) as they seem to continue to face challenges in the transition from HCFC-141b. FTOC seeks additional foam chemistry experts and an expert in building science related to energy efficiency from A5 or nA5 parties.

7.1.2 HTOC

The HTOC met in London, UK at IMO, in February 2019. The HTOC is seeking to recruit additional experts in four areas to improve A5/non-A5 and regional balance while also considering gender balance: 1) fire protection applications in civil aviation in A5 parties, in particular South East Asia, 2) knowledge of halon alternatives and their market penetration in A5 parties, particularly in Africa, South America and South Asia, 3) knowledge of banking and supplies of halon and alternatives in A5 parties, particularly in Africa and South America, and 4) knowledge of ship breaking activities from A5 or non-A5 parties.

7.1.3 MBTOC

MBTOC met in Qingdao, China in March 2019. Membership continues to be at a historical low with 16 members (including one economist). The required expertise in soils, structures and commodities and QPS is adequate to complete the current tasks. MBTOC is still seeking to recruit experts for the nursery industries, particularly an expert having a clear understanding of issues affecting the strawberry runner industries globally.

7.1.4 MCTOC

MCTOC (chemicals sub-group only) met in Vienna, Austria in March 2019. At the end of 2018, MCTOC had 21 out of 34 members (and 3 co-chairs) whose 4-year terms of appointment ended. With sincere gratitude for their years of voluntary service to the Montreal Protocol, MCTOC commends and farewells 6 of those members, Jiang Biao (China), Jorge Cáneva (Argentina), Davide Dalle Fusine (Italy), Eamonn Hoxey (UK), Surinder Singh (India), Roland Stechert (Germany), and also consulting expert, Archie McCulloch (UK). Taking into account balance, 15 members have been reappointed (for additional terms of up to 4 years) and 4 new members have been appointed, following nominations in consultation with national focal points of the relevant parties and in accordance with TEAP's terms of reference. MCTOC is still seeking to strengthen expertise in the following identified key areas: destruction technologies; laboratory and analytical uses.

7.1.5 RTOC

RTOC met in Rome in December 2018. RTOC currently has 42 members (15 A5, 27 nonA5, 4 female). The large membership on the RTOC exceeds what is suggested in the TEAP TOR for size of TOCs (about 20 members), but this has been important to ensure the expertise within the committee covers the many RACHP sectors, supports efforts to achieve balance within the committee, and sustains the continuing contributions of RTOC and many of its members to the work of TEAP task forces responding to recent and future decisions of parties related to this sector. With the recent appointment of members, RTOC is not seeking additional experts at this time. RTOC co-chairs continue to assess current expertise, and to improving gender and geographical balance. RTOC co-chairs are working to review the structure and function of RTOC, in order to manage the increasing workload across the wide range of RACHP sectors.

7.2 Continuing challenges

The role of TEAP and its TOCs continuosly evolves to meet current and future needs of the parties. The TEAP, its TOCs and other TSBs, have changed their focus, as the Montreal Protocol has moved from introducing and strengthening control schedules to managing the use of controlled chemicals and then complying with the Protocol. The panel is now also addressing the adoption of the Kigali Amendment and the HFC phase-down. TEAP continues to work so that its TOCs are structured in size and expertise to support future efforts of the parties and takes the opportunity in this report to address ongoing challenges and bring them to the attention of the parties.

The challenge to TEAP and TOC leadership remains to identify candidates with adequate history and experience as well as technical expertise and time, in order for TEAP to continue to meet the significant demands of delivering outputs to support the deliberations of parties, without loss of continuity. The main approach taken by TEAP and its TOCs is to appoint experts in the required technical areas, to contribute into TEAP Task Forces, and/or TOCs, where new appointees can share their experience, knowledge, ability to communicate and write, and their capacity to contribute in a timely manner. Some of these experts could become TOC or TEAP members should the parties request further studies on such new technical areas.

The workload related to the tasks assigned to TEAP and its TOCs has grown substantially in recent years with the responses to various requests of the Parties; if unaddressed this situation will increasingly affect the delivery and timeline of TEAP's outputs. Members of TEAP and

TOCs often concurrently serve on TEAP Task Forces adding to the workload and making it difficult to meet deadlines.

TOCs have been challenged with attrition through retirement of members and loss of expertise. This is of growing concern to the consensus process of the committees where a range of independent expert opinions is necessary. Absence of funding is of growing concern for TOC and TSB co-chairs, with the substantial administrative responsibility to bring their respective groups to consensus, generate draft reports, and then deliver final products within strict deadlines. The members of TEAP and its TOCs provide their expertise and work on a voluntary basis and many are finding the increasing time commitment and overall workload required difficult/impossible to manage in the context of a full-time occupation.

TEAP is well aware of the need to re-invigorate its membership and leadership, whilst maintaining involvement of TOC and senior expert members with substantial experience to ensure the continuity of its work for Parties. In view of the Kigali Amendment, TEAP has also made progress in recruiting contributing members with the expertise needed to address any knowledge gaps.

To ensure that the functioning of the TEAP and its TOCs continue providing timely assessments to support the discussions of parties, both TEAP and the parties may need to consider the overall annual workload, the deadlines for delivery and the support provided to TEAP, at the time of making decisions requesting this work.

TEAP welcomes the opportunity to further engage with Parties to address these challenges to the functioning of the TEAP and its TOCs going forward and remains committed to providing parties with independent, technical consensus reports to support their work.

Annex 1: TEAP and TOC membership and administration

The disclosure of interest (DOI) of each member can be found on the Ozone Secretariat website at: http://ozone.unep.org/en/assessment-panels/technology-and-economic-assessment-panel. 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.

1. Technology and Economic Assessment Panel (TEAP) 2019

TEAP is presently composed by three co-chairs, the co-chairs of the Technical Options Committees and five senior experts as indicated in Table 1 below. Senior experts currently provide expertise related to Montreal Protocol Processes, including Replenishment, global financing mechanisms, economics, energy efficiency and climate change. Expertise brought together by the five TOCs composing TEAP and current membership can be found in the sections below.

Table 1. TEAP Membership at May, 2019

Co-chairs	**Affiliation**	**Country**	**Appointed through**
Bella Maranion	U.S. Environmental Protection Agency	US	2020
Marta Pizano	Independent Expert	Colombia	2022
Ashley Woodcock	Manchester University NHS Foundation Trust	UK	2022
Senior Experts	**Affiliation**	**Country**	**Appointed through**
Suely Machado Carvalho	Independent Expert	Brazil	2019*
Marco Gonzalez	Independent Expert	Costa Rica	2020
Rajendra Shende	Terre Policy Centre	India	2020
Sidi Menad Si-Ahmed	Independent Expert	Algeria	2019*
Shiqiu Zhang	Centre of Env. Sciences, Peking University	China	2022
TOC Chairs	**Affiliation**	**Country**	**Appointed through**
Paulo Altoé	Independent Expert	Brazil	2020
Adam Chattaway	Collins Aerospace	UK	2020
Sergey Kopylov	Russian Res. Institute for Fire Protection	Russian Fed.	2021
Kei-ichi Ohnishi	AGC, Inc.	Japan	2019*
Roberto. Peixoto	Maua Institute (IMT), Sao Paulo	Brazil	2021
Fabio Polonara	Universitá Politecnica delle Marche	Italy	2022
Ian Porter	La Trobe University	Australia	2021
Helen Tope	Energy International Australia	Australia	2021
Daniel P. Verdonik	Jensen Hughes Inc	US	2020
Helen Walter-Terrinoni	Air conditioning, Heating and Refrigeration Institute	US	2021
Jianjun Zhang	Zhejiang Chemical Industry Research Institute	PRC	2019*

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

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.

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

FTOC members currently have expertise in: Producing and handling foam blowing agents; foam formulation; foam production (XPS, Spray Foam, appliance etc.) and life cycle analysis; emissions and banks modeling; certification testing for foams; regulations related to foams; global foam markets including forecasting future production; historical knowledge of foams, foam blowing agents, regulations, and the Montreal Protocol; the building envelope and reducing energy demand from buildings; appliance design and production energy efficiency.

Table 2. FTOC Membership at May 2019

Co-chairs	**Affiliation**	**Country**	**Appointed through**
Helen Walter-Terrinoni	Chemours	US	2021
Paulo Altoé	Independent Expert	Brazil	2020
Members	**Affiliation**	**Country**	**Appointed through**
Samir Arora	Industrial Foams	India	2020
Paul Ashford	Anthesis	UK	2019*
Angela Austin	Independent Expert	UK	2019*
Kultida Charoensawad	Covestro	Thailand	2019*
Roy Chowdhury	Foam Supplies	Australia	2020
Joseph Costa	Arkema	US	2020
Gwyn Davis	Kingspan	UK	2022
Rick Duncan	Spray Polyurethane Association	US	2020
Koichi Wada	Japan Urethane Industry Institute	Japan	2022
Ilhan Karaağaç	Kingspan	Turkey	2020
Shpresa Kotaji	Huntsman	Belgium	2022
Simon Lee	Dow	US	2020
Yehia Lotfi	Technocom	Egypt	2022
Lisa Norton	Solvay	US	2019*
Miguel Quintero	Independent Expert	Colombia	2019*
Sascha Rulhoff	Haltermann	Germany	2022
Enshan Sheng	Huntsman	China	2022
Dave Williams	Honeywell	US	2022
Guolian Wu	Samsung	US	2020
Consulting Experts	**Affiliation**	**Country**	**One-year renewable terms**
Sally Rand	Independent Expert	US	

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

3. TEAP Halons Technical Options Committee (HTOC)

Following the Kigali Amendment to the Montreal Protocol, the role of the Halons Technical Options Committee (HTOC) has broadened to cover low-GWP alternatives to halons, HCFCs, and high-GWP HFCs. However, the Kigali amendment does not bring the need for any additional areas of expertise in the fire protection sector, because the use remains unchanged. From a safety standpoint, the HTOC remains concerned that the flammability of refrigerants, foam blowing agents and solvents requires fire protection expertise which almost exclusively resides in the HTOC.

Generally speaking, the HTOC maintains expertise in three main areas: 1) the use of halons, HCFCs, high-GWP HFCs and their alternatives in fire protection, including emissions and bank estimates, 2) "banking" i.e., collection, recycling/reclamation, and re-deployment of these fire extinguishants including their application standards, purity requirements, and destruction issues, and 3) issues impacting current and future use, e.g., continued reliance on halons for existing uses in military, oil and gas, merchant shipping, etc., and for existing/new installations in civil aviation, and phase-down requirements of fire protections uses of high GWP HFCs. (It is important to note that as many HTOC members are fire protection experts, their expertise goes well beyond the use of only halons, HCFCs, high-GWP HFCs and their alternatives for fire protection, and is applicable in evaluating fire risk of the flammable refrigerants as well.)

Within the three main areas, the expertise is further divided into sectoral expertise and regional expertise. From a sectoral perspective, the HTOC has experts on fire protection requirements for all of the enduring uses of halons, HCFCs, high GWP HFCs and their alternatives within civil aviation, military, telecommunications, oil and gas, power generation, merchant shipping, explosion protection, etc. From a regional standpoint, the HTOC has expertise covering North America, Eastern and Western Europe, Australia and Japan, with some more limited expertise in Anglophone North Africa (Egypt), the Middle East (Kuwait), South America (Brazil), Asia (India and World Bank expertise on halon production phase-out in China). As noted in the matrix of expertise needed, the HTOC is continuing to look for additional experts to promote A5/non-A5 and regional balance while also being mindful of gender balance. Specific knowledge being sought is on the use of halons, HCFCs, high GWP HFCs and their alternatives in Central and South America, South East Asia (including China), and Africa (particularly central and south Africa). The HTOC is also looking for additional experts in banking and supplies of these fire extinguishants throughout Africa, South America and Asia, China's civil aviation industry, and in ship breaking activities, particularly on better knowledge of the anticipated lifetimes of ships and the actual quantities of halons contained on ships.

Table 3. HTOC Membership at May 2019

Co-chairs	**Affiliation**	**Country**	**Appointed through**
Adam Chattaway	Collins Aerospace	UK	2020
Sergey N. Kopylov	Russian Res. Institute for Fire Protection	Russian Fed.	2021
Daniel P. Verdonik	JENSENHUGHES, Inc.	USA	2020
Members	**Affiliation**	**Country**	**Appointed through**
Jamal Alfuzaie	Independent Expert	Kuwait	2022
Johan Åqvist	FMV	Sweden	2019*
Youri Auroque	European Aviation Safety Agency	France	2019*
Michelle M. Collins	Independent Expert - EECO International	USA	2022
Khaled Effat	Modern Systems Engineering	Egypt	2021
Carlos Grandi	Embraer	Brasil	2020
Laura Green	Hilcorp Alaska, LLC	USA	2020
Elvira Nigido	A-Gas Australia	Australia	2020
Emma Palumbo	Safety Hi-tech srl	Italy	2022
Erik Pedersen	Independent Expert	Denmark	2020
R.P. Singh	CFEES, DRDO	India	2020
Donald Thomson	MOPIA	Canada	2020

Mitsuru Yagi	Nohmi Bosai Ltd & Fire and Environment Prot. Network	Japan	2020
Consulting Experts	**Affiliation**	**Country**	**One-year renewable terms**
Thomas Cortina	Halon Alternatives Research Corporation	USA	
Matsuo Ishiyama	Nohmi Bosai Ltd & Fire and Environment Prot. Network	Japan	
Nikolai Kopylov	Russian Res. Institute for Fire Protection	Russian Fed.	
Steve McCormick	United States Army	USA	
John G. Owens	3M Company	USA	
John J. O'Sullivan	Bureau Veriitas	UK	
Mark L. Robin	Chemours	USA	
Joseph A. Senecal	FireMetrics LLC	USA	

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

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 soilborne pests and pathogens attacking various crops where methyl bromide is used (currently under the Critical Use exemption) 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 4. MBTOC Membership at May 2019

Co-chairs	Affiliation	Country	Appointed through
Marta Pizano	Independent Expert	Colombia	2021
Ian Porter	La Trobe University	Australia	2021
Members	**Affiliation**	**Country**	**Appointed through**
Jonathan Banks	Independent Expert	Australia	2022
Mohamed Besri	Institut Agronomique et Vétérinaire Hassan II	Morocco	2021
Fred Bergwerff	Oxylow BV	Netherlands	2021
Aocheng Cao	Chinese Academy of Agricultural Sciences	China	2022
Sait Erturk	Plant Protection Central Research Institute	Turkey	2019*
Ken Glassey	MAFF – NZ	New Zealand	2022
Eduardo Gonzalez	Fumigator	Philippines	2022
Rosalind James	USDA	US	2020
Takashi Misumi	MAFF – Japan	Japan	2022
Christoph Reichmuth	Honorary Professor – Humboldt University	Germany	2022
Jordi Riudavets	IRTA – Department of Plant Protection	Spain	2019*
Akio Tateya	Technical Adviser, Syngenta	Japan	2022
Alejandro Valeiro	Nat. Institute for Ag. Technology	Argentina	2022
Nick Vink	University of Stellenbosch	South Africa	2022

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

5. TEAP Medical and Chemicals Technical Options Committee (MCTOC)

The Medical and Chemicals Technical Options Committee brings together expertise on metered dose inhalers and their alternatives, aerosols, sterilants, production for feedstock uses of controlled substances, solvent and process agent applications, chemical substances of interest because of their ozone depletion or greenhouse warming potentials, laboratory and analytical uses, and destruction of controlled substances. Members are experts in asthma and chronic obstructive pulmonary disease and their treatment, pharmaceutical manufacturing and marketing, aerosol manufacturing and marketing, hospital and industrial sterilisation of medical equipment, chemical manufacturing, laboratory and analytical procedures, destruction technologies. Members have research, academic, clinical, regulatory, laboratory, industrial, and commercial experience.

Table 5. MCTOC Membership at May 2019

Co-chairs	**Affiliation**	**Country**	**Appointed through**
Kei-ichi Ohnishi	AGC Inc.	Japan	2019*
Helen Tope	Energy International Australia	Australia	2021
Jianjun Zhang	Zhejiang Chemical Industry Res. Institute	China	2019*
Members**	**Affiliation**	**Country**	**Appointed through**
Emmanuel Addo-Yobo	Kwame Nkrumah University of Science and Technology	Ghana	2022
Fatima Al-Shatti	Consultant to the International Ozone Committee of the Kuwait EPA	Kuwait	2022
Paul Atkins	Oriel Therapeutics Inc. (A Novartis Company)	USA	2022
Bill Auriemma	Diversified CPC International	USA	2021
Olga Blinova	Russian Scientific Center "Applied Chemistry"	Russia	2022
Steve Burns	AstraZeneca	UK	2021
Nick Campbell	Arkema	France	2022
Nee Sun (Robert) Choong Kwet Yive	University of Mauritius	Mauritius	2022
Rick Cooke	Man-West Environmental Group Ltd.	Canada	2021
Maureen George	Columbia University School of Nursing	USA	2021
Kathleen Hoffmann	Sterigenics International Inc.	USA	2020
Jianxin Hu	College of Environmental Sciences & Engineering, Peking University	China	2022
Ryan Hulse	Honeywell	USA	2020
Rabinder Kaul	SRF Limited	India	2022
Javaid Khan	The Aga Khan University	Pakistan	2022
Andrew Lindley	Independent consultant to Mexichem UK Ltd. And European Fluorocarbon Technical Committee (EFCTC)	UK	2020
Gerald McDonnell	DePuy Synthes, Johnson & Johnson	Ireland	2022
Robert Meyer	Greenleaf Health	USA	2022
Timothy J. Noakes	Mexichem (UK) Ltd.	UK	2022
John G. Owens	3M	USA	2020
Jose Pons Pons	Spray Quimica	Venezuela	2019*
Hans Porre	Teijin Aramid	Netherlands	2021
John Pritchard	Independent Consultant, Inspiring Strategies	UK	2022
Rabbur Reza	Beximco Pharmaceuticals	Bangladesh	2022
Paula Rytilä	Orion Corporation Orion Pharma	Finland	2019*
Rajiev Sharma	GSK	UK	2021
Peter Sleigh	Mexichem (UK) Ltd.	UK	2022

Jørgen Vestbo	Manchester University NHS Foundation Trust	Denmark	2021
Kristine Whorlow	Non-Executive Director	Australia	2022
Ashley Woodcock	Manchester University NHS Foundation Trust	UK	2019*
Yizhong You	Journal of Aerosol Communication	China	2020
Lifei Zhang	National Research Center for Environmental Analysis and Measurement	China	2022
Consulting Experts	**Affiliation**	**Country**	**One-year renewable terms**
Hideo Mori	Tokushima Regional Energy	Japan	

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

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 heat pump systems, Transport refrigeration, Air-to-air conditioners and heat pumps, Water and space heating heat pumps, Chillers, Vehicle air conditioning, Energy efficiency and sustainability applied to refrigeration systems, Not-in-kind technologies, High-Ambient-Temperatures applications, Modelling of RACHP Systems. Members have research, regulatory and commercial experience.

Table 6. RTOC Membership at May 2019

Co-chairs	Affiliation	Country	Appointed through
Peixoto, Roberto	Maua Institute, IMT, Sao Paulo	Brazil	2021
Polonara, Fabio	Universita delle Marche, Ancona	Italy	2022
Members	**Affiliation**	**Country**	**Appointed through**
Abdelaziz Omar	Cleat consulting	Egypt	2022
Bambhure Jitendra	Independent Expert	India	2022
Britto, Maria C	Johnson Controls, JCI	Brazil	2021
Calm, James M.	Calm Consultancy	USA	2022
Cermák, Radim	Ingersoll Rand	Czech Republic	2022
Chen, Guangming	Zhejiang University, Hangzhou	PR China	2022
Colbourne, Daniel	Re-phridge Consultancy	UK	2022
De Vos, Richard	GE Appliances	USA	2022
Devotta, Sukumar	Independent Expert	India	2022
Dieryckx, Martin	Daikin Europe N.V,	Belgium	2022
Dorman, Dennis	Trane Co.	USA	2022
Elassaad, Bassam	Independent Expert	Lebanon	2022
Gluckman Ray	Gluckman Consulting	UK	2020
Godwin, Dave	U.S. EPA	USA	2022
Grozdek, Marino	University of Zagreb	Croatia	2022
Hamed, Samir	Petra Industries	Jordan	2022
Herlin, Herlianika	PTAWH	Indonesia	2021
Janssen, Martien	Re/genT B.V.	The Netherlands	2022
König, Holger	Independent Expert	Germany	2022
Kauffeld, Michael	Fachhochschule, University Karlsruhe	Germany	2022
Koban, Mary E.	Chemours Co	USA	2021
Köhler, Jürgen	University of Braunschweig	Germany	2022
Kuijpers, Lambert	Independent Expert	The Netherlands	2020
Lawton, Richard	Cambridge Refrigeration Technology CRT	UK	2022
Li, Tingxun	Guangzhou San Yat Sen University	PR China	2022
Malvicino, Carloandrea	FCA (Fiat)	Italy	2022

Mohan Lal D.	Anna University, Chennai	India	2019*
Mousa, Maher	Independent Expert	Saudi Arabia	2019*
Nekså, Petter	SINTEF Energy Research	Norway	2022
Nelson, Horace	Independent Expert	Jamaica	2022
Okada, Tetsuji	JRAIA	Japan	2022
Olama, Alaa M.	Independent Expert	Egypt	2022
Pachai, Alexander C.	Johnson Controls, JCI	Denmark	2022
Pedersen, Per Henrik	Independent Expert	Denmark	2022
Rajendran, Rajan	Emerson	USA	2022
Rochat, Héléne	TopTen	Switzerland	2022
Rusignuolo, Giorgio	UTC Carrier	USA	2022
Vonsild, Asbjørn	Independent Expert	Denmark	2022
Yana Motta, Samuel	Honeywell (USA)	Peru	2019*
Yamaguchi, Hiroichi	Toshiba Carrier Co	Japan	2020

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

Annex 2: 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 2019.

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."

Ensuring appropriate and sufficient technical expertise is the priority consideration for the TEAP and its committees.

Body	**Required Expertise**	**A5/ Non-A5**
Foams TOC	XPS technology and conversion in Asia especially in India and China	A5
	PU System House technical experts	Southern Africa, Middle East, India. Mexico
	Additional foam chemistry experts	A5/ non-A5
	Building envelope/ energy efficiency	A5/ non-A5

Halons TOC	Fire suppression applications in civil aviation Knowledge of halon alternatives and their market penetration Knowledge of banking and supplies of halon and alternatives Knowledge of ship breaking activities	A5, South East Asia A5, Africa, South America, South Asia A5 Africa, South America A5 or non-A5
Methyl Bromide TOC	Issues related to the validation of alternatives to MB for certification of nursery plant materials related to movement across state and international boundaries and related risk assessment Expert in economic assessment of alternatives to MB Expert in QPS uses of MB and alternatives	A5 or non-A5 Non-A5 A5
Medical and Chemical TOC	Destruction technologies (experts with knowledge on the range of different technologies) Laboratory and analytical uses (experts with knowledge of analytical procedures)	A5 or non-A5
Refrigeration TOC	Not seeking additional experts at this time	
Senior Experts	Extensive knowledge of the MLF operations and/or assessing financial needs of A5 parties relating to MLF replenishment Extensive knowledge of global financing mechanisms and options relevant to ozone and climate protection	A5 or non-A5 A5 or non-A5