MONTREAL PROTOCOL

ON SUBSTANCES THAT DEPLETE

THE OZONE LAYER

UNEP

REPORT OF THE
TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL

JUNE 2016

VOLUME 1

PROGRESS REPORT

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UNEP Technology and Economic Assessment Panel

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Foreword

The June 2016 TEAP Report

The June 2016 TEAP Report consists of three volumes:

Volume 1*: Progress Report:*

- *TOC Progress Reports*
- *TEAP Essential Use Nominations Report May 2016*
- *Follow-up on TEAP's response to Decision XXVI/7*
- *Decision XXVII/7: Investigation of carbon tetrachloride discrepancies*
- *List of TEAP and TOC members at May 2016*
- *Matrix of Expertise*

Volume 2*: June 2016 TEAP Critical Use Nominations Report*

Volume 3*: Decision XXVII/5 Working Group Report: Issues Related to the Phase-out of HCFCs*

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1 Introduction

This is volume 1 of 3 of the June 2016 TEAP Report and contains Progress Reports from the five Technical Options Committees (TOCs) composing the TEAP: the Flexible and Rigid Foams TOC (FTOC), the Halons TOC (HTOC), the Methyl Bromide TOC (MBTOC), the Medical and Chemical TOC (MCTOC) and the Refrigeration and Air Conditioning and Heat Pumps TOC (RTOC).

HTOC's report includes a follow-up on TEAP's response to Decision XXVI/7 and an evaluation of Essential Use Nominations is included with MCTOC's report.

An annex of the TEAP and TOC membership list, as at 31st May 2016, which includes each member's terms for re-appointment and an annex of the matrix of needed expertise on the TEAP and its TOCs, appears at the end of this document.

1.1. Key messages

To facilitate review of this report by Parties, TEAP presents the main findings contained in each of the TOC reports in the following section.

1.1.1. FTOC

Total global polymeric foam production is increasing by about 4-5 % per year, from 21.9 million tonnes in 2014 to an estimated 27.1 million tonnes by 2019. The increased use of foam insulation in buildings provides an opportunity for substantial energy savings. Foam insulation is also increasingly being adopted for the development of the cold chain in A5 Parties, in order to improve food handing and reduce waste.

When new blowing agents are introduced, system reformulation is necessary. Where thermal performance is essential, it is important to consider long-term performance with the transition to low Global Warming Potential (GWP) blowing agents.

National and regional regulations regarding Ozone Depletion Potential (ODP) and GWP, and codes and standards related to thermal performance and energy consumption, fire safety, and volatile organic compounds (VOC) emissions are currently driving the choice of blowing agents used by foam manufacturers.

Blowing agents, ranging from hydrochlorofluorocarbons (HCFCs) to hydrofluorocarbons (HFCs) and hydrofluoroolefins (HFOs) / hydrochlorofluoroolefins (HCFOs), are manufactured and supplied by a limited number of chemical companies. This makes the supply chain potentially vulnerable for the next few years of transition, if for example, one of the suppliers exits the industry, or suffers a major plant failure.

Of the two major low GWP blowing agents, hydrocarbons (HCs) have fire safety concerns for small and medium enterprises (SMEs) and local air quality impacts, whilst less flammable/non-flammable alternatives, such as HFO/HCFOs, are more expensive. Some A5 foam manufacturers are waiting advice and direction on how to transition from HCFCs directly to low GWP alternatives, thereby avoiding the cost and effort associated with having to transition twice via high GWP HFCs.

There are currently three HFO/HCFO products (HFO-1234ze(E), HCFO-1233zd(E), HFO-1336mzz(Z) either available commercially or in developmental quantities with additional capacity under construction. Blends of HFO/HCFOs with other blowing agents (such as HC, and methyl formate) are gaining popularity, and may reduce cost, improve safety, and improve thermal performance.

1.1.2. HTOC

Including 3,3,3-trifluoro-2-bromo-propene (2-BTP) for aviation use, there are now six new fire extinguishing agents reported in various stages of development, four for streaming in the halon 1211 sector and two for flooding in the halon 1301 sector.

The HTOC continues to work successfully with the International Civil Aviation Organisation (ICAO) Secretariat in mandating the introduction of halon alternatives. At its upcoming General Assembly in September 2016, ICAO will propose that halon alternatives will be required in cargo bays of newly designed aircraft in 2024. This would complete the mandates for halon alternatives for newly designed aircraft.

HTOC is working with the Scientific Assessment Panel (SAP) on what the effect would be on the ozone layer from the potential amounts of additional emissions that could come from any new halon production needed to meet additional civil aviation requirements that cannot be met through existing, recycled halon. The SAP has added these extra halon emissions to their baseline and is in the process of running the 2-dimensional model on the potential effects to the ozone layer. The HTOC and SAP expect the results to be completed in time for presentation to OEWG-38 as part of the HTOC 2016 Progress Report.

1.1.3. MBTOC

By the end of 2014, official reporting indicates that nearly 98% of global methyl bromide (MB) consumption for l controlled, non-QPS (non-Quarantine and Pre-Shipment) uses had been successfully replaced with alternatives although stocks and potential non-compliant/ illegal uses may offset this. Critical Use Nominations for about 340 tonnes of MB have been submitted for either 2017 or 2018 by five Parties for six sectors where implementing alternatives has proven more difficult in these countries, i.e., strawberry runners, strawberry fruit, ginger, tomatoes and structures (flour mills and dwellings).

The largest present use MB is QPS, which despite being relatively stable at about 11,000 tonnes per year is generally increasing in A5 Parties and decreasing in non-A5s. MBTOC considers that technically and economically feasible alternatives would be immediately available for 30-40% of QPS uses.

Challenges remain for A5 Parties to report stocks and identify/put in place mechanisms for correct identification and tracking of final use of MB imported into a country that could lead to non-compliance and/or illegal trade.

1.1.4. MCTOC

The global transition away from chlorofluorocarbon (CFC) metered dose inhalers (MDIs) is almost complete. It is almost certain that 2015 was the final year for essential use exemptions for CFCs for MDIs under the Montreal Protocol. In China and Russia, where manufacturing transition is moving towards completion, CFC MDIs were manufactured entirely from CFC stockpiles in 2015. Over the next few years, global stockpiles of CFC MDIs will be exhausted, and the market will be completely free of MDIs containing ozone-depleting substances (ODS).

China nominated 65 tonnes of carbon tetrachloride (CTC) for laboratory and analytical uses for the testing of oil, grease and total petroleum hydrocarbons in water for 2017. MCTOC recommends that Parties authorise an essential use exemption for that amount, and requests that China, prior to any further nomination, provides specific information (see Chapter 5) on the evaluation of alternative international methods, progress in the development of its alternative method, and a timeline for phase-out of CTC in laboratory and analytical uses.

The Russian Federation was authorised an essential use exemption of 75 tonnes of CFC-113 for 2015 for solvents used for cleaning in aerospace applications. The Russian Federation has eliminated most CFC-113 uses with a variety of alternatives and is on track to meet its planned phase-out during 2016.

MCTOC has reviewed the information submitted by Parties under Decision XVII/6 on process agent use exemptions, make-up and emissions for those uses. Based on the information reported, it is recommended that Parties consider a number of specific changes to Tables A and B of Decision XXII/7 (see Chapter 5). Furthermore, a number of specific recommendations are made for information to be provided by Parties in order to understand better the remaining eleven process agent uses (see Chapter 5).

The Ozone Secretariat has provided data on Parties' production, import and export of ODS used as feedstock for the year 2014. These data include quantities used as process agents. In 2014, total production for feedstock uses was 1,165,679 tonnes, representing a total of 448,395 ODP tonnes. Emissions from ODS feedstock use are not reported by Parties. Using a surrogate emission factor, for guidance purposes only, estimated emissions associated with ODS feedstock and process agent uses in 2014 can be calculated as 5,828 tonnes, or 2,242 ODP tonnes. Both regulators and producers can act to ensure that emissions from feedstock uses of ODS are kept at minimal levels.

1.1.5. RTOC

The RTOC progress report focuses on updates to the technology as described in the RTOC 2014 Assessment Report.

The progress report maintains the traditional structure of Assessment reports. Information are shown for the different sub-sectors, namely: Refrigerants, Domestic appliances, Commercial refrigeration, Industrial systems, Transport refrigeration, Air-To-Air air conditioners and heat pumps, Water heating heat pumps, Chillers, Vehicle air conditioning, and Sustainable refrigeration.

A new Chapter has also been added, addressing Not-in-Kind (NIK) technologies, defined as "those technologies which do not use the vapor compression reverse (Rankine) cycle as a thermodynamic basis".

The activity of two new Working Groups (WGs) within the RTOC is also presented in the progress report. The two WGs have been established in order to tackle i) the high ambient temperature condition operation and ii) demand, banks and emissions scenario calculations.

2 Flexible and Rigid Foams TOC (FTOC) Progress Report

2.1. Executive summary

- Total global polymeric foam production is increasing by about 4-5 % per year, from 21.9 million tonnes in 2014 to an estimated 27.1 million tonnes by 2019. The increased use of foam insulation in buildings provides an opportunity for substantial energy savings. Foam insulation is also increasingly being adopted for the development of the cold chain in A5 Parties, in order to improve food handing and reduce waste.

- Foams are manufactured by many producers from small and medium enterprises (SMEs) to multi-national corporations (MNCs) in all regions of the world. In A5 Parties, the polyurethane foam manufacturing industry is fragmented and consists of many SMEs, whose raw materials are often supplied by one or a few local system houses. System houses provide the technical skills to produce complex raw material mixtures including blowing agents, polyols and additives needed to make foam. However, the blowing agents, ranging from hydrochlorofluorocarbons (HCFCs) to hydrofluorocarbons (HFCs) and hydrofluoroolefins (HFOs) / hydrochlorofluoroolefins (HCFOs), are manufactured and supplied by a limited number of chemical companies. This makes the supply chain potentially vulnerable for the next few years of transition, if for example, one of the suppliers exits the industry, or suffers a major plant failure.

- Arkema, Honeywell and Chemours have all published papers regarding their development of hydrofluoroolefins (HFOs) and hydrochlorofluoroolefins (HCFOs). There are currently three HFO/HCFO products (HFO-1234ze(E), HCFO-1233zd(E), HFO-1336mzz(Z) either available commercially or in developmental quantities with additional capacity under construction. Capital costs for a new plant are high, in the region of $100-200 million, and it can take 18 months to 5 years to construct a facility, and achieve full production. Blends of HFO/HCFOs with other blowing agents (such as hydrocarbons (HC) and methyl formate (MF) are gaining popularity, and may reduce cost, improve safety, and improve thermal performance. Optimised foam formulations using HFO/HCFOs or blends of HFO/HCFOs with other blowing agents, will require product approval and qualification/certification testing, for the blowing agent and also for the foam products. This can be done in parallel with the construction of the HFO/HCFO manufacturing facility but can also take from 18 months to several years

- The physical and chemical properties of foams (dimensional stability, water vapour permeability, adhesion/strength, shelf-life, yield, etc.) are affected by system reformulation, which is necessary when new blowing agents are introduced. The thermal insulation qualities of foams are highly dependent upon the blowing agent trapped in the foam cell matrix. Regulations and test methods used to assess thermal insulation performance, and thermal insulation standards, vary from region to region. Where thermal performance is less important or unregulated, or where the thickness of material is not a limiting factor, non-fluorinated or fugitive blowing agents which rapidly diffuse out of the matrix can be used including methyl formate, methylal, water, ethanol, dimethyl ether (DME) or carbon dioxide. Where thermal performance is essential, it is important to consider long-term performance with the transition to low Global Warming Potential (GWP) blowing agents.

- National and regional regulations regarding Ozone Depletion Potential (ODP) and GWP, and codes and standards related to thermal performance and energy consumption, fire safety, and volatile organic compound (VOC) emissions are currently driving the choice of blowing agents used by foam manufacturers. For specific applications, the choice of low GWP alternatives including hydrocarbons (HCs), methyl formate, methylal, CO_2 (Water) and HFO/HCFO is determined by many factors including cost, product performance, availability, production technology, final application and the size and technical capability of local foam manufacturers. Of the two major options, HCs have fire safety concerns for SMEs and local air quality impacts, whilst less flammable/non-flammable alternatives, such as HFO and HCFO chemicals, are more expensive. Some A5 foam manufacturers are waiting advice and direction on how to transition from HCFCs directly to low GWP alternatives, thereby avoiding the cost and effort associated with having to transition twice via high GWP HFCs. However, transition from HFC to HFO and HCFO chemicals is a drop in solution.

- In Article 5 Parties, rural development is increasing the use of polyurethane foam especially in low cost housing construction. In some A5 Parties, import of HCFC 141b itself is restricted or under license, but polyols containing HCFC-141b can be imported without restriction, creating a loophole which can act as a disincentive to phase-out HCFCs. Article 5 Parties face common challenges in phasing out fluorinated blowing agents including an increased need to meet stringent regulations on energy efficiency, a limited choice of alternatives, the cost of non-flammable alternatives, safety issues and the high investment costs for SMEs planning to use hydrocarbons. India and Brazil each have several hundred SMEs facing these issues.

2.2. Global drivers of foam production

Global production of the major types of polymeric foams produced using a blowing agent is estimated to grow by nearly 24% between 2014 and 2019 (see table 2.1). The majority of flexible foams used in furniture, bedding and automotive applications are now mainly produced using water, CO_2 or methylene chloride as blowing agents. Rigid polyurethane foams, some flexible polyurethane foams and extruded polystyrene and other types of foam use a wide range of blowing agents including HCFCs, HFCs, HFOs, water, dimethyl ether, ethanol, carbon dioxide, methyl formate, methylal and HCs.

Table2.1. Estimated Global Production Polymer Foam Products (tonnes)

	2016	2016	**CAGR**
Polyurethane			
Rigid	5,687,400	7,670,000	6.2%
Flexible	5,607,300	6,850,000	4.1%
Total PU Foam Production	**11,294,700**	**14,520,000**	**5.2%**
Polystyrene			
EPS	7,800,000	9,247,150	3.5%
XPS	1,445,000	1,631,850	2.5%
Total PS Foam Production	**9,245,000**	**10,879,000**	**3.3%**
Others			
Total (Phenolics, Polyolefins, EVA, ENR)	**1,320,000**	**1,568,600**	**3.5%**
TOTAL ESTIMATED GLOBAL FOAM PRODUCTION	**21,859,700**	**26,967,600**	**4.4%**

Source: ialconsulants & Smithers Rapra 2015

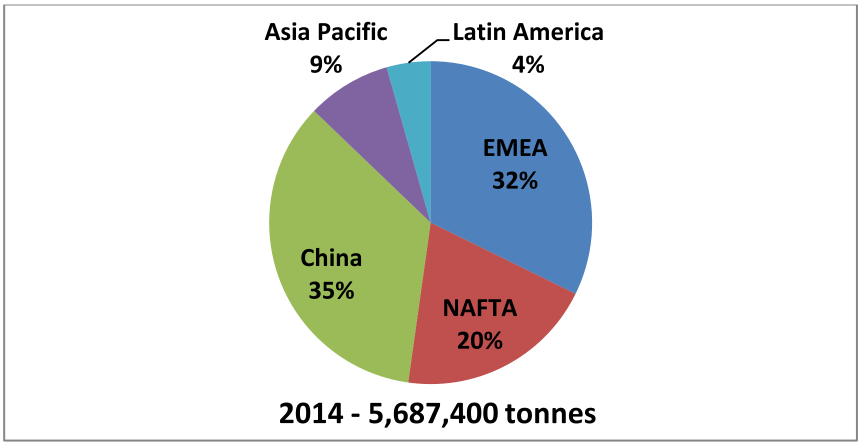
The significant drivers for all thermal insulation materials include pressure on power generation capacity, national government building codes, and increased demand for rapidly constructed houses and commercial buildings.

Polymeric foams used as thermal insulation material offer an excellent way to reduce energy consumption and the resulting CO_2 emissions. Oxford Economics forecast that global construction output (in value) will grow by 85 % between 2015 -2030. China, the US, and India are estimated to account for 57 % of the growth, and India is expected to overtake Japan as the world's 3rd largest construction market by 2021.

In "Buildings & Climate Change: A Summary for Decision-makers UNEP's Sustainable Buildings & Climate Initiative (SBCI), it is stated that not only do buildings use about 40 % of global energy for heating and cooling, but in addition, that they emit approximately one third of all greenhouse gas (GHG) emissions. Therefore, increased building insulation offers great potential for achieving significant GHG emission reductions, in developed and developing countries.

Rigid polyurethane foam accounts for a significant amount of the insulation material used in the cold chain sector, and is forecast to grow in parallel with the development of the cold chain in A5 countries and with increasing global urbanisation. India and many other developing countries are prioritising cold-chain development through the construction of warehouses and other facilities for freezing or chilling food awaiting transport, in order to feed its rapidly growing population and reduce wastage.

Fig. 2.1. The Relative Size of Rigid Polyurethane Foam Production, by Region, 2014 (%)



Source: ial consultants & Labyrinth Research & Markets Ltd.

2.3. Regulations and codes

The development and implementation of national and regional regulations relating to the energy efficiency of appliances and buildings continues to drive the global demand for high performance insulation materials, typically polymeric foams.

In the **United States (US)**, the Significant New Alternatives Policy (SNAP) program implemented by the Environmental Protection Agency (EPA) has changed the landscape for foam blowing agents. The SNAP program lists alternatives to ozone-depleting substances (ODS) as acceptable or unacceptable, depending on the overall health and environmental impacts of available substitutes. In Rule 20 in July 2015, the SNAP program communicated a change of status to unacceptable for the blowing agents HFC-134a, HFC-245fa and HFC-365mfc and other higher GWP HFCs for use in polyurethane, phenolic, and polystyrene foams between 2017 and 2021. The SNAP program excluded changes to HFC blowing agents used in spray foams and one component foams in Rule 20; however, they were included in proposed Rule 21 (published April 2016) with transition dates all prior to January

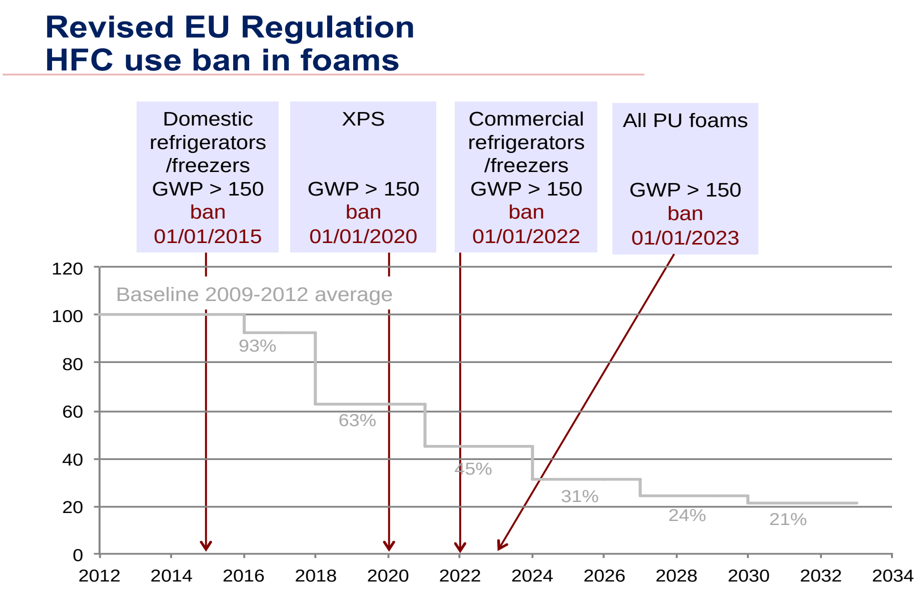
1, 2021. The proposed Rule 21 also includes a change of status to unacceptable for methylene chloride for use in flexible foams, integral skins, and polyolefins as well. There are extended timelines in both rules for military, space and aeronautics related applications.

Foams***	
Rigid Polyurethane and Polyisocyanurate Laminated Boardstock	January 2017
Flexible Polyurethane	January 2017
Integral Skin Polyurethane	January 2017
Polystyrene Extruded Sheet	January 2017
Phenolic Insulation Board and Bunstock	January 2017
Rigid Polyurethane Slabstock and Other	January 2019
Rigid Polyurethane Appliance Foam	January 2020
Rigid Polyurethane Commercial Refrigeration and Sandwich Panels	January 2020
Polyolefin	January 2020
Polyurethane Marine Flotation Foam	January 2020
Polystyrene Extruded Boardstock and Billet (XPS)	January 2021
Rigid Polyurethane Spray Foam	No status change finalized
Closed Cell Foams	Applicability to imports not finalized

***SNAP Fact Sheet July 20, 2015 Final Rule – Protection of Stratospheric Ozone: Change of Listing Status for Certain Substitutes under the Significant New Alternatives Program

In the **European Union (EU),** high GWP fluorinated gases are being phased down, according to the F-gas regulation (EU regulation 517/2014). In 2015, all HFCs with GWP greater than 150 were banned for foam use in domestic appliances. Labelling is obligatory on foams and polyol-blends, and the presence of HFC has to be mentioned in the technical documentation and marketing brochures for spray polyurethane foams (SPF) used in building insulation, refrigerated containers and trucks. By 1/1/2023 all HFCs with GWP greater than 150 will be banned from all foam manufacturing. **(See Fig2.2)**

Fig 2.2. HFC phase down according to F-Gas Regulations in EEA



The F-Gas regulation operates on the supply side through a quota system, which will likely mean that supply of blowing agents to the foam sector could become restricted well before the phase-out dates noted above. This is especially likely because the bulk of the demand is in the refrigeration and air conditioning (RAC) sector. A recent EPEE Study (presented at a side event at MOP-27) indicated that the RAC sector will have difficulty in meeting its phase-down targets, leading to an inevitable increase in price. Shortages of supply of HFC-365mfc/227ea for foam blowing are already being seen, because the previous manufacturer has been purchased by a company with a focused RAC interest.

In other non-A5 countries, there have been substantive new national and regional regulatory requirements for foam blowing agents with respect to their GWP. Regulations have been enacted or proposed that will require the elimination of the use of high GWP blowing agents in Canada, Japan and Australia by 2023.

Manufacturers of HFO and HCFO chemicals are planning to increase manufacturing capacity to meet the expected need for low GWP blowing agents. Capital costs for a new plant are in the region of $100-200 million and can take 18 months to several years to construct and achieve full production. Optimised foam formulations using HFO and HCFO chemicals or blends of HFO and HCFO chemicals with other blowing agents (such as HC and methyl formate) will require product approval and qualification/certification testing, not only for the blowing agent itself, but also for the foam products where the blowing agent is used. This foam formulation development, qualification and gaining of foam approvals can take also from 18 months to several years, but is often done in parallel with the construction of the HFO/HCFO manufacturing facility using product from existing facilities.

A5 Parties have an interest in transitioning to low GWP solutions directly from HCFCs. However, there is concern about the price, and adequacy of supply of suitable alternatives such as HFO and HCFO chemicals for SMEs in these Parties, as they make decisions about transitions. Foam manufacturers and blowing agent producers need re-assurance that market shift will be driven through regulatory changes in A5 Parties, in order to make the necessary and timely investment.

In the PU hydrocarbon-blown sector, FTOC has become aware of two unsaturated Perfluorcarbon foam additives (FA-188 and PF-5056, both from the same manufacturer), which are being used to optimise cell formation in order to gain maximum thermal performance improvement. FA-188 is a perfluorinated olefin, which is used in very small quantities and has a GWP of only around 100, but there are concerns about its potential breakdown products, which currently remain unclear. PF-5056 has a high GWP. FTOC plans to continue reviewing such new additives and their potential environmental impact in order to be sure that Parties are appropriately informed.

New regulations affecting the use of blowing agents in extruded polystyrene (XPS) have been introduced that will drive the point of sale replacement of HFC-134a foams by low GWP alternatives in the EU (Jan 1 2020) and the US (January 1 2021). Manufacturing conversion will have to be completed in early 2019 to remove higher GWP HFCs from the supply chain in Europe. HFO-1234ze(E) is only available from a single supplier, and has significantly higher cost when used as a direct replacement for HFC-134a. Blends are also being tested by some companies, as a lower cost option.

Code changes in Japan may require another transition for XPS producers to meet new thermal requirements (Class 3).

Some A5 XPS producers have already converted to zero ODP alternatives. Other A5 XPS producers continue testing zero ODP alternatives and/or low GWP alternatives to prepare for transition away from HCFCs. In China, HCFC-142b/22 blends are used with HCFC-22 predominating because of price and availability. These could transition directly to low GWP alternatives, including HFC-152a, CO_2, HCs, dimethyl ether (DME), alcohols etc. However, building codes for fire protection will limit HCs as an alternative. HFC-134a has low solubility in foam systems and lower thermal conductivity than the low GWP alternatives, and is used in blends with the aforementioned alternatives to better balance XPS foam performance. HFO/HCFO technology is also being evaluated either neat or blended with one or more of the aforementioned blowing agents

2.4. Status of blowing agents in current use

The complex chemical mixtures required to make polyurethane foam may be supplied directly from system houses, or blended in situ at production facilities. Typically, each system house supplies many SMEs. In some countries, SMEs may not have a choice of system house, limiting their choice of blowing agent. Suppliers of both systems and blowing agents, to the foam manufacturing industry are very aware that health, safety and environmental issues are critical in any decision to transition from HCFCs to alternatives that are flammable and emit VOCs.

HCFC-141b is still the dominant blowing agent for rigid foams in major ASEAN and African countries, along with water and methylene chloride for flexible foams. In some A5 countries, import of HCFC 141b itself is restricted or under license, but polyols containing HCFC 141b can be imported without restriction, creating a loophole which can act as a disincentive to phase out HCFCs. Transition to the next generation blowing agents such as cyclopentane and HFC-245fa is occurring, but it might be appropriate for some foam manufacturers to transition directly to HFO/HCFOs. In India and many parts of Asia, SMEs form the largest number of HCFC-141b consumers, and HFO and HCFO chemicals may be the best technical option for phase-out of HCFCs because they are non-flammable, but they are more expensive than HCFCs and HFCs in many cases. Demonstration projects are urgently needed to develop methods to reduce loading and costs, and there may be a delay in transition until these are completed.

High GWP HFCs, (e.g. HFC-134a) are still widely used in non-A5 Parties, mainly for production of extruded polystyrene and specific PU products such as PU Spray Foam. HFC-134a is often blended with HFC-152a to enhance product properties. HFC-152a has high solubility in XPS foam, which enhances physical characteristics, but also diffuses out of the foam matrix very quickly. HFC-134a has low solubility in XPS foams and a low diffusion rate, which means that it provides consistent, long-term thermal performance. Finding an acceptable alternative to HFC-134a for use in polystyrene foam remains a challenge. HFCs are due to be phased out in many non-A5 Parties by 2022. However, producers in non-A5 Parties may need to transition to these chemicals, or to blends containing these chemicals, in order to meet HCFC phase-out targets.

In India, labelling of pre-blended polyols and insulation boards containing HFCs has been required as of January 1 2015 and "included in descriptions used for advertising". In addition, there is an annual reporting obligation on manufacturers of pre-blended polyol containing HFCs (covering imports and exports)

Hydrocarbons (HCs) are a popular alternative to HCFCs. Large and medium sized foam producers who have installed safety equipment and are consequently able to safely handle flammable materials use them in many countries worldwide. However, in some countries and regions, local regulations limit the use of hydrocarbons because they are flammable and are VOCs. Currently, pentanes are considered to offer a low variable cost alternative to HFCs and HCFCs in polyurethane foams. Transitioning SMEs to HCs is problematic due to capital costs, safety handling, and training required. However, one leading supplier has converted small users of as little 6t/month to HCs cost effectively. Overall, the conversion to HCs is now slowing as the major foam manufacturers and domestic appliance producers have nearly all converted to HCs or other zero ODP alternatives.

The flammability risk is a limiting factor to the adoption of HCs by many foam-manufacturing SMEs, many of which are often located in areas of high population density, and who may lack experience of handling flammable materials or managing the cost of the safety measures. Flammability is a risk to be managed at all stages of the supply chain, from the manufacturer of the HC and transportation to the system house or foam producers, as well as during foam manufacture and subsequent storage.

Foam-quality pentanes and blends (n-pentane, isopentane, and cyclopentane) are available globally but are mainly produced in the EU and parts of Asia and shipped globally. Cyclopentane supply of sufficient quality for use in foams is further limited as there are no high purity producers in the US.

Polyisocyanurate Boardstock is currently largely foamed by n-pentane, but other alternatives (isopentane, cyclopentane, HFO and HCFO chemicals may be used or blended with n-pentane to optimize thermal performance as energy efficiency requirements change. Domestic Appliances use HFCs, cyclopentane or pentane blends; HFO and HCFO chemicals and blends of HCs with HFO and HCFO chemicals improve thermal performance.

Many Article 5 Party appliance manufacturers have converted to high GWP HFCs, HCs or blends of the two. This sector is anticipated to show rapid growth due to investment in the cold chain for food handling and to reduce food wastage. Large foam manufacturers switched to HCs under HPMP Phase 1, while the remaining SMEs will transition under the terms of HPMP Phase 2.

In Europe, EPS (expanded polystyrene) dominates the market for residential insulation and is the largest market for HC blowing agents due to the high losses during production. This use is not expected to change.

Methyl formate use as low GWP blowing agents is slowly increasing around the world in pour-in-place applications (such as discontinuous panels and commercial refrigeration) of spray foams and integral skin foams. Transition requires that the systems house for the specific application optimises the chemical mixture used for foam manufacture. These chemicals provide an alternative to HCFCs in some applications for SMEs. Whilst flammability is a risk before blending, the use of pre-blended polyols with methyl formate produced by local system houses may reduce the flammability risks at the SME.

Methylal is used as a co-blowing agent with HFC's. Flammability of the polyol blend is a limiting factor when used as a sole blowing agent.

CO_2 (Water) blown foam is a feasible option for applications where insulation requirements per thickness unit are less critical. Examples include some spray foams, pipe insulation and water heater insulation. CO_2 (water blown) is being used successfully to blow rigid spray polyurethane foams used for insulation in residential construction and prefabricated buildings in part of North America. Water blown polyurethane foams are also becoming popular in Europe for a range of applications including underfloor heating, roofing and wall insulations. In China, these foams are finding applications in pipe insulation and water heater insulation

Carbon dioxide (CO_2) is used as a blowing agent in the manufacture of some grades of extruded polystyrene either neat or blended with other blowing agents. It is also used in the production of flexible polyurethane foams used for comfort applications in furniture, bedding and automotive seating.

HFOs and **HCFOs** provide an alternative to HCs, which avoids the flammability issue and therefore the capital investment required to address safety when using HCs as a blowing agent. The transition to HFOs and HCFOs amongst PU foam SMEs is currently slowed by both their greater expense and limited supply in A5 Parties, although this is now improving. Strategies for lowering the cost of HFO and HCFO chemicals by using blends with other blowing agents are being implemented.

Manufacturers of HFO and HCFO chemicals are planning to increase manufacturing capacity to meet the expected need for low GWP blowing agents expected to result from the implementation of F-gas regulations. Capital costs for a new plant are high, in the region of $100-200 million and can take 18 months to several years to construct and achieve full production. Optimised foam formulations using HFO and HCFO chemicals or blends of HFO and HCFO chemicals with other blowing agents (such as HC and methyl formate) will require product approval and qualification/certification testing, not only for the blowing agent itself, but also for the foam products where the blowing agent is used. This foam formulation development, qualification and gaining of foam approvals can take also from 18 months to several years, but is often done in parallel with the construction of the HFO and HCFO chemical manufacturing facility using product from existing facilities.

DME, ethanol and butanes are used as non-fluorinated blowing agents for extruded polystyrene and some one component polyurethane foams that are dispensed from an aerosol can.

Methylene chloride is still used as a blowing agent in the production of flexible foams in A5 Parties. The US SNAP program has proposed a change of status of methylene chloride to "unacceptable" for use in foams, although foam produced from methylene chloride in A5 Parties can be exported to the US provided the foam is open-celled. Clearly, this use adds to the global annual emissions of methylene chloride.

Blends of blowing agents are gaining popularity in all regions, and are used in commercial production in most sectors. Blends offer a way forward to reduce overall costs of transition away from HFCs and HCFCs, while also optimising the thermal performance of foam. There are demonstration projects underway to optimise and test blends of methyl formate, methlyal, and HCs with HFO and HFCO chemicals for foams used in building insulation. These may reduce cost, improve safety, and improve thermal performance.

2.5. Conclusion

The chemical industry is working in conjunction with systems houses and foam manufacturers, to provide suitable polyols and foam blowing agents that optimise costs and performance parameters determined by national and regional agencies concerned with improving energy efficiency by reducing CO_2 emissions from burning fossil fuels. Capacity planning for alternatives will require continued communication between regulators, producers and users to ensure smooth transitions. Continued testing will be needed as local codes and standards and energy efficiency requirements are upgraded.

3 Halons TOC (HTOC) Progress Report

The Halons Technical Options Committee (HTOC) met from 7-9 March 2016 in Cologne, Germany. Attending members were from Brazil, Canada, France, India, Kuwait, Japan, Russia, South Korea, Sweden, the United Kingdom, and the United States of America.

The following is the HTOC update for 2016.

3.1. Agents

In addition to 3,3,3-trifluoro-2-bromo-propene (2-BTP), discussed in the Civil Aviation Update section below, there are five new agents reported in various stages of development, three for streaming in the halon 1211 sector and two for flooding in the halon 1301 sector. For the streaming sector, Fluoroketone (FK) 6-1-14 is approved under SNAP for non-residential streaming applications. As of today, there are no system approvals using this agent. One of the other two streaming agents is available in test quantities while the other streaming agent is only available in laboratory test quantities. One of the flooding agents is very new in the development process and is not yet currently available in any quantities. The other flooding agent, hydrochlorofluoroolefin (HCFO)-1233zd(E), has already been approved by the US EPA's Significant New Alternatives Policy (SNAP) program for use as a foam blowing agent, solvent and refrigerant, and is in production and commercial applications in those three sectors. Recently it has been submitted for regulatory approval in the US under the SNAP program as a total flooding fire-extinguishing agent as well. There remains, however, a lengthy process of testing and other approval processes before it could be commercialised as a fire-extinguishing agent.

3.2. Military

Militaries continue to manage responsibly their usage of halons and have begun to consider the issues related to the long-term availability of hydroflurocarbons (HFCs). The US Army hosted a 2-day military fire protection workshop in Oct 2015 with other US military services, industry, academia, and Allied military partners to exchange information regarding issues of mutual concern. Another workshop is being planned for 2017. Parties should encourage their militaries to participate in future collaborations such as this.

FK-5-1-12 has been specified by the US Air Force as a streaming agent for flight line applications. It is currently deployed in the European Union (EU) and North America and is expanding globally.

3.3. Civil aviation update

3.3.1. International Civil Aviation Organization (ICAO)

The HTOC continues to work with ICAO on the phase-out of halons within civil aviation.

As requested from the ICAO General Assembly in 2013, the International Coordinating Council of Aerospace Industries Associations (ICCAIA) suggested to ICAO that the deadline for mandating halon replacements in cargo compartments should be for Type Certification (completely new aircraft designs) after 2024 but without the 2040 European Union (EU) retrofit deadline. As a result, HTOC provided technical support to the ICAO Secretariat staff as they developed a draft Resolution (equivalent to a Conference Room Paper (CRP)) that would provide, amongst other things, 2024 as the date when cargo bays of newly designed aircraft could no longer use halons. The operative paragraphs for the draft Resolution are provided below.

1. *Urges* States and their aviation industries to intensify development and implementation of acceptable halon alternatives for fire extinguishing and suppression systems in aircraft cargo compartments;

2. *Urges* States to determine and monitor their halon reserve and quality of halon;

3. *Encourages* ICAO to continue collaboration with the International Aircraft Systems Fire Protection Working Group and the United Nations Environment Programme's Ozone Secretariat through its Technology and Economic Assessment Panel's Halons Technical Options Committee on the topic of halon alternatives for civil aviation;

4. *Encourages* States to collaborate with the Industry Consortium for engine/APU applications and the Cargo Compartment Halon Replacement Working Group established by the International Coordinating Council of Aerospace Industries Associations;

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

6. *Declares* that this resolution supersedes Resolution A38-9.

If approved, this would complete the requirements for phase-out dates for all halon uses for all newly designed aircraft and for some in-production aircraft. The ICAO Council mandates for the the replacement of halon would then be as follows:

- in lavatory fire extinguishing systems used in aircraft produced after December 31, 2011
- in handheld fire extinguishers used in aircraft produced after December 31, 2016;
- in engine and auxiliary power unit fire extinguishing systems used in aircraft for which application for type certification will be submitted after December 31, 2014;
- in cargo compartment fire suppression systems used in aircraft for which application for type certification will be submitted after a specified date in the 2024 timeframe.

It is important to note that the ICAO standards do not require changing all in-production aircraft, or retrofitting existing aircraft, to halon alternatives. With lifetimes of 30-40 years, this means that halon will continue to be used in civil aviation for many, many more years even with the existing mandates. It is also important to note that these changes to ICAO standards are not requirements. States are expected to try as best as possible to meet these standards but they are allowed, and do, file "differences" which explain how they will not meet the standards, in part or whole. This means that they could allow the use of halons past these dates for new designs.

3.3.2. Aircraft engine nacelle protection

The Halon Alternatives Aviation Propulsion System (HAAPS) consortium is still in Phase I (organizational stage). A managing entity (ME) has been selected and the Original Equipment Manufacturer (OEM) air framers have agreed to proceed with and fund the next steps: define the consortium administration and governance, intellectual property protection, member rights & benefits, supplier integration and participation. Phase 2 will then commence and a technical statement of work (requirements, performance validation, down selection criteria, etc.,) will be developed.

Powdered Aerosol F – the company proposing this agent is working to define a way forward to complete the Minimum Performance (MPS) testing.

A blend of CO_2 and FK-5-1-12 has been proposed by an aircraft OEM and a fire protection systems manufacturer. It has been evaluated by the US Federal Aviation Administration (FAA) and a design concentration has been defined. Also, the FAA is re-evaluating CO_2 in its own right.

3.3.3. Portable extinguishers

The agent 2-BTP has completed toxicity testing and the registrant has received a Pre-Manufacturing Notice (Consent Order #14-0260) to import 2-BTP in the US under the Toxic Substances Control Act for use in portable extinguishers in aircraft and in engine nacelle/auxiliary power unit fire extinguishing systems. US SNAP listing is still pending but it has been proposed as acceptable for these two applications in the recently released Notice of Proposed Rulemaking found in the US Federal Register at 74 FR 22810; April 18, 2016.

3.3.4. Cargo compartments

The water mist/nitrogen system is still under development for cargo bays. Proof of system performance and flight readiness is scheduled to be complete by the end of 2018.

The European Aviation Safety Agency (EASA) is proceeding with rulemaking task RMT.0560 "Halon: Update of Part-26 to comply with ICAO Standards".

A proposed rule is setting dates from which newly manufactured large aircraft (aeroplanes and rotorcraft) shall not use halon as an extinguishing agent in lavatories or in portable fire extinguishers.

The proposal should be addressed to the European Commission in the course of 2016, for an adoption of the final Regulation in 2017.

The applicable dates should be:

- One year after entry into force of the said Regulation, for the built-in fire extinguishers
- 31 December 2018, for the portable fire extinguishers

3.3.5. Response to Decision XXVI/7

Decision XXVI/7 on the availability of recovered, recycled or reclaimed halons includes the following requests:

> 1. To encourage parties, on a voluntary basis, to liaise, through their national ozone officers, with their national civil aviation authorities to gain an understanding of how halons are being recovered, recycled or reclaimed to meet purity standards for aviation use and supplied to air carriers to meet ongoing civil aviation needs and on any national actions being taken to expedite the replacement of halons in civil aviation uses as called for by the Assembly of the International Civil Aviation Organization (ICAO) in its resolutions A37-9 and A38-9;
>
> 2. To also encourage parties, on a voluntary basis, to submit information provided in accordance with paragraph 1 of the present decision to the Ozone Secretariat by 1 September 2015;

3. To request the Ozone Secretariat to report to the parties, prior to the thirty-sixth meeting of the Open-ended Working Group, any information provided by parties in accordance with paragraph 1 of the present decision;

The full decision is contained in Annex 3 of this report for reference. In response to the above paragraph 2, the Ozone Secretariat received information from four parties: Australia, Canada, the EU and the US. The Ozone Secretariat has asked the HTOC to review the received information for the parties.

3.3.5.1. Australia

Australia ceased importation of bulk halons from 31 December 1992, for all but essential uses. In response to concerns about a lack of availability of new halons for servicing critical infrastructure and the increasing availability of used halons as a result of decommissioning equipment, in 1993 Australia established a National Halon Bank to manage the supply of used halon.

The majority of halon held at the Bank originated from industry and government agencies following the decommissioning of non-essential halon fire protection systems. Small quantities of halon in portable extinguishers are still being surrendered from members of the public through metropolitan and country fire brigades. At present, all surrendered halon able to be reclaimed is being retained, with only severely contaminated halon destroyed. Halon is reclaimed to [International Standards Organisation (ISO) 7201-1 1989 standard. Halon from the Bank is only available for approved essential uses of Australian industry, which is limited to aviation, ocean going shipping and certain defence applications. International sales of halon will be considered, preferably on a Government-to- Government basis, subject to the agreement of the relevant National Ozone Unit.

Since 2000, Australia has had its National Halon Management Strategy in place, and it provides a basis for estimating the amount of halon that would be required to meet Australia's essential uses out to 2030. The amount of halon required into the future was independently reviewed in 2012, taking into account concerns about the slow transition from halon in the civil aviation sector.

The most conservative estimate is that around 60 tonnes of Halon 1211 would be required for domestic essential uses until year 2100 and that around 230 tonnes of Halon 1301 would be required until year 2100. The Bank currently holds around 98 tonnes of halon 1211 and 183 tonnes of halon 1301.

While in the past, Australia has destroyed halon excess to expected domestic requirements, no usable halon has been destroyed in the last five years or so as a result of global concern about regional and overall shortages of halon.

Subject to consultation, Australia is planning to introduce restrictions on the use of halon for lavatory waste compartments for new production aircraft by the end of 2016 and for handheld portable fire extinguishers for new production aircraft by the end of 2018.

3.3.5.2. Canada

In Canada there are two certified halon recycling facilities that receive halon from maintenance service providers or building fire protection systems. One recycles halon to ASTM standards and provides it to Canadian aviation maintenance service providers, while the other recycles or reclaims halon that it then exports to the USA for use in civil aviation.

In Canada, there is no physical halon bank where users can buy or sell halons, but some maintenance service providers and recycling facilities have recycled/reclaimed halons in stock. There is currently enough halon to meet the immediate needs of civil aviation, but there is no consensus among companies regarding medium term availability, i.e., 5 to 10 years.

Given that halon can be recovered, reclaimed and reused in Canada without the need for a permit, no data on quantities available in banks or inventories are available. It is therefore difficult to ascertain whether a shortage of halon to meet the needs of civil aviation is expected in Canada.

Canada is a member state of the ICAO and is actively participating in global efforts to develop alternatives to halon. Currently only Original Equipment Manufacturers, including one Canadian company, participate in the Industry Consortium Halons Alternatives for Aircraft Propulsion Systems for engine/auxiliary power unit/nacelle applications. The Cargo Compartment Halon Replacement Working Group is sponsored by the International Coordinating Council of Aerospace Industry Associations, of which the Aerospace Industry Association of Canada is a member. Transport Canada has actively participated in the Working Group in the past. The purpose of these two organizations is to identify globally-accepted non-halon fire-extinguishing solutions in these applications.

The Canadian Aviation Regulations (CARs) under the Aeronautics Act and the Federal Halocarbon Regulations, 2003 (FHR 2003) are regulations that apply to the civil aviation sector in Canada and compliance with them is mandatory. Additionally, various Minimum Performance Standards provide further requirements for civil aviation.

The FHR 2003 do not currently contain any provisions to expedite the replacement of halons in civil aviation, but will be amended to implement the ICAO Resolutions as adopted by Canada. It should be noted that Canada submitted a Notification of Compliance With or Differences from Annex 8 – Airworthiness of Aircraft indicating that there are no acceptable alternatives for uses in engine and auxiliary power unit applications and additional research is necessary. The FHR 2003 will therefore be amended according to Canada’s Notification.

The Ozone-depleting Substances Regulations, 1998 contain provisions for the import and export of ozone-depleting substances and products containing them. With respect to halon, these Regulations allow export in bulk for an essential purpose, reclamation or destruction, and import of fire-extinguishing equipment for use in aircraft, military ships or military vehicles. The import of halons in bulk is not allowed.

3.3.5.3. European Union (EU)

The EU commissioned a consultant to provide an analysis on the use of halons in the European civil aviation industry. They provided a summary of the findings, but the consultant’s report was considered confidential and was not reviewed by the HTOC.

A significant fraction of the halons in European aircraft originates from the US. The remaining fraction comes from numerous reclamation facilities in Europe that receive halons either directly from users or service companies or indirectly via gas traders/suppliers. Halon contaminated with high amounts of impurities is destroyed.

Air carriers usually outsource the maintenance of extinguishing equipment to service companies. In general, the halon supply to the aviation industry appears to be stable in most EU countries, although some countries have reported a shrinking availability of European halon suppliers. Problems may be associated with the size of the domestic aviation industry and not with a shortage of halon supply, e.g., minimum purchase orders may be beyond annual needs.

Aircraft operating in the EU go through an airworthiness certification process managed by EASA, whose requirements are based on standards developed by ICAO. There are also farreaching agreements between the EU and the US on aircraft safety regulations, and the Specifications adopted by EASA are largely aligned with those of the US FAA.

In the EU it appears that national civil aviation authorities and individual airlines have relatively limited impact on halon alternatives development, as airframe manufactures are in charge of system designs. There are limited national efforts to develop alternatives to halon. Type certification appears to represent a barrier for small-scale research and development in the EU. Service and aviation companies tend to think they have no influence or control over replacement and therefore they have little incentive to invest in research.

3.3.5.4. United States (US)

In July 2013, the FAA established a Halon Replacement Aviation Rulemaking Committee (ARC) to evaluate US compliance with international requirements for the adaption of halon replacements in civil aviation and to make recommendations on actions that should be taken to manage the safe and orderly transition out of halon. The ARC began its work in November 2013 and submitted its final report to FAA in December 2014.

Below are the main conclusions and recommendations of the FAA Halon ARC report.

Conclusions from the halon ARC:

- As no new halon is being produced for fire protection, the supply of previously produced halon is finite and will eventually run out.
- While residual supplies are being used or held for use in key areas including military, oil and gas, and other critical fire protection applications, their use in civil aviation represents the largest source of future demand for halons.
- Halons are installed in handheld extinguishers, engines, and cargo compartments of all new production aircraft. Based on the current slow pace of alternative development and implementation, this situation is likely to continue for the foreseeable future.
- The transition to alternatives in civil aviation will continue to be slow in the absence of the discovery of a drop-in replacement, a policy signal that significantly raises the cost of recycled halon, or a firm requirement that alternatives be implemented.
- The FAA has determined, based on available information, that regulatory action on the use of halon in civil aviation is not currently warranted.
- A significant percentage of the recycled halon used by civil aviation in the US and worldwide comes from a very small number of recyclers. There is a relatively small amount of halon in the aviation supply chain at any one time, and recyclers have limited ability to project future supplies. As such, there is concern about the potential for future supply disruptions and the impact a supply disruption would have on aviation safety.
- The ARC's estimates of the amount of halon being used to service existing aircraft are higher than previous estimates and represent higher emission rates than most other halon applications.
- Halons will be needed to service existing aircraft for the next 30-40 years. Based on current estimates of the use and supply of recycled halons worldwide, it is likely that there will be an insufficient supply of recycled halons to meet the needs of civil aviation during that timeframe.

Recommendations from the halon ARC:

- Identify a dedicated halon replacement aviation focal point within FAA.
- Develop guidance that raises awareness of the ICAO Annexes, highlights US support for ICAO timelines, and outlines the benefits of compliance with ICAO Annexes.

- Increase engagement at technical and management levels with the industry consortiums on engines and cargo compartments.
- Ensure that ample funding is available and that priority is given to halon alternatives research and testing at the FAA Tech Center.
- Support adoption at the 39th ICAO Assembly of a resolution for a reasonable timeframe for halon replacement in cargo compartments.
- Engage with other States to determine what action they are taking to comply with the ICAO timelines and seek a harmonized approach.
- Work with industry to develop guidance to limit the uncertainty related to issues that must be newly addressed for a replacement agent and those assumed to remain constant between a halon system and a replacement system.
- Reach out to the airframe manufacturers and airlines to discuss the issue of halon supply, the potential for supply chain disruption, and the potential virtues of maintaining additional supplies of halon to obviate against potential short-term supply disruptions.
- ARC believes that private industry should, either independently or collaboratively, investigate the creation of a commercial aviation halon stockpile to mitigate the potential for a supply disruption.
- Conserve halon by reducing unnecessary emissions during certification testing of aircraft fire suppression systems, due to improper maintenance procedures, and due to detection and alarm-related faults.
- Study the potential to conduct certification testing on aircraft systems by non-emissive means.
- Investigate to determine if current emission rates and unnecessary discharges are unacceptably high and if there are steps that can be taken to reduce them.
- Work with Contracting States under the Chicago Convention (i.e., ICAO) to encourage policies to remove international barriers to movement of recycled halons as a way of fostering a non-disruptive supply chain.

3.3.6. HTOC and Scientific Assessment Panel (SAP) halon analysis

Based on the findings in the Decision XXVI/7 report that unless civil aviation changes its course in implementing halon alternatives, it was nearly indisputable that they would run out of available recycled halon to support their uses in the 2036 – 2045 timeframe, the HTOC met with SAP co-chairs to see what the effect would be on the ozone layer from the potential amounts of additional emissions that would come from any new halon production needed to meet additional civil aviation requirements that cannot be met through existing, recycled halon. The HTOC updated the analysis using additional information on potential emission rates from civil aviation and annual emission rates based on atmospheric measurements. The results were used to estimate a range of potential extra annual emissions through the year 2034 - 2075. The low range of additional emissions assumed a civil aviation annual emission rate of 5% and retrofit of European flagged aircraft in 2040, per their existing regulation, Regulation (EC) No 1005/2009. The high range of additional emissions assumed an annual civil aviation emission rate of 8% and did not include retrofit of any aircraft. The SAP has added these extra halon emissions to their baseline and is in the process of running the 2-dimensional model on the potential effects to the ozone layer. The HTOC and SAP expect the results to be completed in time for presentation to OEWG-38 as part of the HTOC 2016 Progress Report.

3.4. Regional updates

3.4.1. South America

A workshop conducted in Colombia by a member of the HTOC with the National Ozone Unit (NOU) under the United Nations Development Programme (UNDP), in the fall of 2015, highlighted the continuing need for awareness of halon phase-out throughout the servicing and end-user communities. The workshop attendees commented afterwards that they were unaware of the potential for shortages of halon for servicing the military and civil aviation in the near future, and the role they can play in encouraging airline manufacturers to switch to halon alternatives. Colombia does not have a national halon bank nor did they have a national plan. The NOU was proactive in producing the workshop and moving forward with halon management plans, liaising with end-users, and including more awareness activities. The findings were similar to a workshop conducted the previous year in Chile.

3.4.2. Russian Federation update

The market continues to be estimated as well balanced with no surplus available for outside markets. More than 25 tonnes (t) / year of halon 2402 was available as a free agent ready for purchase in the period from 2013 to 2015. Table 1 provides information on the Russian installed base, recycling, and emissions from 2007 to 2015.

Table 3.1: Changes in Russian Bank of Halon 2402

	2007	2009	2010	2011	2012	203	2014	2015[1]
Recycled amount, t	80.0	120.0	21.0	23.0	23.0	25.0	30.0	40.0
Annual offer of free agent, t	10.0	20.0	24.0	25.0	25.0	28.0	30.0	28.0
Emissions, t	8.0	10.0	1.6	3.0	2.2	2.0	3.0	3.8
Total bank, t	947.0	941.0	939.4	936.4	934.2	932.2	929.2	925.4

Note 1: Data obtained by January 2016

There is an inert gas powder combination in Russia that is being developed and tested on fuel tanks up to 20,000 cubic meters, which has been approved for some applications. It is intended for open spaces such as refineries and non-occupied spaces. It was tested in high wind and at +40°C and met performance requirements.

3.4.3. China update

An agreement has been reached between the Foreign Economic Cooperation Office (FECO) and the Ministry of Public Security (MPS) to establish a halon management center (HMC) as part of MPS Fire Safety Division. The MPS is responsible for Fire Safety and Fire Fighting in China. The HMC will operate as a clearing house and plans to develop a database with information on halon 1301 and 1211 stocks and halon fire extinguishing systems in China. It may also track trading of halons. The operational details of the HMC will be developed in cooperation with FECO. Surveys on remaining halons in two Provinces have been completed. It is expected that the identified stocks of obsolete halons will be collected under the guidance of the new HMC at MPS. The halon 1211 stock at Dongyang has been moved to a new location as part of the relocation of the company. When the HMC starts operating, the stock and future sale of halon 1211 from the stock will be reported by the new HMC.

A contract has been signed with Lantian SinoChem for setting up a halon 1301 recycling facility at their location in Hangzhou. The recycling facility will be the only recycling facility for halon 1301 in China. The HTOC believes that Lantian SinoChem is the only halon 1301 producer in China (for feedstock use in the manufacture of the pesticide fipronil). The World Bank plans to discuss with FECO how to avoid “leakage” from this production of halon 1301.

The halon 1211 recycling center at Shenjie Fire Equipment Company in Guangdong is still on hold. The company is committed to continue the project, but is still waiting for a solution regarding classification as a hazardous waste. Shenjie was bought by a company in a non-Article 5 Party, in 2009 and maintains a majority ownership in the facility.

3.4.4. India update

Halon 1211 has been replaced totally in India except for aviation and military. The military has Russian airplanes that use halon 1211. It has been replaced with one of four agents: CO_2, watermist, HFC-236fa, and ABC dry powder. In buildings, halon 1301 is being replaced with CO_2 (40%), water mist (10%), and equal amounts of HFC-227ea and FK-5-1-12.

All systems manufacturers are working towards refining design of alternative agents, so adoption for their use becomes more acceptable, i.e., Fluorochemical is using higher container pressures and different means of delivery for FK-5-1-12 and HFC-227ea, which makes it possible to deliver the agents further, thus making the existing alternatives more usable.

According to ship breaking authorities in Alang, India (see https://en.wikipedia.org/wiki/Alang) it is expected that a significant quantity of halon 1301and 2402 will be salvaged from ships from Russia, Japan, and the European region in the 2016 -17 period. Significant quantities of halons are also expected to be derived from salvage activities in Bangladesh. Owing to the absence of a formalized communications structure, details regarding the availability of salvaged halons are not readily available to recyclers and end users nor to the Ozone Secretariat. There is concern that salvaged halons may pass into the marketplace in an unregulated manner and be misused. Vendors at the Alang port feel that there is not an adequate system in place for sale of salvaged halons to responsible agencies. As an example, one vendor had 2400 kg of halon 2402 and his attempts to contact a reputable recycler were not successful. There is a need to improve the communications system for salvaged halons otherwise a substantial amount of halons from shipbreaking will be wasted.

4 Methyl Bromide TOC (MBTOC) Progress Report

4.1. Executive summary

1 January 2015 marked the phase-out deadline for controlled uses of Methyl Bromide (MB) in A5 Parties, ten years after non-A5 Parties. As of that date, controlled uses of MB are only allowed under the Critical Use Exemption. By the end of 2014 official reporting indicated that about 98% of the global consumption baseline (all Parties) for controlled (non-exempt) uses had been replaced with alternatives (or re-categorised to QPS), however use of stocks and potentially non-compliant or illegal uses affect this outcome. Remaining Critical Use Nominations (CUNs) are for pathogens and pests of strawberry fruit and runners, tomatoes and structures. As a result, over 90% of present global MB consumption is for QPS applications; however, non-exempted (controlled) uses still face some challenges, including illegal trade of MB, which may lead to risks of non-compliance.

An increasing QPS consumption trend is evident over the past decade in A-5 Parties, whilst non-A5 Parties have decreased MB consumption for such exempted uses overall. Average global consumption continues to be around 11,000 t/yr despite bans on QPS use in the EU. The Asia Pacific region (comprising both non-A5 and A-5 Parties), the US, Australia and New Zealand presently account for about 80% of the global QPS consumption.

Alternatives to MB for QPS presently under development and/or in use for pest control in commodities include controlled atmosphere systems with lower O_2 levels, for tobacco and grain, ethanedinitrile (EDN) for sawn timber and logs (quarantine pests) and methyl iodide for controlling quarantine aphids in Japan. As of 2020, the New Zealand EPA will require all QPS MB fumigations to be applied with recapture equipment.

The International Plant Protection Convention (IPPC) has indicated that the Commission for Phytosanitary Measures (CPM) is considering quarantine treatments with sulfuryl fluoride as well as modified atmospheres for controlling some quarantine pests. A revision to ISPM-15 to consider new treatments is also envisioned.

Research conducted in the US forest nursery industry (which uses MB under the QPS exemption) indicates that reduced rates of metam sodium and 1,3-D applied under Totally Impermeable Film® (TIF) lead to control levels comparable to MB (also at reduced dosage under TIF). In the EU, where all MB uses are banned (including QPS), the strawberry runner industry reports good pest and disease control with crop rotation, dazomet and metam sodium.

Grafting (often combined with other treatments) as an alternative to MB continues to increase globally in tomato (for which CUNs are still sought). Substrates continue to prove technically and economically feasible for producing protected crops in many countries around the world. Anaerobic Soil Disinfestation (ASD) and biosolarisation are receiving attention as potential alternatives to MB for strawberries, vegetables, fruit orchards and other crops.

Dimethyldisulfide (DMDS) is a soil fumigant proving especially effective against nematodes and weeds, which is now registered and available in various countries around the world. Registration of EDN is also being sought for soil applications.

Sustainable use of phosphine as the main fumigant for commodity pest control is being promoted, with a focus on avoiding development of resistance. Additional research on fumigant alternatives to MB for controlling arthropod pests focuses on inert gases, contact insecticides and diatomaceous earths for arthropod control.

Illegal trade of MB, unreported stocks and unreported production in some countries continue to be of concern. Article 5 Parties have also indicated possible deviation of MB imported for QPS being used for controlled uses.

4.2. Introduction

1 January 2015 marked the phase-out deadline for controlled uses of MB in A5 Parties, ten years after non-A5 Parties. As of that date, MB use for applications subject to Protocol controls is only allowed under the Critical Use Exemption (see May 2016 TEAP Report vol. 2) amounting to about 2% of the global baseline. This indicates that successful development and adoption of alternatives has now occurred for the large majority of controlled uses for which MB was once used. A vast amount of information has been generated on such alternatives and is available to the Parties (see for example MBTOC, 2015).

The 2016 MBTOC Progress Report focuses primarily on alternatives to MB for those sectors for which critical uses are still requested: pre-plant (soils) - strawberry fruit and runners, tomato and ginger - and structures such as flourmills and dwellings.

Since over 90% of present global MB consumption is for QPS applications, relevant developments with respect to the development, adoption and/or availability of alternatives to MB for QPS are reviewed. Production and consumption trends of MB for QPS are also considered in this report.

Finally, a section on remaining issues and challenges, including illegal trade of MB, and potential risks of non-compliance that some Parties may be encountering is also included.

4.3. MB production and consumption

MBTOC uses Article 7 data reported by the Parties to the Ozone Secretariat and made available through the Data Access Centre as its official source of information on total MB production and consumption. However, MBTOC notes that other sources of information are available and suggests that further analysis could be conducted to develop a clearer picture of international MB trade at present. Information drawn from these sources does not always match information available from the Ozone Secretariat. Following are examples of websites illustrating this point:

https://www.zauba.com/import-METHYL+BROMIDE/hs-code-3808-hs-code.html is a website showing customs codes and usage amounts for various chemicals. The code for methyl bromide is 38247700, where 38 is the chapter number, 24 is the heading for miscellaneous chemicals and 7700 corresponds to bromomethane.

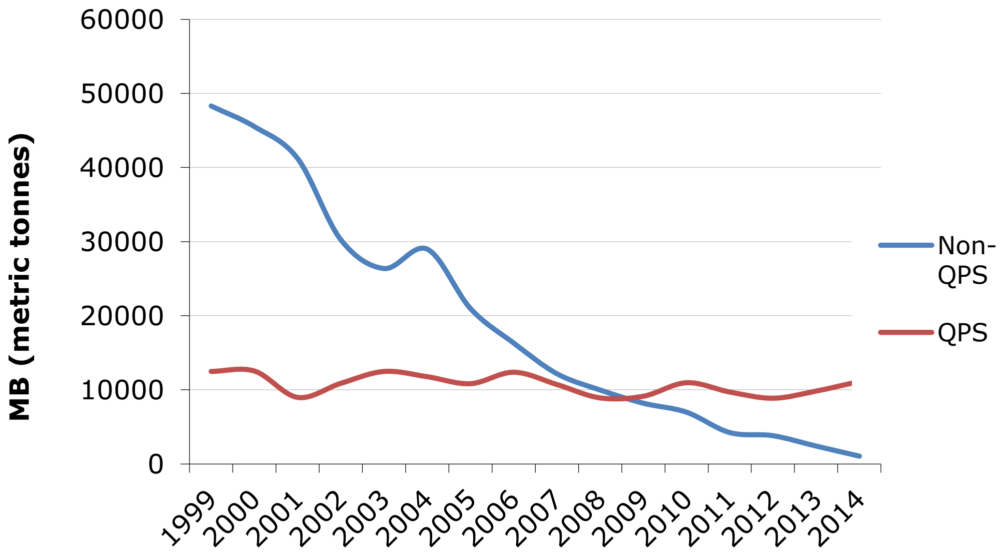
http://www.cybex.in/HS-Codes/Prepared-Binders-Foundry-Moulds-Cores-Heading-3824.aspx, provides statistics for individual countries (see for example http://tonga.prism.spc.int/index.php/component/advlisting/?view=download&fileId=912 where it is recorded that in 2013Tonga imported 1 tonne of MB, not shown in official data.

The International Trade Centre's (ITC) market analysis tools also keep record of trade with chemicals including methyl bromide (bromomethane, same harmonized code as above). This service is free for users in developing countries:
http://legacy.intracen.org/marketanalysis/OptionsFees.aspx

4.3.1. Global production for controlled and exempted (QPS) uses

On the basis of Ozone Secretariat data and other official data from Parties, by the end of 2014, about 98% of the global consumption baseline (all Parties) for controlled (non-exempt) uses had been replaced with alternatives (or re-categorised to QPS). By the end of 2014, in proximity of the phase-out deadline of 1st January 2015, about 91 % of the total consumption baseline for A5 Parties had been replaced with alternatives (Fig. 4.1).

Fig 4.1. Global consumption of MB for controlled and exempted (QPS) uses 1999-2014

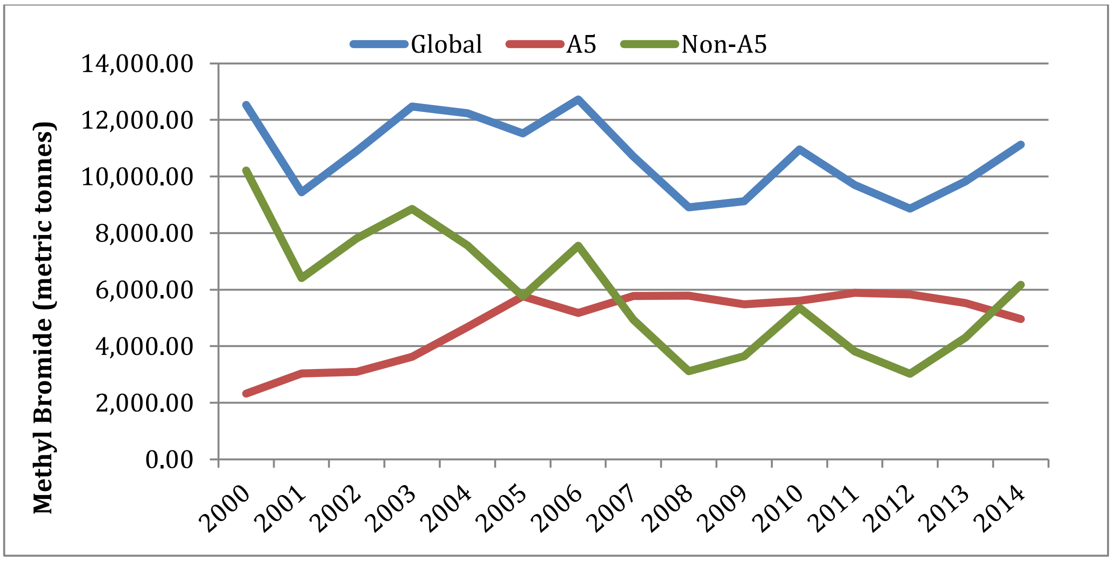


Source: Ozone Secretariat Data Access Centre, 2016. The global baseline for controlled uses was about 71,700 metric tonnes in 1995

4.3.2. Methyl bromide consumption for QPS

When considering the QPS sector on its own, an upward consumption trend is observed in the past two years (2013-2014) in non-A5 Parties and a levelled or decreasing trend in A-5 Parties. The increase is due to higher consumption reported by the US for 2014. Over the past 15 years however, this trend has been the inverse (i.e., increasing in A5 Parties and decreasing in non-A5s). Overall average consumption continues to be around 11,000 t/yr.

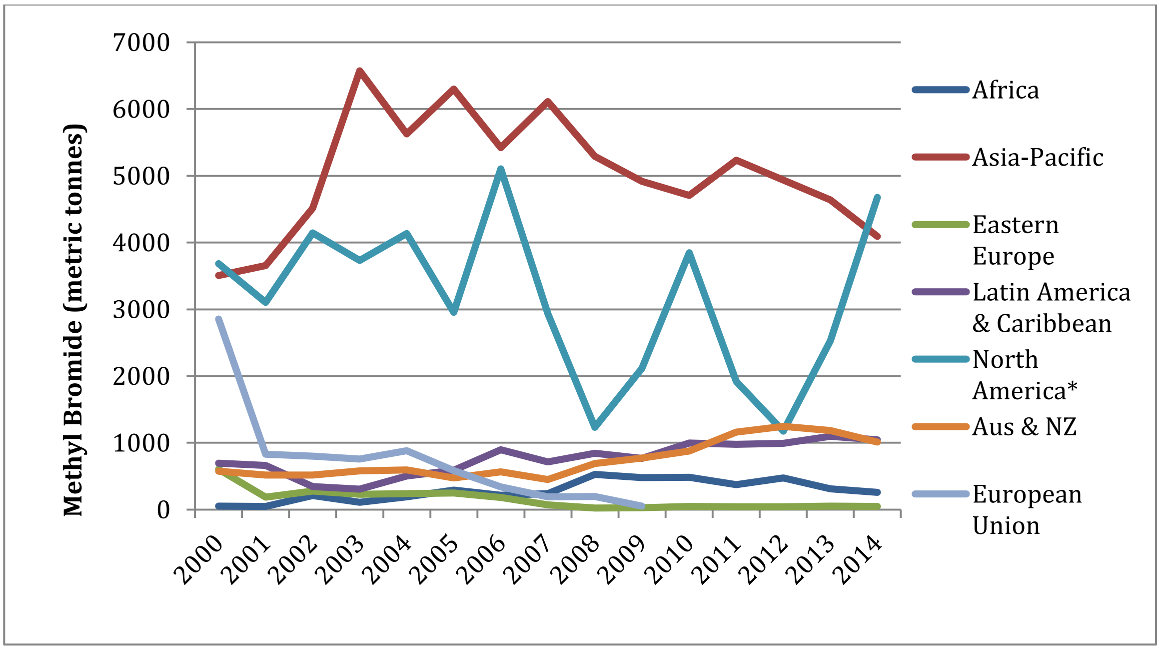
Fig 4.2. MB consumption for QPS purposes 2000 - 2014



Source: Ozone Secretariat Data Access Centre 2016

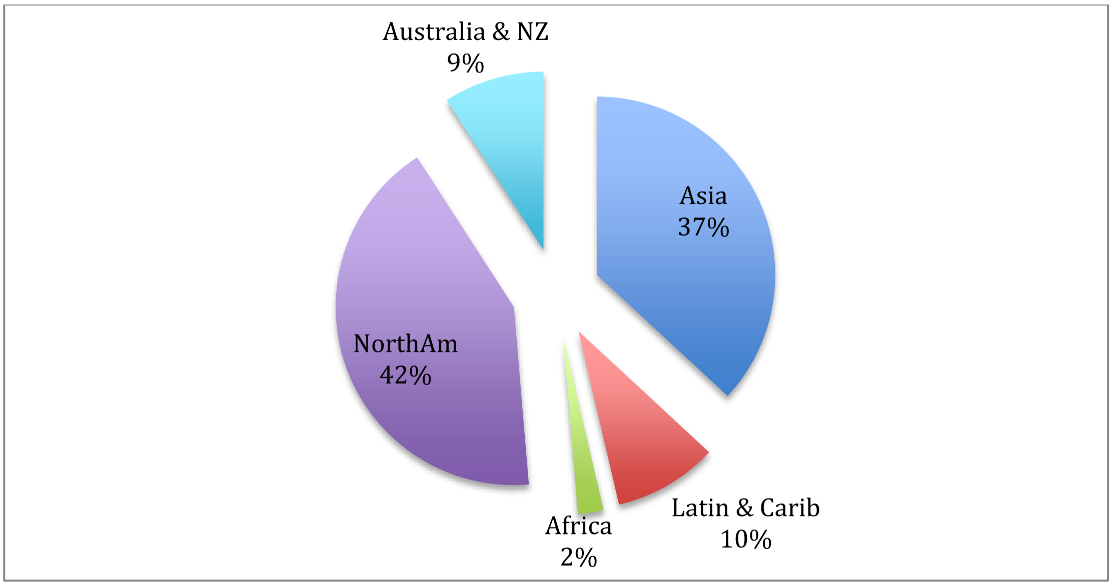
Figs. 4.3 and 4.4 below provide analysis on regional consumption of MB for QPS uses, and show that the Asia Pacific region (which includes both non-A5 and A-5 Parties) North America (US and Canada, where Canada's share is nil), and Australia and New Zealand presently account for about 80% of total QPS consumption.

Fig. 4.3. MB consumption for QPS purposes by region, 2000-2014**



Source: Ozone Secretariat Data Access Centre 2016. * USA + Canada. **Does not account for A5/non-A5 separately

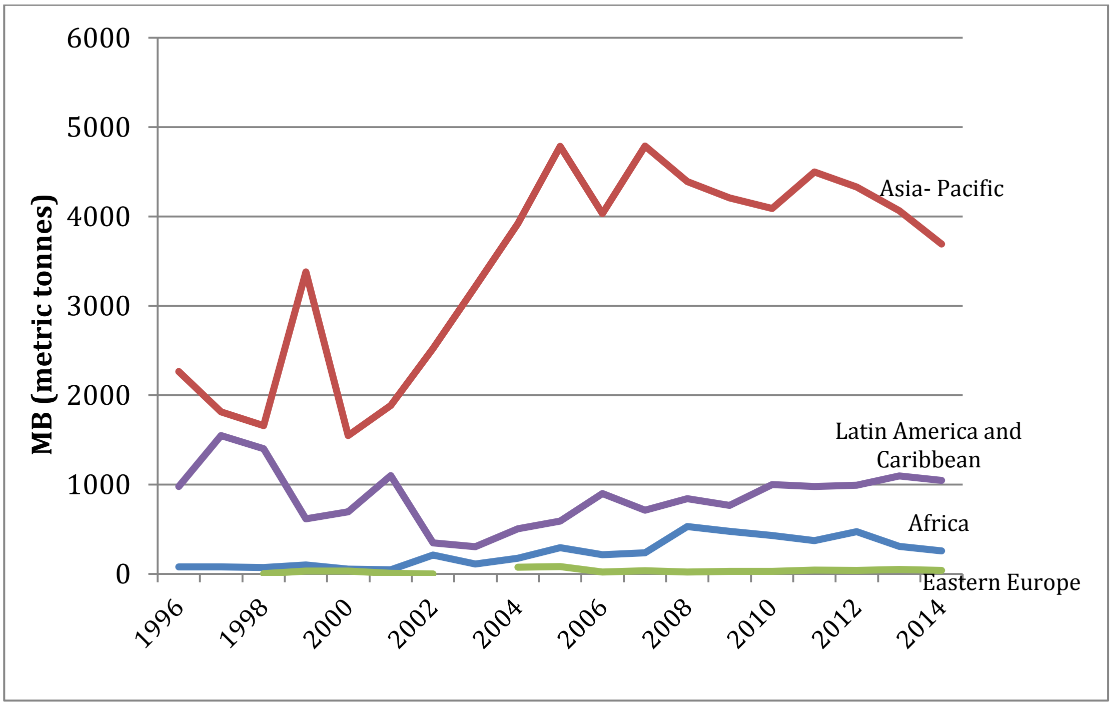
Fig 4.4. Percentages of the global consumption of MB for QPS uses on a regional basis (2014)



Source: Ozone Secretariat Data Access Centre April 2016. Western Europe consumption is zero.

Separate consideration of Article 5 Parties (Fig. 4.5) shows that the Asia-Pacific region is by far the largest consumer. There is a downward trend in recent years, but a large overall increase since 1996. Large consumers in this group include India, Viet Nam, China, the Republic of Korea, and Thailand.

Fig 4.5. MB consumption for QPS purposes in A5 regions



Source: Ozone Secretariat Data Access Centre 2016

4.4. Update on alternatives to MB and reducing MB use and emissions

4.4.1. Alternatives for QPS

4.4.1.1. Adoption of alternatives

A controlled atmosphere system that uses nitrogen to lower O_2 levels below 1% combined with high temperatures (38°C) is being used commercially in Indonesia for commodities such as tobacco (exposure time 4 days). It can also be used on grains with good results. Forty-six similar facilities are reported in 18 countries (Mahmudi, 2014).

Adoption of controlled and modified atmospheres (low oxygen) with or without warm to high temperature is increasing, and can be used in many applications, from stored grain and other commodities to treating ship holds, and aircraft (ECO2, 2016)

EDN also continues to show promising results. Trials with this fumigant were shown to achieve 100% mortality of the European house borer *Hylotrupes bajulus* within 24 h, under an environment of 25°C and75% relative humidity (Emmery *et al.*, 2015).
Hall *et al* (2015) tested the sorption characteristics of EDN for recently harvested pine logs, and tested an EDN sorption model for sawn timber. Over a 10 hour (h) period, average concentrations were 17.3% +/- 0.7 of the initial dose for logs with sealed ends and 9.4% +/- 0.4 for unsealed ends. This is a high rate of sorption compared with other fumigants, such as MB. A proportional drop in headspace concentration over time was consistent for the two doses (20 and 50 g/m3) evaluated, confirming that EDN sorption is influenced by the dose applied. Bark cover did not significantly influence EDN sorption.

Najar-Rodriguez *et al.* (2015) compared the toxicity of EDN in the laboratory to that of reduced rates of MB, using different life stages of the burnt pine longhorn beetle, *Arhopalus ferus.* Naked insects were fumigated with MB at 10°C and 20°C for 4 h or with EDN at the same temperatures for 3 h. The mortalities achieved and the CT products calculated indicate that (1) a reduction in MB usage may be possible for the treatment of logs exported from New Zealand and that (2) EDN has potential as a phytosanitary alternative to MB for the treatment of logs. Pranamornkith *et al* (2014 ab) tested the control of burnt pine longhorn beetle (*Arhopalus ferus*) adults using a range of EDN concentrations. The Lethal Dose for 99.99% kill LD99 for adults after a 3 h exposure at 15°C was 12.6 g/m3. Changes in the dose of EDN did not affect the sorption pattern. Increased moisture content and end-grain sealing both reduced sorption, but these effects were relatively small and the differences in sorption patterns caused by moisture content or end-grain sealing decreased over time.

Methyl iodide is still under study as a potential fumigant for controlling aphids (*Aphis craccivora*, *Myzus persicae*), mealybug (*Planococcus citri*), mites (*Tetranychus urticae*, *T, kanzawai*) and thrips (*Frankliniella intonsa*, *Thrips tabaci*) on fruit and vegetables in Japan. 20-30 g/m^3 for 2 h at 10°C or higher and 40-61 g/m^3 for 3 h at 10°C or higher were recommended to control those insect pests as quarantine treatment schedules (Naito *et al*. 2014 and Naito *et al*. 2015).

4.4.1.2. Improved efficiency of MB treatments

A presentation at a conference in Surabaya, Indonesia, (Anonymous, 2014) covered ten years of the Australian Fumigation Accreditation Scheme (AFAS), a programme comprising 600 fumigation companies in nine countries and which was developed for products exported to Australia. The scheme has resulted in a 50% reduction in detected fumigation failures requiring re-fumigation on arrival into Australia, therefore saving MB. The scheme is being developed under the new International Cargo Cooperative Biosecurity Arrangement to include trade between additional countries. The International Cargo Cooperative Biosecurity Arrangement is also developing standardised methods for heat treatment of export commodities and proper storage conditions thereafter (Cox, 2014).

4.4.1.3. Recapture

The company Nordiko reported that their recapture systems are now in 30 countries and they estimate that their systems have capacity to capture about 500 tonnes MB/year in total worldwide (Nordiko, 2014).

The New Zealand EPA requires all MB fumigations to be carried out using recapture equipment from 2020 but two regional authorities have fully adopted it early and another large authority has a staged implementation for completion in 2019. A locally based company is developing a recapture system large enough to deal with ship hold fumigations (Glassey Pers comm and http://www.genera.co.nz/content/Latest-News/52.aspx)

4.4.1.4. IPPC update

With the aid of the Ozone Secretariat, MBTOC has taken steps to reactivate the MOU between the Ozone Secretariat and the International Plant Protection Convention (IPPC), which was drawn in 2012 to *"Promote and facilitate collaboration between the Montreal Protocol and the IPPC through joint participation of technical experts in the technical panels and committees of both treaties, such as the Methyl Bromide Technical Options Committee, the Technical Panel on Phytosanitary Treatments and the Expert Working Group on Alternatives to Methyl Bromide, to enhance communication and advice consistent with the aims of both agreements."*

The IPPC has indicated to MBTOC that the Commission for Phytosanitary Measures will be discussing the following issues:

- Review of the outcome of some research findings in relation to *Ceratitis capitata* population response differences to cold and heat treatments, and consider if it addresses the concerns raised with regards to the nine draft cold treatments currently on hold
- Consider comments on four draft Phytosanitary treatments that were submitted to the 2015 member consultation (sulphuryl fluoride Fumigation of Insects in Debarked Wood (2007-101A); sulphuryl fluoride fumigation of Nematodes and Insects in Debarked Wood (2007-101B); heat treatment of Wood Using Dielectric Heating (2007-114); and vapour heat treatment for *Bactrocera tryoni* on *Mangifera indica*
- Develop at least one draft ISPM on treatment requirements with higher priorities (Fumigation is priority 1 and Modified Atmosphere is priority 2).

TPPT reports are available under: https://www.ippc.int/en/core-activities/standards-setting/expert-drafting-groups/technical-panels/technical-panel-phytosanitary-treatments/

4.4.1.5. Alternatives to MB for nurseries exempted as QPS

In the US, MB continues to be used as a pre-plant soil fumigant for the production of various types of nursery materials under the QPS exemption. This exemption applies to a range of nursery industries, including strawberry runners, ornamental plants, turf, fruit and nuts.

This exemption also includes the forest nursery industry in the Pacific Northwest in States such as Washington and Oregon (Weilland *et al.*, 2013; Weilland *et al.*, 2016). Research into MB alternatives and into reducing fumigation rates with the use of high barrier films has reported that reduced rates of metham sodium and 1,3-D applied under Totally Impermeable Film® (TIF) were comparable to MB (also at reduced dosage under TIF) in particular for controlling *Fusarium* and *Pythium*, two of the most troublesome diseases affecting forest nurseries. Some additional adjustments in rates are still necessary, but it is apparent that these alternative fumigants can provide equivalent results for this application (Weilland *et al*, 2016).

In all other countries such a QPS exemption is not allowed and industries have sought alternatives. For instance, in the EU (MB was banned for all uses including QPS in 2010) the strawberry runner industry, which includes Spain, one of the largest producers of runners in the world, mainly use crop rotation, dazomet and metham sodium for pest and disease control, with good results (López-Aranda, 2016).

4.4.1.6. Review of log treatments

Armstrong *et al.* (2014) have reviewed over 30 fumigants for treating logs; the review did not include phosphine as it is already being used for around 65% of export logs needing treatment. The international ban on ethylene dibromide in 1984, restrictions on MB beginning in 1991, and concurrent increases in environmental and worker safety regulations increased the cost of registration of new fumigants, and together with public pressure to reduce overall insecticide use, diminished commercial interest in maintaining older fumigants or developing new ones.

The review identified:

1. *EDN*, which is currently under study as a MB alternative for export logs in New Zealand, was recommended for further study. Recent studies determined the efficacy of EDN on the life stages of Burnt pine longhorn beetle, *Arhopalus ferus* (Mulsant) and the effects of dose, moisture content, end-grain sealing, and load factor on EDN sorption rates. However, these studies were specific to sawn timber, not logs, and more research is

needed to determine penetration and sorption factors for logs, the most tolerant species and life stages to EDN for selected forest insects, and laboratory and commercial efficacy tests.

2. *Sulphuryl fluoride*, a common timber and structural fumigant for termites, was a distant second possibility. Environmental issues and the difficulty with efficacy against insect eggs cannot be overlooked. However, if EDN is rejected pursuant to a technological and economic study, sulfuryl fluoride has positive characteristics that make it the only additional fumigant alternative to MB that can be recommended for further study.
3. Research in New Zealand is addressing the potential for using reduced rates and/or fumigation times when MB is used to control forest insects. Although this research obviously is not a "methyl bromide alternative", positive results from this research could translate into significant reductions in MB use and cost savings to the log export industry. Hence, continued research on reduced MB rates was recommended.

The review further looked at non-chemical treatments and methods, including controlled and modified atmospheres, energy treatments (irradiation, microwave, electrical, and infrared), physical treatments (cold, heat, pressure, and vacuum), log debarking, pest management systems, and systems approaches.

The most relevant recommendations are:

1. *Combined heat and modified atmosphere*: Based on work done in 1997 by Dentener *et al*. that showed significant efficacy of CO_2 or nitrogen at 40°C for controlling *Prionoplus reticularis* in less than 7 h, modified atmospheres plus heat should be further studied as a non-toxic treatment for New Zealand export logs under commercial conditions.

2. *Debarking*: Further studies are needed to determine if in-forest debarking at point of harvest can meet phytosanitary requirements. This is needed to establish a technological and economic baseline from which to compare the costs of alternative treatments.

4.5. 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, structural and commodity applications for which MB was used in the past (MBTOC, 2015).

A few cases have proven more difficult to replace: in non-A5 Parties strawberry runners (Canada and Australia) and in A5 Parties strawberry fruit and tomato (Argentina), ginger (China), wood houses and mills (South Africa).

4.5.1. Alternatives for remaining CUNs in the soil sector

The outcome of the critical use exemption requests is shown in the May 2016 TEAP report Volume 2 and gives a detailed overview of the immediate situation with adoption of alternatives.

Additionally, this report provides a short and broader overview of the current situation with alternatives. In Europe, strawberry runner production for export continues to increase even though MB use has been banned for six years (Meszka and Malus, 2014; Wu *et al.* 2012) and key alternatives such as 1,3-D/Pic and Pic alone are either banned or only available for emergency use. The main control options used by strawberry runner growers in the EU include crop rotation, dazomet and metham sodium (López-Aranda, 2016).

Adoption of grafting (often combined with other relevant treatments) as an alternative to MB continues to increase globally in tomato, eggplant, pepper and cucurbits (Kunwar *et al.* 2015; Penella *et al*.2015; Rysin and Louws, 2015; Silverman *et al*. 2014).

Substrates are technically and economically feasible for intensive production systems under cover in many countries, e.g. protected vegetables, strawberries, ginger and flowers, and in certain situations also for open field crops. Soilless production of ginger seed is for example in wide use in Hawaii, US and is considered a suitable alternative to MB (Kratky and Bernabe 2009).

Anaerobic Soil Disinfestation (ASD) is a non-chemical alternative that involves incorporation of a carbon source combined with impermeable film and with abundant irrigation to saturate the soil to manage a wide range of soilborne pests (Rosskopf *et al,* 2015). This technique continues to receive increasing attention as a potential alternative to MB in developed and developing countries for strawberries, vegetables, fruit orchards and other crops.

Browne *et al.* (2015) recently report that in California, US, ASD provides tree growth stimulation that is equal to that of soil fumigation with sustained benefits across time. Rosskopf *et al.* presently work on vegetable crops using different organic amendments and coupling ASD with solarization (proving excellent for weed control) and determining levels of nitrous oxide produced during ASD. Work on control of fusarium wilt of strawberries with ASD is presently underway in California, US (Muramoto *et al,* 2015).

More work is needed to evaluate factors influencing the effectiveness and cost of ASD treatments and to adapt this procedure to diverse cropping systems and environments (Browne *et al*, 2015; Momma and Kobara 2014).

Biofumigation is proving to be very effective as part of a production system in many crops such as vegetables in Spain (Díez *et al*, 2011) and was implemented successfully in Ecuador (Castellá-Lorenzo *et al,* 2014). Repeated biosolarisation treatments (mainly with chicken manure) are reported effective for controlling *Macrophomina phaseolina* in soil and increasing yields of some crops to similar or higher levels than those previously reported with 1,3-D/Pic, a key alternative to MB (Chamorro *et al.* 2015).

Recent research further reinforces the potential of biological control as an alternative to MB. For example, the biocontrol agent *Pasteuria penetrans* has shown good potential for controlling some species of nematodes and can now be mass-produced in vitro (Kokalis-Burelle, 2014).

4.5.1.1. Dimethyl disulfide (DMDS)

DMDS (commercial name Paladin®) is a soil fumigant especially effective against nematodes and weeds, which is now registered and available in the US, Israel, Morocco, Turkey, Jordan, Lebanon, Egypt, Mexico, Korea and others (Arkema, 2016).

DMDS is producing very encouraging results, for example in Spanish strawberry nurseries where it is applied in conjunction with herbicides and/or other fumigants (García-Sinovas 2014). Trials with this fumigant have also started in Australia in 2014, where DMDS combinations with fumigants are being evaluated for appropriate plant-back times after treatment. DMDS and DMDS/Pic co-applied with dazomet led to results that were not significantly different to those obtained with MB/Pic (Mattner *et al,* 2015). Adjustments to plant-back times and ways to mask the unpleasant, garlic-like odor emitted by DMDS, are both factors that are restricting its adoption.

4.5.1.2. EDN trials on soils and update on registration

Efforts to register EDN as a soil fumigant are under way in several countries for example Australia (expected to be completed by mid 2016). Large-scale trials are under way in New Zealand, Russia, Turkey, Egypt, South Africa, Israel and Saudi Arabia. Actions towards registration for soil fumigation are further being taken in India, China, South Korea, the US and the EU. Registration of EDN for use on timber is under way in Malaysia and Indonesia.

Thalavaisundaram *et al.* (2015) found that EDN showed considerable potential as an alternative fumigant to MB/Pic for strawberry runner production. Soils treated with EDN under VIF provided weed control and runner yields equivalent to MB/Pic, however pathogen control was not always comparable, in particular at low soil depths (40-50 cm). There was evidence that pathogens surviving at low depths in EDN-treated soils recolonized the upper soil by harvest, and this may mean that EDN requires deeper injection (> 15 cm) than MB/Pic to be effective against pathogens. Alternatively, co-application of EDN with Pic may improve pathogen control, since Pic is highly efficacious against fungi. Results showed that sealing soil with VIF improved the efficacy of EDN for soil disinfestation and runner production, compared with LDPE.

4.5.1.3. High barrier films

The Montreal Protocol requires every effort to reduce emissions of MB and barrier films have been shown to be very effective at improving the efficacy of MB and MB/Pic treatments in soil. All remaining preplant soil uses of MB, including soil uses for QPS, should be using barrier film as they are widely adopted and available worldwide. It should be noted that MBTOC bases its standard presumptions for critical uses of MB on application with VIF.

High barrier films continue to show excellent results in enabling lower rates of fumigants (MB as well as others) (Cabrera *et al*, 2015; EPA, 2016) to achieve the desired levels of control and some countries are now making their use mandatory or at least providing incentive for their use.

4.5.2. Alternatives for remaining critical uses in the structures and commodities sector

4.5.2.1. Phosphine

Sustainable use of phosphine as the main fumigant for commodity pest control has been described in recent reviews (Arthur 2015; Rogers *et al.* 2015). In particular, recent studies focus on guidelines and methods to avoid the development of stored product pests, which are resistant to phosphine (Jagedeesan *et al*. 2015; Konemann *et al*. 2015).

Phosphine generators are now more widely available commercially. The generated gas is generally delivered in a stream of CO_2 as a fire suppressant and diluent. Some MLF funded MB phase-out projects implemented in A5 Parties have trialled and demonstrated such generators, for example for treatment of stored wheat in Egypt, bagged grain in Syria, and stored maize in silo bins in Kenya (UNEP, 2014, UNIDO, 2015).

A recent project funded by the MLF in Tunisia has used phosphine generators to control *Ephestia kuehniella* and *Ectomylois ceratoniae* attacking dates. The results obtained confirm that phosphine may be considered as an efficient alternative to MB for date disinfestation (Dhouibi *et al.* 2015, Dhouibi and Hammami, 2015).

As reported in MBTOC's 2015 Progress Report, $ECO_2FUME^{®}$ (non-flammable mixture of phosphine and carbon dioxide) was recently registered in Morocco (ONSSA 2015) for grain fumigation and adoption is happening quickly.

4.5.2.2. Other alternative fumigants and contact insecticides

Additional research on fumigant alternatives to MB has focused on inert gases (Ren *et al*.2015; Gautam *et al*. 2015; Hansen *et al*. 2015). Further research has been presented on contact insecticides and diatomaceous earths for arthropod control (Eroglu 2015; Guedes 2015; Jimenez *et al.* 2015; Korunic *et al*. 2015; Sansur *et al*. 2015; Stejskal *et al.* 2015; Subramanyam *et al*. 2015; Wijayaratne 2015). The use of aerosols and contact insecticides for structural treatments is increasing in the US, given that with robust Integrated Pest Management (IPM) in place, infested sites needing treatment within a mill can be specifically identified (Campbell *et al.* 2014). Common aerosol treatments are pyrethrin applied alone or with an insect growth regulator (IGR), such as methoprene or pyriproxyfen. Increased cleaning and sanitation is also being emphasized.

The USDA-ARS Center for Grain and Animal Health Research, Manhattan, KS, is conducting research to look at factors such as aerosol dispersion in field sites, how structural barriers affect distribution, and the efficacy of aerosols at different particle sizes. These aerosols can be applied through portable systems brought into the facility or through overhead systems installed in the facility itself. Their research indicates that aerosols as part of an IPM System can reduce the need for whole site fumigation of mills and food processing facilities (Arthur, 2015; Campbell *et al.* 2014; Diaz-Montano *et al.*, 2015; Perez-Mendoza *et al.*, 2014; Arthur *et al.*, 2014).

4.5.2.3. Biological control

Adoption of biological control and related methods as a friendly approach for the environment, workers and customers, increasingly present alternative options for certain areas of stored product protection and this avoids the need and use of fumigants. For example, recent research has demonstrated the effectiveness of *Holepyris sylvanidis* against *Tribolium* larvae and of parasitic wasps against other pest insects in storage. Mating disruption by use of highly concentrated pheromones was also shown to be promising within an IPM strategy (Athanassiou, 2015; Thakur and Renuka, 2015).

4.5.3. Update on registration of alternatives

4.5.3.1. Ethanedinitrile (EDN)

The manufacturers of EDN (Draslovka) are in the process of registering EDN™ FUMIGAS in Indonesia (timber), New Zealand (logs and timber), Malaysia (timber which has quarantine approval already), South Korea (timber, treatment of logs against pine wilt nematode, fumigation of old cultural wooden structures and soil) and Saudi Arabia.

Australia currently is the only country that has registered EDN™ FUMIGAS for timber fumigation. The soil disinfestation registration is pending with all submissions completed and may be approved in 2016.

4.6. Illegal trade, possible unreported use and other issues

Illegal trade of MB and unreported stocks continue to be of concern. Article 5 Parties continue to signal problems with possible deviation of MB imported for QPS, which may end up in controlled uses. Further, MBTOC has found news items that give indication of illegal trade and possibly production in some countries. Some examples are included below.

4.6.1. Illegal trade in the Caribbean

Last year a family on vacation in the Virgin Islands suffered severe reactions arising from exposure to MB, which was illegally used to fumigate hotel premises. Later in the year there were reports of MB still being available in Puerto Rico and possibly other Caribbean countries. See http://www.wboc.com/story/30619617/use-of-banned-pesticide-not-isolated-event-in-us-territories

4.6.2. Possible unreported methyl bromide use in India

As a Party to the Montreal Protocol, India is required to report production and consumption under the Article 7 of the Protocol for both controlled and exempted uses. QPS consumption has been reported every year since 1993. The Party reported MB **production** for QPS between 1993 and 2002 (average of about 100 metric tonnes per year) and zero since 2003.

Although India has not reported production or consumption for controlled uses in more than 15 years, MBTOC has indicated in at least the last three of its most recent Assessment Reports, that various Indian companies offer MB manufactured in India, as well as fumigation services with this product available for use in their websites. Some examples can be found at http://sarthichem.com/AboutUs.html and http://www.ippl.co.in/soil_fumigation.html or http://www.ippl.co.in/commodity_fnumigation.html).

Periodically, MBTOC has also come across news items mentioning MB use in India – for controlled uses. One recent such example may be found here: http://www.mumbaimirror.com/mumbai/others/Bugged-by-bedbugs-passengers-hold-up-train/articleshow/50490689.cms where an incident involving trains' disinfestation to control bedbugs with MB is reported. Bedbugs are not considered as quarantine pests for which the QPS exempted MB could be used, so this use would fall under the controlled category.

More recently, aircraft disinfestation (for rodent control) with methyl bromide was also reported: http://www.mumbaimirror.com/mumbai/others/Rats-on-AIs-Dreamliner-cause-flight-nightmares/articleshow/51933546.cms. (MBTOC notes that under some circumstances, this treatment could be classified as QPS).

4.6.3. Canister disposal

Parties have approached MBTOC requesting assistance on adequate disposal of empty MB canisters. Canisters are made of aluminum and can be recycled like any other aluminum can. In some countries, by law, growers had to take empty canisters to the place of purchase. After use, canisters were collected and stored in well-ventilated area for two months before recycling. The empty recycled canisters were tested in an accredited laboratory to detect any MB residues.

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5 Medical and Chemicals TOC (MCTOC) Progress Report (including Recommendations for Essential Use Nominations)

5.1. Medical

5.1.1. Developments in the phase-out of ODS in metered dose inhalers

The global transition away from chlorofluorocarbon (CFC) metered dose inhalers (MDIs) is almost complete. In 2015, the total quantity of CFCs used globally to manufacture MDIs was 210 tonnes. This corresponds to a reduction of 98 per cent from 1997 when global annual CFC use for MDI manufacture peaked at about 10,000 tonnes. This compares also with about 10,000 tonnes of hydrofluorocarbons (HFCs) used to manufacture MDIs in 2015.

Manufacturing transition is moving towards completion in the last remaining countries, China and Russia. It is almost certain that 2015 was the final year for essential use exemptions for CFCs for MDIs under the Montreal Protocol. While China had an essential use exemption for 2015, no CFCs were produced to supply MDI manufacture in 2015. In both China and Russia, CFC MDIs were manufactured entirely from CFC stockpiles in 2015.

IMS Health data supplied by IPAC[1] to MCTOC shows a continued diminution in the availability to patients of CFC MDIs globally. The most recent data available indicates that in 2014 HFC MDIs accounted for 77 per cent, and CFC MDIs for 23 per cent, of all MDI sales worldwide. Due to inventory in the supply chain, CFC MDIs manufactured in a certain year might be available in the market for up to two years beyond. MCTOC expects that as China and Russia complete their manufacturing transition, CFC MDI sales and use will continue to fall and the final tail of the CFC phase-out will be completed.

Proprietary non-MDI devices in development and on the market have continued to diversify and multiply, and companies are investing in their own unique delivery technologies. Nevertheless, the MDI has remained a mainstay of inhaled therapy. In 2014, the total global use of MDIs has remained constant at about 60 per cent versus dry powder inhalers (DPIs) at 32 per cent, based on dose equivalence, with considerable regional variation. However, this overall ratio is not expected to change greatly in the next decade due to the relatively low cost of salbutamol MDIs compared to multi-dose DPIs. Figure 5-1 shows global sales on a dose basis (derived from standard units[2]) for different treatment types for the period 2007- 2014. In 2014, CFC MDIs accounted for about 13 per cent of all inhaled medication globally, HFC MDIs for about 46 per cent, DPIs about 32 per cent, and nebulised solutions about 8 per cent.

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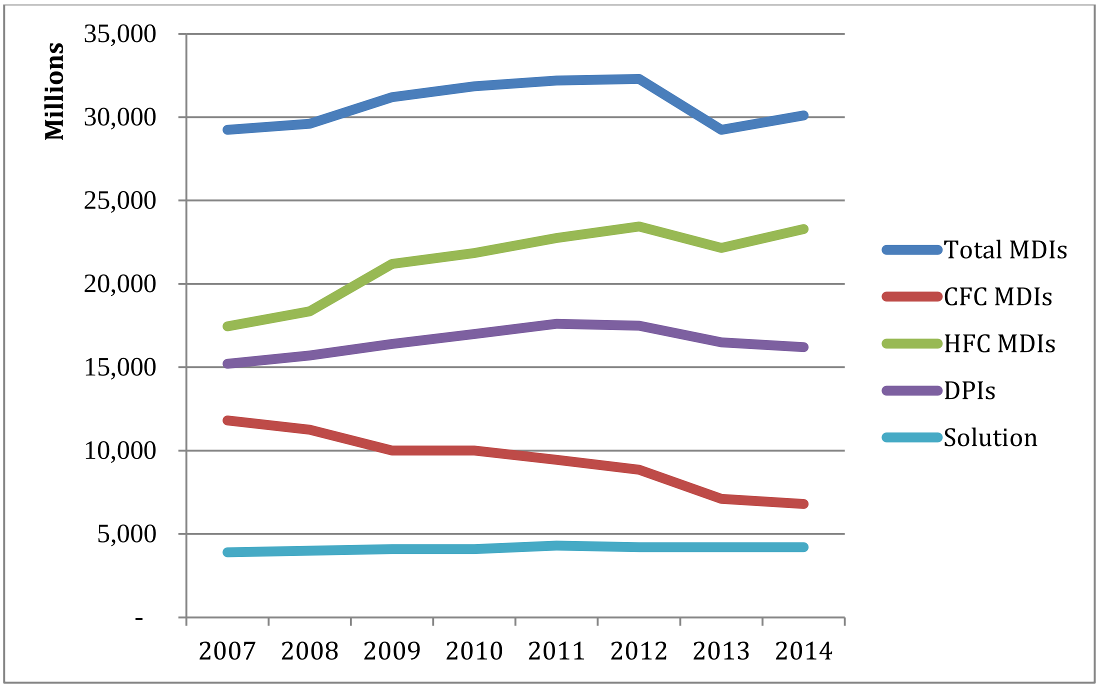
[1] IMS Health is a company that gathers and analyzes pharmaceutical market data. IPAC is the International Pharmaceutical Aerosol Consortium, a group of companies that manufacture medicines for the treatment of respiratory illnesses, such as asthma and COPD. IMS Health; IMS MIDAS granted IPAC permission to submit this data to MCTOC/TEAP.

[2] A standard unit is defined by IMS as the number of dose units, such as the number of inhalations/puffs, tablets, the number of 5ml doses, or the number of vials, sold for a particular product. For standard unit comparisons of DPIs versus MDIs it is important to note that for DPIs: 1 puff (1 SU) = 1 dose, whereas in general for MDIs: 2 puffs (2 SUs) = 1 dose. Translating standard units into the absolute number of actual MDIs or DPIs can be complex because different devices provide a range of doses. A rough estimate is made for MDIs by dividing the SUs by 200 and for DPIs by 60.

Figure 5.1 Global sales of inhaled medication on a dose basis, 2007-2014



In Europe, a number of new inhalers have been approved in recent years.[3] These cover a range of new molecules (e.g. indacaterol, glycopyrronium, aclidinium), as well as previously approved molecules in a different delivery system (e.g. Bufomix Easyhaler, DuoResp Spiromix). These include several DPIs and MDIs for the commonly prescribed combinations of salmeterol and fluticasone, and formoterol and budesonide.

In the United States (US), some of the novel inhalers (listed in the footnote) have also been approved. In addition, there has been an approval of a new multi-dose dry powder inhaler for the delivery of albuterol (salbutamol), the "ProAir RespiClick", and it is anticipated that further new delivery devices for existing molecules will be forthcoming[4] in the next several years.

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[3] New inhalers approved include: GSK Relvar/Breo Ellipta (vilanterol/fluticasone furoate); GSK Anoro Ellipta (vilanterol/umeclidinium); GSK Incruse Ellipta (umeclidinium); GSK Seretide Diskus (salmetrol/fluticasone); Novartis Ultibro Breezhaler (indacaterol/glycopyrronium); Novartis Seebri Breezhaler (glycopyrronium); Novartis Onbrez Breezhaler (indacaterol); Mundipharma Flutiform (MDI) (formoterol/fluticasone); AstraZeneca Symbicort Turbuhaler (budesonide/formoterol); AstraZeneca Eklira Genuair (aclidinium); AstraZeneca Duaklir Genuair (formoterol/aclidinium); Boehringer Ingelheim Spiriva Handihaler/Respimat (SMI) (tiotropium); Boehringer Ingelheim Spiolto Respimat (SMI) (olodaterol/tiotropium); Chiesi Fostair (MDI)/Nexthaler (beclomethasone/formoterol); Orion Corporation Bufomix Easyhaler (budesonide/formoterol); Teva Duoresp Spiromax (budesonide/formoterol); Sandoz Airflusal Forspiro (salmetrol/fluticasone); Elpen Pharma Rolenium Elpenhaler (salmetrol/fluticasone); CIPLA Seroflo (MDI) (salmetrol/fluticasone); Mylan Sirdoupla (MDI) (salmetrol/fluticasone); Celon Pharma Salmex (salmetrol/fluticasone); Polfarmex Asaris (salmetrol/fluticasone).

[4] http://newsroom.mylan.com/2016-02-19-Mylans-ANDA-for-Generic-Advair-Diskus-Accepted-for-Filing-by-FDA: Mylan N.V. announced its abbreviated new drug application (ANDA) for fluticasone propionate 100, 250, 500 mcg, and salmeterol 50 mcg inhalation powder has been accepted for filing by the U.S. Food and Drug Administration (FDA). This product is the generic version of GlaxoSmithKline's Advair Diskus®.

In the last 5 years, the developing world has worked to achieve transition away from CFC MDIs, taking into account patient safety, preferences, affordability and availability. MDI use has increased overall as treatment is moving from oral to inhaled therapy, which is now more affordable. DPI use has become more widely accepted and its availability has increased, especially as single-dose DPIs. Advances in manufacturing technology have been made. New companies are in the market, manufacturing DPIs and MDIs.

In the past, there were only a few molecules (salbutamol, beclomethasone, budesonide, salmeterol), and now there are companies with ten or more individual drug moieties (e.g., ciclesonide, formerotol, indacaterol, glycopyrronium, indacaterol plus glycopyrronium, tiotropium, ciclesonide, formeterol plus budesonide, ciclesonide plus formeterol plus tiotropium, beclomethasone plus formeterol, etc.) and a variety of other combination products. Also, regional manufacturers are taking the place of global companies in supplying inhalers to domestic and regional markets, and competing on the global stage. The demand for the single-dose DPI is high, driven by the affordability of buying one dose at a time. The devices, which are mostly used in India, Bangladesh and many other least developed and emerging markets, include Rotahaler (Cipla, India), Twisthaler (Aptar), Bexihaler (Beximco, Bangladesh), Revilizer, Cyclohaler, Transhaler (Lupin, India), etc. Nonetheless, increasing personal wealth in emerging economies enables access to newer classes of drugs and to inhalers from multinational companies due to the perception of higher quality.

Over the next 5 years, stockpiles of CFC MDIs will be exhausted, and the market will be completely free of products containing ozone-depleting substances (ODSs). Increasing competition will lead to greater affordability of older medications such as beclomethasone, although newer therapies will be at a premium price. Products recently launched in western markets will become available in growth economies. Local pharmaceutical companies that wish to develop multi-dose DPI products have to overcome the barriers presented by the high level of investment required and access to the technology.

The GINA, Australian, Japanese, and British treatment guidelines have previously recommended salbutamol alone as first line therapy in asthma. However, these guidelines have been now revised to recommend inhaled corticosteroids (ICS) as first line therapy, because this anti-inflammatory therapy improves asthma control. Other countries are likely to follow. Salbutamol relieves symptoms but does not improve asthma control. However, the low cost of salbutamol MDI/single-dose DPI compared with even the cheapest ICS may prevent patient/physician adherence to guidelines in socially and economically disadvantaged populations.

5.1.2. Developments in the phase-out of ODS in medical aerosols, and sterilants

Anecdotal reports indicate that hydrochlorofluorocarbon (HCFC) use in pharmaceutical aerosols in China could be about 500-800 tonnes for HCFC-141b and 1,600-2,000 tonnes for HCFC-22 per year. The complete phase-out of HCFCs in sterilization uses to meet the Montreal Protocol schedule is readily achievable.

5.1.3. Reporting accounting frameworks for essential use exemptions for CFCs for the manufacture of MDIs

MCTOC has reviewed reporting accounting frameworks submitted by China and the Russian Federation for essential use exemptions for CFCs for the manufacture of MDIs. The following section describes the information provided in those reporting accounting frameworks submitted by Parties for 2015. This section also provides updates on Parties with authorised essential use exemptions in previous years that have, or have not, reported accounting frameworks.

5.1.3.1. Argentina

Argentina's essential use exemption was authorised by Parties for 2012. Argentina's accounting framework for 2012 showed CFC stocks on hand at the end of 2012 of about 5 tonnes.

All the companies except one in Argentina opted for technologies using HFC-134a as the excipient in their MDIs. Laboratorio Pablo Cassará initially converted its salbutamol MDI production to HFCs, but has been implementing an MLF project to use iso-butane as the propellant. MCTOC understands that Laboratorio Pablo Cassará plans to launch its first salbutamol isobutane MDI in 2016. According to the information obtained from the Secretary of Industry, this pharmaceutical company finished the research in 2015 and submitted the results of the project to the national regulatory agency (ANMAT) in order to get approval of that new formulation; at the present time, there is no news about the final decision and the date when, if approved, this product would be launched into the market.

5.1.3.2. China

Parties authorised an essential use exemption of 182.61 tonnes of CFCs for the manufacture of MDIs in China for 2015. MTOC stated in the 2014 TEAP Progress Report, "*It is possible that China may be able to manage its phase-out from CFC stockpiles, although this is not yet clear. Despite reported stockpiles, MTOC is recommending an essential use exemption for CFC production and consumption for 2015 in the expectation that China would supply its requirements from accumulated stockpile, with new CFCs produced only if absolutely necessary.*" According to China's accounting framework for 2015, China did not produce any CFCs under its exemption and used 124.04 tonnes CFCs for domestic MDI manufacture supplied from its stockpile.

Consumption in 2014 and 2015 continued a consistent downward trend, and was less than the CFC quantity authorized by Parties for China for 2015 (182.62 tonnes). This consumption trend appears to differ from China's earlier predictions when nominating CFCs for MDI manufacture for 2015, when it was stated, "*Demand is expected to grow for CFC MDIs in 2014 and 2015 due to an increased emphasis on inhaled therapy*".

China has stated that 2015 would be the last year in which there would be manufacturing of salbutamol CFC MDIs, with the intent of providing sufficient product to allow salbutamol HFC and CFC MDIs to co-exist over a subsequent transition period of one year, and a complete phase-out of salbutamol CFC MDIs by December 31, 2016. IMS Health data reports four locally manufactured salbutamol HFC MDIs available on the market. Salbutamol CFC MDIs make up the large majority of CFC demand in China (about 85 per cent of the 2015 nomination). Beclomethasone and other active ingredients make up the remainder of CFC demand for MDI manufacture. For beclomethasone and other active ingredients, China has stated that 2016 will be the last year to manufacture CFC MDIs, with complete phase-out by December 31, 2017. IMS Health data reports one locally manufactured beclomethasone HFC MDI available on the market.

At the end of 2014, a stockpile of 515.90 tonnes of CFCs (including 106 tonnes CFCs intended for the Russian Federation) remained, which had increased from 476.60 tonnes of CFCs in 2014. At the end of 2015, China's CFC stockpile had decreased to 391.86 tonnes. Given consumption trends, China's CFC stockpile at the end of 2015 is equivalent to another 3 years supply (2016-2018). The CFC stockpile of 391.86 tonnes appears to exceed the likely future MDI requirements through to China's own scheduled phase-out strategy. This arises in part because CFCs were produced in China for export to the Russian Federation that will now not be exported.

The quantity of CFCs in the stockpile may lead to:

- CFC MDIs being manufactured and supplied for longer than is projected by China's phase-out strategy or in quantities that might disrupt smooth transition; and/or

- The need for destruction of CFCs

China has stated that its CFC manufacturer has made a commitment that all CFCs produced under the quota issued by the authorities will be used for MDI purposes only, and any remaining substances, if not used in MDI applications will be treated in an environmentally harmless way.

5.1.3.3. Pakistan

More than 20 million Pakistani patients suffer from asthma and chronic obstructive pulmonary diseases (COPD), leading to the use of more than 10 million inhalers every year. Pakistan has phased out all CFC MDIs and the market is now completely shifted to either HFC MDIs or DPIs.

At present, 70 per cent of the inhaler market is HFC-based MDIs and 30 per cent is DPIs. HFC MDIs are relatively more costly compared to the previous CFC-based MDIs. GSK manufactures salbutamol HFC MDI locally. The company Highnoon has strong links with the company CIPLA India and has a plant locally where DPI capsules are filled from imported raw materials from India. The company Mactor has a local plant for MDI manufacture, where MDIs are filled from raw material imported from China. Patients have accepted the HFC-based MDIs and there have been no problems in this regard.

5.1.3.4. Russian Federation

Parties authorised an essential use exemption of 212 tonnes of CFCs to the Russian Federation for the manufacture of MDIs for 2014. The Russian Federation has not submitted any further nominations, in line with the announcement that its nomination for 2014 would be its last. An accounting framework was provided for 2015. The Russian Federation imported 106 tonnes CFCs from China in 2014, out of a total of 212 tonnes authorised by Parties. It reported 69.2 tonnes of CFCs in stockpile of at the end of 2013. With no CFCs used to manufacture CFC MDIs in 2014, the available CFC stockpile at the end of 2014 was 175.2 tonnes. This follows the earlier decrease in CFCs used for MDI production in 2013, when only 142.80 tonnes were used. The reason given was late delivery of imported CFCs, which arrived in the second half of 2013. As a result, the CFC inventory increased at the end of that year. The Russian Federation used 86.44 tonnes CFCs from its stockpile to manufacture MDIs in 2015. At the end of 2015, 88.76 tonnes of CFCs were remaining in stockpile.

Russia is in the final stages of manufacturing conversion to HFC MDIs, with completion likely in 2016. Both Russian MDI manufacturers have installed new equipment and recently produced test batches of HFC-based MDIs. Both companies will use all of the remaining available CFCs for their MDI production. One enterprise paused manufacturing CFC MDIs while it mounted and tested new equipment for HFC MDIs. A full range of affordable imported CFC-free inhalers is available to Russian patients.

5.2. Chemicals

5.2.1. Essential use nomination of Carbon Tetrachloride for laboratory and analytical uses ("testing of oil, grease and total petroleum hydrocarbons in water") by China for 2017

Year	Controlled Substance	Quantity nominated
2017	CTC	65 tonnes

Quantities are expressed in metric tonnes.

Specific Use: Laboratory and analytical uses for the testing of oil, grease and total petroleum hydrocarbons in water (hereinafter referred to as "oil in water").

Recommendation: Recommend

5.2.1.1. Introduction and background

China is requesting continued use of carbon tetrachloride (CTC) for laboratory and analytical uses for the testing of oil, grease and total petroleum hydrocarbons in water. Decision XXIII/6 specifies that after 31 December 2014, the use of 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 and 70 tonnes of CTC for 2015 and 2016 respectively. China has nominated 65 tonnes of CTC for the testing of oil in water for 2017.

China observes the national standard oil in water test, HJ 637-2012 "*Water quality-Determination of petroleum oil, animal and vegetable oils- Infrared photometric method*", in which CTC is used as the solvent to extract oil substances and then determined with an infrared photometric method. The oil in water test is a fundamental requirement in monitoring water quality in China. International standards mainly use non- ODS extraction solvents such as cyclohexane and tetrachloroethylene.

The Ministry of Environment Protection of China (MEP) began revision of the national standard HJ 637-2012 in 2013. The revision of two related standards on monitoring methods, "*Water quality- Determination of volatile petroleum hydrocarbon- Purge and Trap/Gas chromatography (C6-C9)*" and "*Water quality- Determination of extractive petroleum hydrocarbon- liquid-liquid extraction/Gas chromatography (C10-C40)*" also started in April 2014. The proposal was to use cyclohexane as the extracting agent with mid-infrared laser spectroscopy to replace the current infrared photometric detection method. Last year, China indicated its intention to complete the revision and to approve and promulgate the new standards by the end of 2016.

MEP organized a seminar to discuss progress and problems in revising the standards in December 2015. China reported in its nomination this year that it has experienced difficulties in developing a new standard using the mid-infrared laser spectroscopy method. Owing to the lack of detection precision and the high cost of mid-infrared laser spectroscopy, it has now been decided that tetrachloroethylene will be used to substitute CTC because the use of tetrachloroethylene would not require the change of detection equipment, i.e. infrared photometry. However, there are now new challenges because the purity of tetrachloroethylene will need to be improved for analytical purposes, and the MEP is supporting research into purification methods for tetrachloroethylene. It is expected that new standards will now be issued in 2017, and supporting activities to implement the standards carried out during 2018, including training of technicians and management staff, updating and replacing testing apparatus, equipment and reagents, and raising public awareness.

5.2.1.2. Comments

MCTOC has reviewed the nomination for 65 tonnes of CTC for an essential use exemption for China for laboratory and analytical uses. MCTOC thanks China for its responses to the additional questions requested for clarification.

MCTOC is concerned that China does not believe that the current international standards, which are used globally for the measurement of varying levels of oil in water and do not use CTC, can be used in China.

MCTOC has evaluated the proposed alternative method of purifying tetrachloroethylene for use as a solvent for the analysis of oil in water. MCTOC is concerned that the need to remove stabilizers and other chlorinated impurities that otherwise would interfere with the analysis could result in the need to generate purified tetrachloroethylene to a specific standard prior to every analysis. This could lead to a double process that has the potential to cause errors.

The delays required by China to establish a method for the purification of tetrachloroethylene, namely one year of research, plus time for the standard to enter into force and be adopted throughout China, would mean it is likely that China will continue to need to use CTC for this analysis for several years. Currently, China predicts that a new standard would be published in 2017, followed by its promotion.

The MCTOC suggests that China works with other Parties to evaluate further the possible use of currently available international methods for the analysis of oil in water. China has identified the following methods as being used elsewhere for this purpose: EPA1664A; ISO9377-2 2000; ASTM D7066-2004; ASTM D7575-2011; ASTM D7678-2011; IP 426-1998.

5.2.1.3. Conclusions

China is to be commended for its on-going efforts to find an ODS-free method for the analysis of oil in water. MCTOC recommends that Parties authorise an essential use exemption for China for 2017, and requests that China, prior to any further nomination, provides information on:

1. Discussions and evaluations regarding the use of other international analytical methods;

2. Progress in the development of its own method, including the purification of tetrachloroethylene; and,

3. A timeline for the phase-out of CTC in laboratory and analytical uses, indicating the anticipated steps and dates in that process.

5.2.2. Reporting accounting frameworks for essential use exemptions for CFC-113 for use as a solvent in aerospace applications

MCTOC has reviewed the reporting accounting framework submitted by the Russian Federation for an authorized essential use exemption for CFC-113 used as a solvent in aerospace applications for 2015.

The Russian Federation was authorised an essential use exemption of 75 tonnes of CFC-113 for 2015 for solvents used in aerospace applications. In its reporting accounting framework, Russia reported that aerospace applications used 85 tonnes of CFC-113 in 2015, and 75 tonnes of CFC-113 remained at the end of the year. The Russian Federation reported previously it would phase out the use of CFC-113 used as a cleaning solvent in aerospace applications at the end of 2016. The Russian Federation appears to be on track to meet its planned phase-out during 2016.

The Russian Federation has eliminated most of the uses of CFC-113 by using a variety of alternative solvents and cleaning agents in its aerospace applications, including aqueous detergents, organic solvents, chlorinated solvents, and HCFCs. MCTOC understands that alternatives to HCFCs, including HFCs, are also currently being considered and tested for aerospace applications.

5.2.3. Decision XVII/6(7) and (8): Review of information submitted by Parties on the use of controlled substances as process agents

Decision XVII/6 requests,

> "*...the TEAP to review the information submitted in accordance with this decision and to report and make recommendations to the Parties at their Twentieth Meeting in 2008, and every other year thereafter, on process-agent use exemptions; on insignificant emission associated with a use, and process-agent uses that could be added to or deleted from table A of decision X/14;*" and

> "*To request Parties with process-agent uses to submit data to the TEAP by 31 December 2007 and 31 December of each subsequent year on opportunities to reduce emissions listed in table B and for the TEAP to review in 2008, and every other year thereafter, emissions in table B of decision X/14, taking into account information and data reported by the Parties in accordance with that decision, and to recommend any reductions to the make-up and maximum emission on the basis of that review. On the basis of these recommendations, the Parties shall decide on reductions to the make-up and maximum emissions with respect to table B.*"

China, the European Union (EU) and the US submitted information about their process agent uses in accordance with, inter alia, decision X/14(4), which states,

"*That all Parties should:*

> *(a) Report to the Secretariat by 30 September 2000 and each year thereafter on their use of controlled substances as process agents, the levels of emissions from those uses and the containment technologies used by them to minimize emissions of controlled substances. Those non-Article 5 Parties which have still not reported data for inclusion in tables A and B are urged to do so as soon as possible and in any case before the nineteenth meeting of the Open Ended Working Group;*

> *(b) In reporting annual data to the Secretariat for 2000 and each year thereafter, provide information on the quantities of controlled substances produced or imported by them for process agent applications;*"

MCTOC has reviewed the information submitted by Parties under Decision XVII/6 on process agent use exemptions, make-up and emissions for those uses.

It is noted that several Parties are no longer reporting data for certain process agent uses, indicative that these processes are no longer in use in these Parties (see Table A below).

Furthermore, it is noted that the reported emissions from these processes are considerably lower than the maximum emission limits that are given in Table B of Decision XXIII/7 (see Table B below).

Table A: List of uses of controlled substances as process agents[5]

No.	Process agent application Decision XXVII/7	Substance	Permitted Parties Decision XXIII/7	Parties that reported in 2016 for 2014	Parties no longer reporting for that use
1	Elimination of NCl_3 in chlor-alkali production	CTC	European Union, Israel, United States of America	European Union, United States of America	Israel
2	Chlorine recovery by tail gas absorption in chlor- alkali production	CTC	European Union, United States of America	European Union, United States of America	
3	Production of chlorinated rubber	CTC	European Union	European Union	
4	Production of chlorosulfonated polyolefin (CSM)	CTC	China, United States of America	China	United States of America
5	Production of aramid polymer (PPTA)	CTC	European Union	European Union	
6	Production of synthetic fibre sheet	CFC-11	United States of America	United States of America	
7	Photochemical synthesis of perfluoropolyetherpolyperoxide precursors of Z-perfluoropolyethers and difunctional derivatives	CFC-12	European Union	European Union	
8	Preparation of perfluoropolyether diols with high functionality	CFC-113	European Union	European Union	
9	Production of cyclodime	CTC	European Union	European Union	
10	Production of chlorinated polypropene	CTC	China		China
11	Production of chlorinated ethylene vinyl acetate (CEVA)	CTC	China		China
12	Production of methyl isocyanate derivatives	CTC	China, Israel		China, Israel
13	Bromination of a styrenic polymer	BCM	United States of America	United States of America	
14	Production of high modulus polyethylene fibre	CFC-113	United States of America	United States of America	

[5] Table A was last updated in 2011 with Decision XXIII/7: Use of controlled substances as process agents. The table shows Dec. XXIII/7 Tables A alongside the reported information received from Parties in 2016 for the year 2014.

Table B: Limits for process agent uses (all figures are in metric tonnes per year)[6]

Party	Make-up or consumption Decision XXIII/7	Maximum emissions Decision XXIII/7	Reported make-up or consumption for 2014	Reported emissions for 2014
China	1,103	313	178.44	105.63
European Union	1,083	17	508.741	7.338
Israel	3.5	0	Not reported	Not reported
United States of America	2,300	181	Not reported	34.1
Total	4,489.5	511	*[687.181]**	*[147.068]**

* Nominal totals for 2014, which exclude data not reported.

[6] Table B was last updated in 2011 with Decision XXIII/7: Use of controlled substances as process agents. The table shows Dec. XXIII/7 Tables B alongside the reported information received from Parties in 2016 for the year 2014.

5.2.3.1. Recommendations

Based on the information reported, it is therefore recommended that Parties consider removing the following process agent uses from Table A of Decision XXII/7:

- Production of chlorinated polypropene
- Production of chlorinated ethylene vinyl acetate (CEVA)
- Production methyl isocyanate derivatives

For remaining process agent applications, Parties may wish to consider updating and removing certain Parties previously permitted to use ODS as process agents from Table A of Decision XXVII/7, as implied by information no longer reported in 2016 for 2014:

- Israel for elimination of NCl_3 in chlor-alkali production
- United States of America for production of chlorosulfonated polyolefin (CSM)

The Parties may wish to consider reducing the quantities of make up/consumption and maximum emissions levels contained in Table B of Decision XXIII/7 based upon their own reported data.

Furthermore, in order to understand better the remaining eleven process agent uses, Parties may wish to consider revisiting and updating their information on the use of ODS as process agents, and provide the Secretariat with information on current technology used, technology used for reducing emissions, actual emissions, and alternatives available for replacing ODS in these processes by the end of 2017, in time for MCTOC to report next under Decision XVII/6 in early 2018.

5.2.4. 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 under this decision for TEAP assessment.

5.2.5. Use of controlled substances for chemical feedstock

Feedstocks are chemical building blocks that allow the cost-effective commercial synthesis of other chemicals. The use of ODS, such as CTC, 1,1,1-trichloroethane (TCA) (also referred to as methyl chloroform), CFCs, HCFCs and several others, as feedstock allows incorporation of chlorine and fluorine atoms into molecular structures. The resulting products find important uses such as refrigerants, blowing agents, solvents, polymers, pharmaceuticals and agricultural chemicals. Emissions from feedstock use consist of residual levels in the ultimate products and fugitive leaks during production, storage and/or transport processes.

Feedstock is selected by commercial producers to be the most technologically and economically viable at the time to yield the final products. Properly designed and maintained chemical manufacturing facilities using ODS feedstock can operate for as long as 50 years. These facilities can require large initial capital investments over US$100 million, not including the supporting and required infrastructure.

The Montreal Protocol specifies those ODS that are controlled substances, including those that are also used for chemical feedstock, according to Article 1, clause 4, which states:

“ "Controlled substance" means a substance in Annex A, Annex B, Annex C or Annex E to this Protocol, whether existing alone or in a mixture. It includes the isomers of any such substance, except as specified in the relevant Annex, but excludes any controlled substance or mixture which is in a manufactured product other than a container used for the transportation or storage of that substance.”

The definition of production under the Montreal Protocol excludes the amount of controlled substances used as feedstock, according to Article 1, clause 5: “*Production means the amount of controlled substances produced, minus the amount destroyed by technologies to be approved by the Parties and minus the amount entirely used as feedstock in the manufacture of other chemicals. The amount recycled and reused is not to be considered as Production.*”

5.2.5.1. How the ODS feedstock is used

When used as feedstock, ODS are fed directly into the process as a raw material stream or as an intermediate in the synthesis of another product. Emissive losses can occur during production, storage, transport, if necessary, and transfers. Intermediates are normally stored and used at the same site thereby reducing fugitive leaks. Efforts are made to minimize such losses for both environmental and economic reasons.

Table 5.1 shows common feedstock applications, although the list is not exhaustive. Parties report amounts of ODS used as feedstock to the Secretariat but not 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 5.1. 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 (TFA) 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 this refrigerant 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 refrigerant gas 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 have fallen to zero based on recent data.
CTC	Perchloroethylene		High volume use.
CTC	Chlorocarbons	Feedstocks for production of HFC-245fa and some new hydrofluoroolefins (HFOs).	HFOs are low-Global Warming Potential (GWP) fluorocarbons used in refrigeration, air conditioning and insulation.
CTC	Intermediates	Pyrethroid pesticides.	CCl3 groups in molecules of intermediates become =CCl2 groups in pyrethroids.
CTC with 2-chloropropene	Intermediates	Production of HFC-365mfc	
CTC with vinylidene fluoride	HFC-236fa		
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 agrichemicals		
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.

5.2.5.2. Trends in ODS feedstock uses

Parties report the use of ODS as feedstock to the Ozone Secretariat. Data have been provided to the MCTOC by the Ozone Secretariat on production, import and export of ODS used as feedstock for the year 2014. These also include quantities used as process agents because Parties are required to report such consumption in a manner consistent to that for feedstock. Detailed information can be found in Table 5.2 whose data were provided by UNEP.

In 2014, total production for feedstock uses was 1,165,679 tonnes, representing a total of 448,395 Ozone Depletion Potential (ODP) tonnes. Overall use of ODS as feedstock increased by 2.2% (24,885 metric tonnes) compared with 2013, with a corresponding increase of 2.7% in ODP tonnes.

The largest feedstock uses are HCFC-22 (43.6% of the total quantity), CTC (18.3%), and CFC-113 (11.3%). The feedstock use of HCFC-22 has increased by 5.1% from 2013. The majority of HCFC-22 feedstock use is for the production of tetrafluoroethylene (TFE), which can be both homo- and co-polymerized to make stable, chemically resistant fluoropolymers with a myriad of end uses. Feedstock use of CTC has increased by 11.3%, possibly owing to increased production of perchloroethylene. Feedstock use of CFC-113 grew by 15.5% from the previous year, possibly owing to increased production of polymers, and feedstock use in CFC-113a (as an intermediate for trifluoroacetic acid and pesticide production) and HFC production. Other significant ODS used as feedstock experienced reductions over the previous year.

Table 5.2 Amount of ODS used as feedstock in 2014

Substance	ODP	Tonnes	ODP Tonnes
CFC-11	1	0.0	0.0
CFC-12	1	0.0	0.0
CFC-113	0.8	131,156.9	104,925.5
CFC-114	1	37,197.8	37,197.8
Carbon Tetrachloride	1.1	213,222.2	234,544.4
Methyl Chloroform	0.1	105,322.6	10,532.3
Halon 1211	3	0.0	0.0
Halon 1301	10	1,342.3	13,423.2
HBFC-21B2	1	4.9	4.9
HBFC-31B1	0.73	0.7	0.51
HBFC-22B1	0.74	104.2	77.1
Methyl Bromide	0.6	3,392.6	2,035.0
Bromochloromethane	0.12	462.9	55.5
HCFC-22	0.055	508,087.9	27,944.8
HCFC-123	0.02	1,069.1	64.1
HCFC-124	0.022	40,748.7	8,964.7
HCFC-141b	0.11	13,181.6	1,450.0
HCFC-142b	0.065	110,385.3	7,175.0
HCFC-31	0.02	0.0	0.0
Total		1,165,678.7	448,394.9

5.2.5.3. Estimated emissions of ODS

Emissions from ODS feedstock use is not reported by Parties. The estimation of ODS emissions is also inexact. The sophistication of the operating facility can heavily influence emission levels. Highly automated, tight and well-instrumented facilities with proper, closely observed, procedures can have ODS emission levels as low as 0.1% of the ODS amount used as feedstock. At the other extreme, batch processes of limited scale with less tight facilities, with less concern for operational excellence, could have emission levels up to 5% of the ODS amount used as feedstock. The largest volumes of feedstock use are likely to be at the least emissive end of the scale because large capacity plants have the most investment and are better able to control emission levels. This estimated range of emissions levels is based on industry input and anecdotal experience, with no citable references.

For HFC manufacturing facilities, the Intergovernmental Panel on Climate Change (IPCC) recommends an HFC emissions factor of 0.5% of the amount of HFC production. This emission factor is recommended by the IPCC to estimate HFC emissions for the purpose of compiling national greenhouse gas inventories.[7] There is no similar international technical consensus for estimating ODS emissions associated with ODS feedstock uses, however, the chemicals, operational processes, and emissions abatement technologies involved are very similar and can be considered technically analogous to those for HFC production. In order to generate some indicative estimations of ODS emissions, the IPCC emission factor of 0.5% for HFC production has been applied as a surrogate for ODS used as feedstock. Using this surrogate emission factor, for guidance purposes only, estimated emissions associated with ODS feedstock and process agent uses in 2014 can be calculated as 5,828 tonnes, or 2,242 ODP tonnes.

For 2013, analysis of the European Environment Agency's European Pollutant Release and Transfer Register[8] (E-PRTR) shows that HCFC emissions in the EU were 224.12 tonnes, of which 164.1 tonnes can be attributed to production and feedstock uses. EU production of HCFCs in 2013 was reported by the European Environment Agency (EEA, 2013) as 114,907 tonnes[9]. In addition, the E-PRTR reports EU CTC emissions to be 51.4 tonnes for production of 30,864.8 tonnes[8,9]. This indicates emission levels for HCFC-22 and CTC of about 0.2% were achieved in the EU, where advanced technologies are used and waste destruction capability is installed on vents. By comparison, this level is lower than the IPCC guidelines of 0.5% used as a surrogate emission factor in MCTOC's estimate of ODS emissions from feedstock uses. The relatively low rate of emissions achieved also illustrates the effectiveness of local regulation and oversight, and industrial diligence, in the management and control of ODS emissions in feedstock uses.

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[7] This can be found in the 2006 IPCC Guidelines for National Greenhouse Gases Inventories Volume 3, Chapter 3.10, accessible at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf , accessed March 2016. The Guidelines state, "*For Tier 1, in the absence of abatement measures, a default emission factor of 0.5 percent of production, not counting losses in transport and transfer of materials, is suggested for HFCs and PFCs, based on data supplied to AFEAS (2004).*"

[8] European Environment Agency, European Pollutant Release and Transfer Register (E-PRTR) for 2013, http://prtr.ec.europa.eu, accessed March 2016.

[9] European Environment Agency, http://www.eea.europa.eu/publications/ozone-depleting-substances-2013, accessed March 2016.

5.2.5.4. How to minimize ODS feedstock emissions

Both regulators and producers can act to ensure that emissions from feedstock uses of ODS are kept at minimal levels. In the EU, the US, China, and several other countries, all new operations are required to be licensed for operation. These licences usually define specific maximum emission limits, as well as the methodology to quantify them.

Producers can follow specifically defined responsible use practices, which, inter alia, define equipment to control processes, closed-loop loading and recovery, and thermal destruction of vapour emissions. It is considered by MCTOC experts that, when strictly followed, these responsible use practices can limit ODS emissions to about 0.1% of the ODS amount used as feedstock in continuous processes. Less responsible operation, and batch processes, can lead to emissions as high as 5% of feedstock quantities. Close cooperation between producers and regulators can continue to make these operations safe and environmentally sustainable.[10]

5.2.6. n-Propyl bromide

n-Propyl bromide (1-bromopropane, $CH_3CH_2CH_2Br$, n-PB, CAS No. 106 94 5) is being used as a solvent in a range of applications. Its boiling point, 71^oC, is comparable to that of CFC-113 (48^oC), hexane (69^oC), methyl chloroform (TCA, 74^oC) and trichloroethylene (87^oC), making it potentially attractive as a solvent with similar physical properties. Its solvent properties are typical of those of lower molecular weight hydrocarbons and organohalogen compounds. Due to the presence of bromine in the molecule, however, concerns have been expressed based both on its potential for ozone depletion and its toxicity. n-Propyl bromide has an estimatedlifetime of less than 25 days and very low ODP, with locational and seasonal variations[11].

Regarding its toxicity, the National Toxicology Program report (NTP TR 564, August 2011) and the American Conference of Governmental Industrial Hygienists (ACGIH®) (February 2012) established a threshold limit value (TLV®) for n-propyl bromide of 0.1 ppm. In 2014, ACGIH published a time weighted average exposure limit (TWA) of 0.1ppm for n-propyl bromide. The Japan Society for Occupational Health set a TLV of 0.5ppm for n-propyl bromide in 2013. These relatively low workplace exposure standards indicate that its use in solvent applications is likely to be problematic, and will limit its use in countries with more stringent occupational health and safety controls.

Nevertheless, n-propyl bromide continues to appear as a marketed solvent at trade exhibitions with demand in a number of markets (e.g. China, Japan and the US). Manufacture is occurring in a small number of countries, including China, Israel and the US. China has production capacity of about 20,000 tonnes per year, and consumes and exports to other markets. Consumption of n-propyl bromide in China is mainly as an electrical cleaning agent or carrier solvent. n-Propyl bromide has also appeared in aerosol cans as an electronics cleaning product in countries such as the US.

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[10] More information on responsible use practices can be found on the website of the Alliance for Responsible Atmospheric Policy at www.arap.org under Responsible Use Principles and Best Practices.

[11] World Meteorological Organization (WMO), *Scientific Assessment of Ozone Depletion: 2014*, World Meteorological Organization, Global Ozone Research and Monitoring Project—Report No. 55, 416 pp., Geneva, Switzerland, 2014.

Chemical manufacturers do not publicise their n-propyl bromide production data for commercial reasons. In the absence of information provided by exporting and/or importing countries, it is difficult for MCTOC to quantify the global consumption of n-propyl bromide and its emissions.

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

6.1. Introduction

In July 2015, the RTOC met at UNESCO in Paris, back to back with the OEWG-36 meeting. Attending members were from non-A5 Parties: Croatia, Czech Republic, Denmark, Germany, Italy, Japan, The Netherlands, Norway, UK, United States (US), and from Article 5 Parties: Brazil, China, Egypt, India, Jamaica, Jordan, Lebanon and Saudi Arabia.

The three main purposes of the meeting were to: (1) to update the RTOC members on the discussions and outcomes of Montreal Protocol meetings, (2) to illustrate the progress of the Task Force XXVI/9 work, and (3) to start planning the work for the 2018 RTOC Assessment Report in terms of content and organization. It was agreed that the next Assessment Report efforts should proceed as had been followed during past Assessments, maintaining the same report structure, while improving it in terms of readability through the use of more graphics and tables. It was also agreed to maintain the structure of Chapters and Chapter Lead Authors, who assume responsibility for a single Chapter. A first table of Chapter membership was also established, to be confirmed or updated if necessary. Compared to the 2014 Assessment Report it was decided to add a new Chapter on Not-in-Kind (NIK) technologies. Members agreed that under "NIK" those technologies that should be considered are those that do not use the vapour compression (reverse (Rankine) cycle as a thermodynamic basis.

It was also decided to add two Working Groups, established in order to address key issues related to: i) high ambient temperature condition operations and ii) demand, banks and emissions scenario calculations (in the following tagged as "modelling" for sake of simplicity). How to incorporate the work of these Working Groups work into the next Assessment Report (as Chapters, Annexes or whatever) will be decided at a later date. The co-chairs announced the appointment of three new members from A5 Parties (i.e., India, Peru and Saudi Arabia). The membership of RTOC at the time of the meeting stood at 37 members.

Subsequently, in February 2016, the RTOC met in Kingston, Jamaica, back to back with a Task Force XXVII/4 meeting, organized at the same venue. Horace Nelson RTOC member from Jamaica hosted the meeting. Attending members were from non-A5 Parties: Belgium, Croatia, Czech Republic, Denmark, Germany, Italy, Japan, The Netherlands, Norway, UK, US, and from A5 Parties: Brazil, China, Egypt, India, Jamaica, Jordan, Lebanon and Peru.

The purpose of the meeting was to brief the RTOC on discussions and outcomes of recent meetings including the 27th Meeting of the Parties to the Montreal Protocol and to prepare the RTOC 2016 progress report to be included in the 2016 TEAP progress report. After being thanked by co-chair Roberto Peixoto for his long and appreciated service as RTOC Co-chair (which finished per 1/1/2016), Lambert Kuijpers, now TEAP senior expert and RTOC member, gave his vision of the progress on the "Dubai Pathway" upon which Parties agreed at MOP-27 towards controlling and phasing down the use of hydrofluorocarbons (HFCs). He also reported on the results of the COP-21 of UNFCCC held in Paris on December 2015 (the Paris Agreement).

Discussion among members focused on the progress report to be released within several weeks after the meeting.

As far as the RTOC membership is concerned, co-chairs announced that no new members had been appointed since the 2015 Paris meeting. New membership, from both A5 and non-A5 parties, will be actively sought in order to cover potential competence gaps open in certain RTOC chapters. Co-chairs invited CLAs to list specific competence gaps in their sub-sectors, if existing, and to suggest possible member candidates that would be able to fill those gaps.

In order to improve the communication among RTOC members a monthly email newsletter named "RTOC news" has now also been published as of September 2015.

In the following sections, the status of the different sub-sectors is reported, focusing on updates to the technology as described in the RTOC 2014 Assessment report (http://ozone.unep.org/Assessment_Panels/TEAP/Reports/RTOC/RTOC-Assessment-Report-2014.pdf).

6.2. Refrigerants

The trend in recent years has been an increase in the number of new refrigerants, most of them unsaturated fluorochemicals (and most of them hydrofluoroolefins and blends of these with saturated HFCs), to replace fluids with Ozone-depletion Potential (ODP) and/or significant Global Warming Potential (GWP).

Since the publication of the RTOC 2014 Assessment report, 7 new refrigerants, most of them blends, have received designation/classification in American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 34 or International Standards Organisation (ISO) 817. Among these fluids there is only one single-compound refrigerant, hydrofluoroolefin (HFO)-1336mzz(Z), which is a low-pressure fluid and is not yet commercially available in significant quantities. The other fluids are mixtures of known components already commercially available and included in the standards. The new mixtures are: R-407G, R-449B, R-453A, R-454A, R-454B, and R-455A.

The search for new alternative fluids may yield more economical solutions, but the prospects of discovering new, radically different fluids are minimal. Interest continues in hydrocarbons (HCs), R-717 (ammonia), R-718 (water), R-744 (carbon dioxide), and Not-In-Kind (NIK) options, but little new headway is apparent.

6.3. Domestic appliances

HC-600a or HFC-134a continue to be the primary refrigerant options for production of new equipment. It is projected that by 2020, about 75% of new refrigerator production will use HC-600a, most of the rest will use HFC-134a, and a small share may apply unsaturated HFC refrigerants such as HFO-1234yf.

Globally, the activity undertaken so far on HFO-1234yf in domestic refrigerator applications remains very limited and is not being pursued with high priority, due to cost implications. The use of HFO-1234yf in a domestic freezer has been tested as a proof of concept.

The Association of Home Appliance Manufactures (AHAM) of North America has recently announced a voluntary goal to phase down HFC-134a in household refrigerators and freezers after 2024. It is not yet clear whether manufacturers will choose HC-600a or HFO-1234yf as both are flammable (A2 or A2L safety class) and still have to adhere to current and emerging safety and energy efficiency standards.

In the proposed US Significant New Alternatives Policy (SNAP) program listing of 29 March 2016, HFC-134a in domestic appliances is listed as undesirable as of 1/1/2021. The EU F-gas regulation 517/2014 prohibits the use of HFC-134a in domestic appliances as of 1/1/2015. This implies that the change to a low GWP refrigerant (defined as GWP <150 in 517/2014, away from HFC-134a, is a real issue here.

The heat pump clothes (laundry) dryer (HPCD) sales using HFC-134a are rapidly growing in the EU. HPCDs using R-407C and HC-290 have also been introduced. New research with R-744 shows significant efficiency gain may be possible. Alternative refrigerant solutions that are being explored include HC-600a and low GWP HFC/HFO/HCFO.

6.4. Commercial refrigeration

While the F-gas regulation 517/2014 is now effective in Europe, in the US, the Environmental Protection Agency (EPA), as already mentioned above, published a final rule for change of status of refrigerants in several applications under its SNAP) program. Of significance were three changes of status – one for supermarket systems, another for condensing units and the third for self-contained coolers and freezers. In all of these applications the high GWP HFC blend R-404A is not allowed in new equipment starting in January 1, 2017 for supermarkets, January 1, 2018 for condensing units and January 1, 2019 & 2020 for self-contained systems. Canada has signalled its intention to do something similar, and the state of California is looking into the European F-gas regulation for its regulation. These are examples of governments that have started down the path of not allowing high GWP HFC refrigerants or HFC based blends in new equipment.

Lower GWP refrigerants and HFC/HFO/HCFO blends (both A1 and A2L) are also being approved for use in various equipment types. The recent impact of these developments is summarized below for both synthetic and natural refrigerants as relevant to commercial refrigeration equipment.

In supermarkets, blends such as R-448A, R449-A, R-449B, R-450A, and R-513A are now beginning to grow in use, starting with Europe and the United States. Component manufacturers (compressors, valves, controls) are releasing new products and approving existing products for use with these new refrigerants, which range from half to a third of the GWP of the refrigerants that they are replacing.

The same holds true for condensing units and self-contained equipment. In the self-contained equipment category, early trials with HFO-1234yf and HFO-1234ze have started to happen as well.

The use of R-407A and R-407F (at approximately half the GWP of R-404A and with similar performance in systems) continues to grow further in many parts of the world.

Non-halocarbon refrigerants such as R-744 are increasingly being used in supermarket systems worldwide – both in cascaded systems (R-744 for low temperature cascaded with a second refrigerant like HFC-134a or similar and R-717 in limited cases) and in transcritical systems. Transcritical systems are being researched extensively to reduce their energy penalty at high ambient conditions through the use of component and system technologies such as ejector, adiabatic condensing, sub cooling and parallel compression. R-744 is also beginning to see its use in walk-in applications with condensing units. Self-contained systems are increasingly moving from R-404A, hydrochlorofluorcarbon (HCFC)-22 etc., to HC-290 or R-744. Charge limits continue to limit the size of the equipment possible with the HC refrigerant.

6.5. Industrial systems

In the time since the release of the 2014 RTOC Assessment report, a number of overarching trends have been identified and are expected to be included in the 2018 Assessment report.

The biggest trend in industrial refrigeration, which also forms a huge challenge, is the constant focus on refrigerant charge reduction. Another big trend in the market is the heat pump market development. Industrial heat pumps use heat that is considered waste in other parts of production processes. An example is the dairy sector, where milk is both cooled and heated in different sequences. The pasteurisation process requires temperatures around 70 to 80°C. Different technologies are used to achieve these temperatures.

For industrial processes, high temperature heat pumps are required, with temperatures to be produced up to about 100°C, sometimes even up to 180°C. Water Vapour Recompression (VRC), which is a process of recovering low heat steam at low pressure and compressing it to a high pressure and high temperature, is gaining a lot of attention.

District energy concepts (District heating combined with District Cooling, (DC) are growing all over the world. In Europe, the two Parties where the District Cooling concept is most applied are France and Sweden. There is now more emphasis on applying DC in the Middle East since the 2014 assessment since it has the largest DC growth potential in the world. Recently the Multilateral Fund Executive Committee approved demonstration projects in the area. Implementing agencies, UNIDO/UNEP, are preparing two demonstration projects in Egypt, Kuwait and Colombia to help establish “New Technologies”, legislation and benefits of DC for the area. District heating and DC are swiftly growing in many markets, including in developing country markets. DC can be driven by vapour compression or absorption (which fits into NIK) but in any case it requires significant investments in infrastructure. This is the reason why they are economically viable only when new buildings or new buildings networks are involved.

In some Parties industrial refrigeration systems have been widely based on HCFC-22. Also in A5 Parties, the trend is now to abandon HCFC-22 looking for drop-in alternatives or for new solutions either based on another F-gas or based on natural refrigerants such as ammonia and/or CO_2.

6.6. Transport refrigeration

R-452A has been introduced during 2015 as a customer option on new truck and trailer refrigeration units (it is a blend consisting of HFC-32, HFC-125 and HFO-1234yf). R-404A continues to be offered as well for its wide availability. R-452A has similar cooling capacity, fuel efficiency, reliability and refrigerant charge as R-404A, but it offers a 45% GWP reduction. The features supporting R-452A in transport refrigeration include non-flammability and low compressor discharge temperatures. By January 2016, one manufacturer has sold 1500+ units with R-452A already. The close property match of R-452A to R-404A gives customers the option to retrofit their existing fleets and operate on R-452A, should they wish. The conversion does not require component changes and it can be carried out in the field during the life of the product.

In addition, research and development (R&D) is going on to assess other non-flammable (A1) lower GWP solutions such as R-448A, R-449A and others. R-513A, R-513B, and R-456A are being considered as future drop in solution for R-134a that is utilized in some refrigerated vans and a large number of marine containers. These blends have approximately 50% of the GWP of R-134a. R&D is ongoing, but no products have been released so far based on these refrigerants.

Flammable (A3) and lower flammable (A2L) refrigerant research has continued, aiming at producing publicly available and technically sound references to support code and standard activities with regard to transport systems. Literature shows that frequency of hazard and probabilities of fatalities for the global reefer container fleet would be below 10^{-6} (one in a million) if adequate design changes were in place and best practice guidelines were established. In February 2016, the first meeting took place to develop the ISO 20854 safety standard for refrigerating systems using flammable and lower flammable refrigerants in marine containers. The feasibility of using HC-290 in trucks has been demonstrated in a demo unit in South Africa and was presented at the MOP-27 in Dubai in 2015. The benefits are an improved energy performance and lower life cycle CO_2 emissions. The project included a risk assessment, careful components selection, and leak simulation tests.

An energy optimization of a cryogenic system has entered a commercial testing phase in the UK. The system uses liquid nitrogen to provide cooling through its expansion and to power a Dearman engine supplying a vapour compression cycle. A second generation machine is being developed but it has not yet reached a commercially viable stage.

A UK supermarket chain continues carrying out trials of an R-744 refrigerated trailer since 2013. They revealed that they have subsequently acquired a second R-744 trailer that can operate at different temperatures and this will be joined by a third in 2016. Since 2012, companies shipping and leasing reefer containers have continued to trial R-744 units from the same manufacturer, also in 2015.

The German and French railways have continued to look at air cycle systems as alternatives to vapour compression systems. DB (Deutsche Bahn) has equipped the first car of an Intercity-Express (ICE) train in March 2015 while Société nationale des chemins de fer (SNCF) has set up a 24-months demonstration program in a regional train.

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

Air conditioners, including reversible air heating heat pumps (generally defined as “reversible heat pumps”), range in size from 1 kW to 750 kW although the majority are less than 70 kW. The most populous are non-ducted single splits, which are produced in excess of 100 million units per year. Whilst nearly all air conditioners manufactured prior to 2000 used HCFC-22, all products sold within non-Article 5 Parties now use non-Ozone-depleting Substance (ODS) refrigerants, albeit largely without the use of low-GWP alternatives. For most products, R-410A is used. Whilst the production of air conditioners using HCFC-22 remains the dominant option within Article 5 Parties there is a substantial shift in many countries to move to HFCs and HCs, whilst globally approximately one half of all units produced globally use non-ODP refrigerants. Nevertheless, the majority of the installed unit population still uses HCFC-22; an estimated two-thirds of a billion HCFC-22 air conditioners are operating worldwide, representing approximately one million metric-tonnes of HCFC-22.

The most substantial recent developments are related to the increased rate of substitution of HCFC-22 and the greater consideration of use of medium and low GWP alternatives. Previously, medium and low GWP alternatives were not being given major consideration (except hydrocarbons (HCs) such as HC-290) whereas now additional manufacturers are adopting HCs and there is also uptake of HFC-32, especially in Japan where in 2014 100% of residential split air conditioner production was switched to HFC-32. Several enterprises in Japan and recently in other Parties as well are promoting and selling air conditioners using HFC-32 outside of Japan. Many enterprises are also considering and evaluating new HFC/HFO blends, such as mixtures of various compositions of HFC-32, HFC-125, HFC-134a, HFO-1234yf and HFO-1234ze. Broad testing has been carried out of these mixtures within various collaborative industry projects and the results are being made available on a regular basis. Whilst R-744 remains to be applied in larger types of systems within more temperature climates, there has not been any significant shift in increasing adoption of the technology.

China has completed the conversion of 18 production lines to HC-290 as part of their HPMP and portable units are being sold widely. In India, at least one plant has produced several hundred thousand HC-290 split air conditioners. There is also new additional information relating to different alternatives performance under high ambient conditions. Nevertheless, some enterprises within the Middle East still see R407C and HFC-134a as favourable alternatives to HCFC-22.

In light of the fact that almost all medium and low GWP alternatives are flammable there has been significant progress with the development of new requirements for safety standards (particularly for increasing refrigerant charge size), with working groups addressing A2, A2L and A3 refriferants at both IEC and ISO level. Due to the complexities of the process it is unclear when amendments will be finally published.

6.8. Water heating heat pumps

In Europe, Japan and the US, the legislation on minimum energy efficiency for space heating and water heating heat pumps became active and has limited the number of air to water heat pumps that can be placed on the market.

For space heating heat pumps the minimum energy efficiency was set as a primary energy efficiency based on seasonal efficiency, placed in an average European climate with a design temperature at -10°C, including standby losses. From September 2015 on, all space heating heat pumps shall have a primary energy efficiency of 100%. For low temperature space heating heat pumps it shall be 115%. This results in a seasonal coefficient of performance (SCOP) of respectively 2.5 and 2.875. From September 2017 onwards, the values shall be 110% (SCOP 2.75) and 125% (SCOP 3.125). The seasonal efficiency is based on a specific temperature pattern and includes standby energy losses. For water heating heat pumps, the requirements are less restrictive except for larger systems that will have restrictions as of September 2018. For the moment, there is no drastic impact on the refrigerants currently used.

HFC-32 has been just introduced by one manufacturer in Japan as the refrigerant for water heating systems (mainly R-744 products are sold in the market). Unlike R-744, which can produce hot water with temperatures up to 90°C, the temperature of the water is limited to 65°C. The main purpose is to offer a cost competitive and high-energy efficiency solution for families with lifestyles suited to operations of this system.

6.9. Chillers

The components, refrigeration cycles used, systems, and application of chillers remains largely unchanged from the 2014 RTOC Assessment Report or since 1980 for that matter with exception of increased use of variable-speed drives. Vapour compression technology dominates all chiller types, and there has been little progress towards commercialisation of magnetic refrigeration based chillers and other not-in-kind technologies. However, absorption chillers are, and will continue to be, part of the global mix of chillers. In all regions, there is a demand for higher performance chillers and the systems that use them, at both full and partial load. Some manufacturers are offering newly designed compressors, have expanded the use of variable speed drives and permanent magnet motors and are using more sophisticated control systems.

Manufacturers, consumers, and regulators alike have had an ongoing interest in low GWP refrigerants with high thermodynamic efficiency. The slow movement to new refrigerants reflects the high cost of product development and tooling changes, as well as the uncertainty in the supply of new refrigerants by chemical producers who also face huge investments and regulatory hurdles. None-the-less, chiller manufacturers seem to be gravitating to lower GWP alternative refrigerants, and have introduced a number of new products that use them.

The 2104 RTOC Assessment Report gave a complete discussion of the trade-offs and research efforts associated with use of lower GWP refrigerants. As noted in the report, in order to be acceptable, new refrigerants should result in products with energy efficiencies that are equal to or better than the refrigerants replaced. Secondly, the global warming effects from chillers are dominated by the energy-related component from their power consumption. Total Equivalent Warming Impact (TEWI) and Life Cycle Climate Performance (LCCP) models typically show that more than 95% of the climate effect is due to energy consumption. The direct global warming effects from refrigerant emissions are significantly smaller since direct emissions have been significantly reduced in recent years through lower charge systems, low-leak designs, manufacturing and testing improvements, and improved service practices.

Chillers have traditionally used an array of refrigerants due to the economics associated with high performance compressors as well as physical size and manufacturing constraints over the range of capacities provided by chillers. Table 9-1 of the 2014 RTOC Assessment Report gave a discussion and complete listing of all chiller types by size, compressor type, and refrigerants used.

After years of research and screening tests, an array of choices is emerging. Some commercialization has started and recent new product introductions indicate that a change has started (As shown in Table 6.1).

Table 6.1: Emerging refrigerants used in chillers

Product	**Refrigerants Presently in Use**	**Emerging Refrigerants**
Large chillers with centrifugal compressors using low pressure refrigerants	Chlorofluorocarbon (CFC)-11[2] HCFC-123 [1] HFC- 245fa	HCFO-1233zd R-514A
Large chillers with centrifugal compressors using medium pressure refrigerants	CFC-12[2] HFC-134a	R-513A HFO-1234yf HFO-1234ze
Mid-size chillers with positive displacement (ccrew) compressors	CFC--12[2] HFC-134a	R-513A HFO-1234yf[3] HFO-1234ze[3]
Small chillers with positive displacement (scroll or recip) compressors	HCFC-22[2] R-407C R-410A	HFC-32[3] R-452B[3]

[1]*Phase out in new equipment in 2020*
[2]*Phased out but may still be used for servicing in Article 5 countries*
[3]*Classified as A2L refrigerant (flammable)*

The emerging refrigerants may not be the final selections. With high efficiency as a primary customer requirement, new product introductions will use refrigerants that likely preserve or improve thermodynamic efficiency with significantly reduced GWPs. A number of refrigerants are listed as safety Class 2L (flammable with flame speeds of 10 cm/sec. or less). Some Parties, notably the U.S., have not yet implemented the necessary product standards and code changes to use these refrigerants in the occupied space or in large machinery rooms without the burdensome requirements of safety Class 2 or 3, highly flammable refrigerants. Even with codes and standards changes, some additional application cost may be expected. Taken together with generally higher refrigerant costs, this means that the cost of new chillers with lower GWP refrigerants is likely higher. Manufacturers typically pass along additional costs, and therefore the price is likely higher, which typically will dampen the demand as long as the existing product is not discontinued.

Regulation is taking a leading role in mandating the adoption of new refrigerants with lower GWPs. There is continued pressure for the use of lower GWP refrigerants in all countries and industry is responding. For example, Air-Conditioning, Heating, and Refrigeration Institute (AHRI) (the manufacturer's trade association in the US) and NRDC (the National Resources Defense Council, Washington, and DC) recently agreed to discontinue sale of chillers using higher GWP refrigerants HFC-134a, R-410A and R-407C by 1/1/2025. This agreement is consistent with the emerging refrigerants listed in Table 6-1. The agreement also provides support to the US EPA's proposal to ban all 3 refrigerants from new production chillers, although the EPA proposed timeline is somewhat quicker. The time to 2025 will allow manufacturers to complete the design and implementation of full product lines, and work on cost reductions. At the same time, refrigerant producers will need to increase capacity to meet demand and put products into the product service infrastructure. Ideally, as the product changes occur, major disruptions will be avoided.

One can also not overlook the role that zero or near-zero GWP refrigerants such as R-717, R-718, and HC-290, and absorption chillers may play. As noted in the 2014 RTOC Assessment Report, these alternatives have been available for some time, and new choices may emerge. It is impossible to predict the market mix that may emerge, especially in view of future government regulations or incentives.

As far as drop-in alternatives or retrofits are concerned, it is too early to tell if manufacturers will offer retrofit packages for use in upgrading existing chillers with the emerging lower GWP refrigerants. While technically possible, it would not be likely for several reasons. First, all compressor types are optimized for the specific refrigerant used. Substituting a different refrigerant usually results in a loss of capacity, efficiency or both. Second, the pressure ratio for fixed displacement compressors may limit the ability of the compressor to reach the appropriate pressure rise when a different refrigerant is used. A similar phenomenon is found in centrifugal compressors when changing refrigerants, but may be overcome with a change in impellers or speed when a variable speed drive is used. Third, many of the emerging refrigerants are safety Class 2L. Use of a safety Class 2L refrigerant to replace a safety class A1 refrigerant may require significant changes to meet the building codes and standards, as well as product standards (such as UL listing to a product standard). These things taken together would likely discourage retrofits.

6.10. Vehicle air conditioning

Since the 2014 RTOC Assessment Report, no new alternatives have been introduced in light-duty mobile air conditioners (MACs). The penetration of HFO-1234yf for new vehicles has continued and has spread to many additional models, primarily in non-A 5 Parties, but is still far from complete. HFC-134a continues to be used in the majority of new vehicles, especially in vehicles used in A5 Parties. Regulations and announcements of such, including the MAC Directive of 2006 in the EU, credit system and model year 2021 HFC-134a phase-out in the US, the Canadian consideration of bans and HFC phasedowns, and the Japanese target GWP of 150 by 2023, continues to be primary factors influencing this trend. In addition, development of R-744 MACs has continued and appears imminent, with announcements from Mercedes-Benz to use it in new S-class and E-class models for the EU beginning in 2017, and indications that Audi A8 and Volkswagen Phaeton models will also use R-744 in 2017.

Other alternatives that were discussed in the 2014 RTOC Assessment report, including hydrocarbons, HFC-152a and additional HFC/HFO blends R-444A and R-445A, have not received much additional consideration and appear unlikely to be chosen for new vehicles in the near future.

The trend in electrified drivetrains continues, with hybrids and battery-electric vehicles capturing more of the market. This is important in terms of refrigerant, as these vehicles will increase the desire for heat pump (heating and cooling) systems in lieu of cooling-only systems. More advanced designs integrating battery and/or electronics cooling with the passenger comfort system are likely to be introduced.

Buses still rely primarily on HFC-134a and R-407C for passenger comfort. Some vehicles using R-744 are operating, and their use, while currently low (perhaps about 20 buses), is increasing but is limited by the availability of open-type compressors. The trend to hybrid electric buses will allow hermetic or semi-hermetic compressors, making the use of R-744 more likely.

Heavy Duty trucks still rely on HFC-134a for driver comfort. Some versions are likely to introduce HFO-1234yf soon.

6.11. Sustainable refrigeration

Sustainable cold chain (SCC) is a new topic that will be explored in the 2018 RTOC Assessment Report. SCC aims to ensure product quality and safety across the cold chain, producing the lowest feasible level of environmental and social negative impacts, by managing materials, energy and waste in a sustainable manner, favoring responsible transport, production and consumption. Various SCC projects have been undertaken, engaging stakeholders in the chain to join efforts, focusing mainly on: (i) food quality and safety to minimize food losses and waste (today one third of food is lost or wasted); (ii) energy efficiency (refrigeration is accountable for the main energy usage in supermarkets and grocery stores); and (iii) integration of sustainable practices across the chain.

Regulations and standards: Several steps have been taken towards sustainable refrigeration, including national or regional-level regulations and well as safety standards development. For instance, the EU F-gas rule has entered into force as of 2015, with specific requirements for some types of equipment already taking effect and others coming into force between now and 2025. Also, controls on the maximum amount of HFCs allowed to be placed on the market in the EU took effect in 2015 with the first reduction from the 2015 amount set for 2016 and 2017. A public consultation on the development of an Integrated Research, Innovation and Competitiveness Strategy towards a sustainable, competitive, energy-efficient, low-carbon economy has been launched by the European Commission. In the US, regulations have been enacted specifically finding certain HFC refrigerants unacceptable in certain applications, including motor vehicle air conditioning (dealt with in Chapter 10), retail food refrigeration, and vending machines (in Chapter 4). These regulations take effect in the time period of 2016 through 2020 (2021-2022-2025). Revisions to standards on the purity of refrigerants (e.g., AHRI Standard 700), safety and refrigerant recovery/recycling equipment (e.g. AHRI Standard 740) have been published.

6.12. Not-in-Kind technologies

This chapter looks into technologies that do not employ vapour compression technology. They are called Not-In-Kind Technologies (NIK). Vapour compression technology has been the dominant technology for all R/AC applications in the last 100 years. Nevertheless, during past years several other technologies have been developed. The development status of those technologies can be classified as:

- R&D status
- Emerging technology
- Commercially available.

Recently, the U.S. Department of Energy developed a study to characterize and evaluate alternatives to vapour-compression technology options to serve future residential and commercial HVAC applications. Provided below are some of the main aspects of this study.

NIK technology classification is divided into three groups according to their particular driving energy. Those are:

- Thermally driven.
- Electro- mechanically driven.
- Solid State driven.

Seventeen NIK technologies from these 3 groups were compared in the study to a baseline vapour compression technology considering the following criteria:

- Energy savings potential.
- Non-energy benefits.
- Cost/complexity.
- Heating and cooling capabilities.
- Development status.
- Market barriers.

Based on these criteria, they were classified as i) most promising, ii) very promising, iii) moderately promising, and i) least promising:

- Most promising: membrane heat pump, thermo-elastic;
- Very promising: evaporative liquid desiccant A/C, magneto-caloric, Vuilleumier heat pump;
- Moderately promising: evaporative cooling, thermo-electric, ground-coupled solid desiccant A/C, absorption heat pump, duplex-Stirling heat pump, thermo-acoustic, adsorption heat pump, thermo-tunneling;
- Least promising: stand-alone solid desiccant A/C, stand-alone liquid desiccant A/C, ejector heat pump, and Brayton heat pump.

The present status, the development of prototypes and equipment, and the expected technical progress of some NIK technologies are as follows:

Thermo-elastic and Membrane Technologies:

A one TR (3.52 kW) window air conditioner prototype operating on thermo elastic technology is undergoing testing. In another facility, one manufacturer developed a one TR (3.52 kW) prototype space conditioning system that operates on Membrane Heat Pump technology using this two stage (latent and sensible) technology. The manufacturer predicts an EER of 26 Btu/Whr or greater.

Absorption, Evaporative and Evaporative Liquid Desiccant Technologies:
Absorption heat pumps are commercially available and have an inherent advantage since they can operate on low heat energy exergy thus saving on precious peak electric power. Evaporative cooling has always been an attractive alternative in Hot-Dry conditions, although Indirect/Direct evaporative cooling can be used in both dry and humid hot conditions, its water consumption rates can be a risk in arid conditions. Evaporative Liquid Desiccant technology, an R&D technology, also consumes water and careful selection is needed in Regions where water is scarce**.**

Ground coupled Solid Desiccant AC Magneto-caloric and Vuilleumier Heat Pump technologies.
Ground coupled Solid Desiccant AC is also a R&D technology and uses low exergy thermal energy**.** Magneto-caloric and Vuilleumier Heat Pump technologies are both in the emerging phase and promising technologies.

6.13. High Ambient Temperatures (HAT)

The performance of low-GWP alternative refrigerants for air conditioners at high ambient temperature conditions has been the focus of several research projects, both globally and in the Parties that experience those conditions. For this reason, a specific Working Group has been established within the RTOC and tasked to assess the performance of different refrigerants and equipment at HAT conditions. Results will be incorporated into the 2018 RTOC Assessment Report as a specific annex.

Presently, three testing projects that focused on HAT conditions have been concluded. Results from these projects were announced at the end of 2015 - early 2016. The three projects followed different procedures rendering a straight comparison of results among them difficult.

The three projects are: PRAHA (Promoting low-GWP Refrigerants for the Air-Conditioning Sectors in High-Ambient Temperature Countries), ORNL (Oak Ridge National Laboratory), and AREP-II (Alternative Refrigerant Evaluation Program). A fourth project, EGYPRA (Egyptian Project for Refrigerant Alternatives), is still in progress and the results are expected at the end of 2016. PRAHA tested five alternatives in 13 custom-built prototypes in four categories built by original equipment manufacturers (OEMs) in the Gulf Cooperation Countries and tested them at an independent lab against base HCFC-22 and R-410A units built by the same manufacturers. ORNL tested 10 alternatives dropped-in, or optimized, in two base units of equal capacity using HCFC-22 and R-410A. AREP-II tested seven alternatives optimized in a number of units by several manufacturers and tested at their premises vs. base R-410A units.

The alternative refrigerants tested show promise in meeting specific air conditioning equipment requirements for operating under HAT conditions; however, setting comparable testing parameters in future testing and field trials will be helpful in assessing and comparing the results. The main other outcome from the projects is that there is need for a comprehensive risk assessment for flammable refrigerants at installation, servicing, and decommissioning at HAT conditions. The commercial availability of both new refrigerants and components, as well as optimized design of equipment, will affect the timing of the transition.

6.14. Modeling and scenarios

There is great interest in scenario developments, as included in the XXV/5, XXVI/9 and XXVII/4 Task Force reports, where a clear idea of the size of demand, banks and emissions is needed in order to estimate the importance of mitigation efforts. For this reason, a specific Working Group has been established within the RTOC with its task aimed at explaining the background and ongoing improvements of models with which scenarios are being built. This detailed explanation will be incorporated in the 2018 RTOC Assessment Report as a specific annex.

Information will be developed using the current model used and should flow to the various RTOC chapters in a coordinated effort. This information will also have to be used if costs for conversion from high GWP refrigerants to low GWP alternatives need to be calculated (this is to be further considered in the 2017-2018 timeframe).

The 2018 Assessment Report is expected to consider these issues, rather than commercial information on the amounts of product manufactured, exported and imported. Data about product inventories and production amounts will be part of the modelling efforts for banks and emission estimates (following the bottom-up approach) that will be further developed and will not be an explicit part of each of the separate RTOC Assessment Report chapters.

In principle three types of models (with emphasis either on banks and emissions or on energy consumption in the third case) are used to calculate data for refrigeration and air conditioning applications. Most of the models have a component that calculates direct and-or indirect emissions from installed R/AC equipment. These are the following:

1. Thermodynamics based models that calculate energy efficiency and energy consumption for an R/AC application under certain outside temperature circumstances. Together with assumptions regarding refrigerant charge and leakage, the results of the calculations can be used to determine direct and indirect emissions (development and results of these models, if appropriate, would be reported in chapter 2 or in the modelling Annex of the RTOC Assessment Report).
2. Inventory models that calculate the amounts of refrigerant charged into refrigeration and air conditioning equipment based on sales data of various types of equipment for a Party or region, which can be defined as the bank of refrigerants. Together with assumptions regarding leakage and recovery during operation and end of life, the refrigerant demand and the refrigerant emissions in a given year can be determined (to be reported on in the modelling Annex, results on demand and banks to be used on in separate chapters of the RTOC Assessment Report). This is the type of model being applied in the various Task Force reports, as mentioned above.
3. Models that focus on total (climate relevant) emission reductions. They depart from assumptions or data on the number of pieces of equipment of certain types in the AC subsector and from test data regarding energy efficiency improvements possible by changing refrigerants. Together with assumptions about the leakage of refrigerant during the operation and at end of life, and the savings in CO_2-eq. by changing to low GWP refrigerants, a total saving in CO_2-eq. is calculated. Emphasis is not on the refrigerant charge amounts here, but on refrigerant emissions and CO_2 emissions related to electricity use dependent on hours of operation, capacity, equipment energy efficiency development, as well as on the power mix in Parties, etc. This is then translated into total CO_2 emissions savings.

Status and ongoing progress for the different model types:

1. One of the main purposes of the use of thermodynamic models is to investigate the characteristics and energy efficiency of (new) refrigerants or refrigerant blends compared to a base case. Calculation of the properties of new refrigerant blends (in particular when containing HFC/HFO fluids) is still work in progress. Refinement to the way cycle components are dealt with in the calculations should also be done. This may, however, be of less importance than the efficiency comparison of various types of refrigerants.
2. This method has been used to calculate demand and emissions for CFCs, HCFCs and HFCs for certain countries; emissions have been used in the emissions reporting to the UNFCCC. This results in uncertainties, which, in particular if data are calculated for scenarios into the future, could become rather large. This issue can only be (partly) resolved by more and better trade and sales data. Accuracy can be improved by making the lifetime, operation and end-of-life leakage estimates more relevant to specific Parties. An important issue is the check with production data. For HCFCs this is possible, for HFCs, and specifically for those HFCs that are being sold into the R/AC market, more needs to be done. Future scenarios are mainly based upon economic growth and resulting growth in equipment numbers. Refinement of these models, as applied in the above Task Force reports, is an issue for ongoing study and improvement.
3. The method described gives the potential of savings in greenhouse gas emissions, in particular for the years up to 2050. So far this method has only been applied for the operation of AC units in developing countries; expansion of the method for other R/AC sub-sectors would be possible, however, would require a substantial amount of additional work.

7 Decision XXVII/7: Investigation of carbon tetrachloride discrepancies

The addendum to the Note by the Secretariat to the Twenty-Seventh Meeting of the Parties to the Montreal Protocol (MOP-27) (UNEP/OzL.Pro.27/2/Add.1) highlighted recent work to address carbon tetrachloride emissions discrepancies, bottom-up and top-down. Carbon tetrachloride (CCl_4 or CTC) is a major ozone-depleting substance and greenhouse gas. Estimates of CTC sources as identified in the various reports of the TEAP and as reported by the parties are inconsistent with abundance observations reported in the most recent *Scientific Assessment of Ozone Depletion: 2014*. To address these discrepancies, a workshop entitled "Solving the mystery of carbon tetrachloride" was held in Dübendorf, Switzerland, from 4 to 6 October 2015. The workshop, which was attended by experts in the fields of science, industry and technology, was held under the auspices of the Stratosphere-Troposphere Processes and their Role in Climate (SPARC) project of the World Climate Research Programme. The workshop was hosted by the Swiss Federal Laboratories for Materials Science and Technology (Empa) and the sponsors of the workshop included Empa, the National Aeronautics and Space Administration of the United States of America, SPARC, the Swiss National Science Foundation and the Ozone Secretariat.

The Secretariat's Note pointed to the significant progress made at this workshop in closing the CTC top-down and bottom-up budget discrepancy, including the following main findings:

(a) New industrial estimates based upon known global CTC production are in close agreement with emissions reported by the parties to UNEP. While reported production estimates to UNEP are accurate, fugitive emissions are non-zero but are not large enough to close the CTC budget discrepancy;

(b) Top-down estimates based on high-frequency, ground-based and airborne measurements indicate continued significant emissions of CTC in the northern hemisphere from industrial regions;

(c) Revisions to ocean and soil lifetimes indicate that losses of CTC are slower than previously estimated. This narrows the gap between the top-down measurements and the bottom-up estimates of emissions based on UNEP-reported production (and consumption) data;

(d) Observations based upon air trapped in snow (firn air) and ice cores have been used to construct time histories of CTC. These data show that pre-1900 natural emissions are small.

Based on the workshop findings and recommendations, a SPARC report has been developed with a final version of that report anticipated to be published in July 2016.

At MOP-27 Parties adopted Decision XXVII/7, which requested TEAP and SAP "to continue their analysis of the discrepancies between observed atmospheric concentrations and reported data on carbon tetrachloride and to report and provide an update on their findings to the Twenty-Eighth Meeting of the Parties." TEAP and SAP met during OEWG-37 to discuss a response to this decision and will provide an update, based on the final SPARC report, to the parties for MOP-28.

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 the publication of the progress report. 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 31st December of the final year of appointment, as indicated in the last column of the following tables.

1. Technology and Economic Assessment Panel (TEAP)

Co-chairs	**Affiliation**	**Country**	**Appointed through**
Bella Maranion	U.S. EPA	USA	2016*
Marta Pizano	Consultant	Colombia	2018
Ashley Woodcock	University of Manchester	UK	2018
Senior Experts	**Affiliation**	**Country**	**Appointed through**
Suely Machado Carvalho	Inst. de Pesquisas Energéticas e Nucleares	Brazil	2019
Marco Gonzalez	Consultant	Costa Rica	2017
Lambert Kuijpers	A/genT Conultancy (TUE Eindhoven)	Netherlands	2016*
Shiqiu Zhang	Sen Yat Sen University	China	2017
TOC Chairs	**Affiliation**	**Country**	**Appointed through**
Mohamed Besri	Inst. Agronomique et Vétérinaire Hassan II	Morocco	2017
David Catchpole	Petrotechnical Resources Alaska	UK	2016*
Sergey Kopylov	Russian Res. Institute for Fire Protection	Russian Fed.	2017
Kei-ichi Ohnishi	Asahi Glass	Japan	2019
Roberto. Peixoto	Maua Institute (IMT), Sao Paulo	Brazil	2017
Fabio Polonara	Universitá Politecnica delle Marche	Italy	2018
Ian Porter	La Trobe University	Australia	2017
Helen Tope	Energy International Australia	Australia	2017
Daniel P. Verdonik	JENSEN HUGHES	USA	2016*
Jianjun Zhang	Sen Yat Sen University	PRC	2017

* *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)

The FTOC met in Montreal Canada May 7/8 2016, attended by 16 members. Ashley Woodcock acted as interim co-chair, and developed the consensus position within the 2016 Progress Report. In 2016, the two outgoing co-chairs were re-appointed to the committee (Paul Ashford, Miguel Quintero), two members retired (Mike Jeffs, Christoph Maurer), and four new members were appointed. Discussions are ongoing within the FTOC to suggest nominations for permanent co-chairs

Co-chair	**Affiliation**	**Country**	**Appointed through**
Ashley Woodcock	University of Manchester	UK	Interim
Members	**Affiliation**	**Country**	**Appointed through**
Samir Arora	Industrial Foams	India	2016*
Paolo Altoe	Dow	Brazil	2019
Terry Arrmitt	Hennecke	UK	2018
Paul Ashford	Anthesis	UK	2019
Angela Austin	Consultant	UK	2019
Kultida Charoensawad	Covestro	Thailand	2019
Roy Chowdhury	Foam Supplies	Australia	2018
Rick Duncan	Spray Polyurethane Association	USA	2018
Koichi Wada	Bayer Material Science/JUFA	Japan	2018
Rajaran Joshi	Owens Corning	India	2018
Ilhan Karaağaç	Izocam	Turkey	2016*
Shpresa Kotaji	Huntsman	Belgium	2018
Simon Lee	Dow	USA	2018
Yehia Lotfi	Technocom	Egypt	2018
Lisa Norton	Solvay	USA	2019
Miguel Quintero	Consultant	Colombia	2019
Sascha Rulhoff	Haltermann	Germany	2018
Enshan Sheng	Huntsman	China	2018
Helen Walter-Terrinoni	Chemours	USA	2018
Dave Williams	Honeywell	USA	2018
Allen Zhang	Consultant	China	2018

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

3. TEAP Halons Technical Options Committee (HTOC)

Mr. D.V. Catchpole (UK) will not seek re-nomination as HTOC co-chair this year. Mr. H.S. Kaprwan (India) will retire as a Committee member this year. A number of long-standing, dedicated experts who have participated on the Committee as Consulting Experts can no longer make regular, ongoing, and constructive contributions to the work of the HTOC. They will leave with our gratitude for their prior contributions to the work of the HTOC.

Co-chair	**Affiliation**	**Country**	**Appointed through**
David V. Catchpole	Petrotechnical Resources Alaska	UK	2016*
Sergey N. Kopylov	Russian Res. Institute for Fire Protection	Russian Fed.	2017
Daniel P. Verdonik	JENSEN HUGHES	USA	2016*
Members	**Affiliation**	**Country**	**Appointed through**
Tareq K. Al-Awad	King Abdullah II Design & Dev. Bureau	Jordan	2016*
Jamal Alfuzaie	Consultant - Retired	Kuwait	2018
Johan Åqvist	Åqvist Consulting Group	Sweden	2019
Youri Auroque	European Aviation Safety Agency	France	2019
Seunghwan (Charles) Choi	Hanju Chemical Co., Ltd.	South Korea	2018
Adam Chattaway	UTC Areospace Systems	UK	2016*
Michelle M. Collins	Consultant- EECO International	USA	2018
Carlos Grandi	Embraer	Brasil	2017
H. S. Kaprwan	Consultant – Retired	India	2017**
Emma Palumbo	Safety Hi-tech srl	Italy	2018
Erik Pedersen	Consultant – World Bank	Denmark	2016*
Donald Thomson	MOPIA	Canada	2017
Robert T. Wickham	Consultant-Wickham Associates	USA	2018
Mitsuru Yagi	Nohmi Bosai Ltd & Fire and Environment Prot. Network	Japan	2017
Consulting Experts	**Affiliation**	**Country**	**Appointed through**
Thomas Cortina	Halon Alternatives Research Corporation	USA	All one year renewable terms
Matsuo Ishiyama	Nohmi Bosai Ltd & Fire and Environment Prot. Network	Japan	
Nikolai Kopylov	Russian Res. Institute for Fire Protection	Russian Fed.	
David Liddy	Consultant – Retired	UK	
Steve McCormick	United States Army	USA	
John G. Owens	3M Company	USA	
John J. O'Sullivan	Bureau Veriitas	UK	
Mark L. Robin	DuPont	USA	
Joseph A. Senecal	Kidde-Fenwal Inc.	USA	
Ronald S. Sheinson	Consultant - Retired	USA	

** Indicates members whose terms expire at the end of the current year ** Will retire 2016*

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

Co-chairs	Affiliation	Country	Appointed through
Kei-ichi Ohnishi	Asahi Glass	Japan	2019
Helen Tope	Energy International Australia	Australia	2017
Jianjun Zhang	Zhejiang Chemical Industry Research Institute	China	2019
Members	**Affiliation**	**Country**	**Appointed through**
Emmanuel Addo-Yobo	Kwame Nkrumah University of Science and Technology	Ghana	2018
Fatemah Al-Shatti	Kuwait Petroleum Corporation	Kuwait	2018
D.D. Arora	Energy and Research Institute	India	2018
Paul Atkins	Oriel Therapeutics Inc. (A Novartis Company)	USA	2018
Steven Bernhardt	Private consultant to Honeywell	USA	2018
Biao Jiang	Shanghai Institute of Organic chemistry, Chinese Academy of Sciences	China	2018
Olga Blinova	Russian Scientific Center "Applied Chemistry"	Russia	2018
Nick Campbell	Arkema	France	2018
Jorge Caneva	Favaloro Foundation	Argentina	2018
Nee Sun (Robert) Choong Kwet Yive	University of Mauritius	Mauritius	2018
David Dalle Fusine	Chiesi Farmaceutici (seconded at Chiesi China)	Italy	2018
Eamonn Hoxey	Johnson & Johnson	UK	2018
Jianxin Hu	College of Environmental Sciences & Engineering, Peking University	China	2018
Javaid Khan	The Aga Khan University	Pakistan	2018
Gerald McDonnell	DePuy Synthes, Johnson & Johnson	USA	2018
Robert Meyer	University of Virginia	USA	2018
Hideo Mori	Tokushima Regional Energy	Japan	2015-2016*
Tunde Otulana	Mallinckrodt Pharmaceuticals	USA	2018
José Pons Pons	Spray Quimica	Venezuela	2019
Hans Porre	Teijin Aramids	Netherlands	2018
John Pritchard	Philips Home Healthcare Solutions	UK	2018
Rabbur Reza	Beximco Pharmaceuticals	Bangladesh	2018
Paula Rytilä	Orion Corporation Orion Pharma	Finland	2019
Surinder Singh Sambi	Indian Institute of Chemical Engineers (Northern Region)	India	2018
Roland Stechert	Boehringer Ingelheim	Germany	2018
Kristine Whorlow	Nat. Asthma Council	Australia	2018
Ashley Woodcock	University of Manchester	UK	2019
You Yizhong	Journal of Aerosol Communication	China	2018

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

5. TEAP Methyl Bromide Technical Options Committee (MBTOC)

Co-chairs	Affiliation	Country	Appointed through
Mohamed Besri	Institut Agronomique et Vétérinaire Hassan II	Morocco	2017
Marta Pizano	Consultant - Hortitecnia Ltda	Colombia	2017
Ian Porter	La Trobe University	Australia	2017
Members	**Affiliation**	**Country**	**Appointed through**
Jonathan Banks	Consultant	Australia	2016*
Fred Bergwerff	Oxylow BV	Netherlands	2018
Aocheng Cao	Chinese Academy of Agricultural Sciences	China	2018
Ken Glassey	MAFF – NZ	New Zealand	2018
Eduardo Gonzalez	Fumigator	Philippines	2018
Takashi Misumi	MAFF – Japan	Japan	2018
Eunice Mutitu	University of Nairobi	Kenya	2016*
Christoph Reichmuth	Honorary Professor	Germany	2018
Jordi Riudavets	IRTA – Department of Plant Protection	Spain	2017
JL Staphorst	Consultant	South Africa	2016*
Akio Tateya	Technical Adviser, Syngenta	Japan	2018
Alejandro Valeiro	Nat. Institute for Ag. Technology	Argentina	2018
Ken Vick	Consultant	USA	2016*
Nick Vink	University of Stellenbosch	South Africa	2018
Eduardo Willink	Ministerio de Agricultura	Argentina	2016*
Suat Yilmaz	Min. of Food, Agriculture and Livestock	Turkey	2016*

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

6. TEAP Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee (RTOC)

Co-chairs	Affiliation	Country	Appointed through
Roberto de A. Peixoto	Maua Institute, IMT, Sao Paulo	Brazil	2017
Fabio Polonara	Universita' Politecnica delle Marche	Italy	2018
Members	**Affiliation**	**Country**	**Appointed through**
James M. Calm	Engineering Consultant	USA	2018
Radim Cermak	Ingersoll Rand	Czech Rep	2018
Guangming Chen	Zhejiang University, Hangzhou	China	2018
Jiangpin Chen	Shanghai University	China	2018
Daniel Colbourne	Re-phridge Consultancy	UK	2018
Richard DeVos	General Electric	USA	2018
Sukumar Devotta	Consultant	India	2018
Martin Dieryckx	Daikin Europe	Belgium	2018
Dennis Dorman	Trane	USA	2018
Bassam Elassaad	Consultant	Lebanon	2018
Dave Godwin	U.S. EPA	USA	2018
Marino Grozdek	University of Zagreb	Croatia	2018
Samir Hamed	Petra Industries	Jordan	2018
Martien Janssen	Re/genT	Netherlands	2018
Makoto Kaibara	Panasonic, Research and Technology	Japan	2018
Michael Kauffeld	Fachhochschule Karlsruhe	Germany	2018
Jürgen Köhler	University of Braunschweig	Germany	2018
Holger König	Ref-tech Consultancy	Germany	2018
Lambert Kuijpers	A/genT Consultancy (TUE Eindhoven)	Netherlands	2018
Richard Lawton	CRT Cambridge	UK	2018
Tingxun Li	Guangzhou University	China	2018
Dhasan Mohan Lal	Anna University	India	2018
Maher Mousa	MHMENG Consultancy	Saudi Arabia	2018
Petter Nekså	SINTEF Energy Research	Norway	2018
Horace Nelson	Consultant	Jamaica	2018
Carloandrea Malvicino	Fiat Ricerche	Italy	2018
Tetsuji Okada	JRAIA	Japan	2016*
Alaa A. Olama	Consultant	Egypt	2018
Alexander C. Pachai	Johnson Controls	Denmark	2018
Per Henrik Pedersen	Danish Technological Institute	Denmark	2018
Rajan Rajendran	Emerson Climate Technologies	USA	2018
Giorgio Rusignuolo	Carrier Transicold	USA	2018
Paulo Vodianitskaia	Consultant	Brazil	2018
Asbjorn Vonsild	Danfoss	Denmark	2018
Sauel Yana Motta	Honeywell	Peru	2018

** 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 June 2016.

Body	**Required Expertise**	**A5/ Non-A5**
Foams TOC	Life cycle analysis Additives Appliances	A5 or non-A5 A5 or non-A5 SE Asia
Halons TOC	Civil aviation Halon Banking and knowledge of halon alternatives and their market penetration Knowledge of shipbreaking and the disposal of halon from this source	A5, South East Asia A5, Africa, A5, South America, and A5, South Asia A5, South Asia
Methyl Bromide TOC	Wide general expertise on alternatives for pre-plant soil fumigation. 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 Quarantine and pre-shipment Expert in economic assessment of alternatives to MB	Non-A5 Non-A5 A5 from Asia Non-A5
Medical and Chemical TOC	Aerosols Destruction technologies Inhalers, including industry or clinical laboratory and analytical uses Process agents Solvents Sterilants	A5 or non-A5
Refrigeration TOC	Additional experts not currently required	-
Senior Experts]	Experience in the “bottom-up analysis” of inventories and banks, together with mathematical modelling for scenario planning	A-5 or Non-A5

ANNEX 3. Decision XXVI/7: Availability of recovered, recycled or reclaimed halons

Recognizing that the global production of halons for controlled uses was eliminated in 2009, but that some remaining uses, in particular for civil aviation, continue to rely on stocks of recovered, recycled or reclaimed halons for fire safety,

Noting that, despite efforts to evaluate the extent of accessible stocks of recovered, recycled or reclaimed halons, there is still uncertainty about the quantity of recovered, recycled or reclaimed halons that is accessible for continuing uses, such as in civil aviation,

Recalling the 1992 International Maritime Organization ban on the use of halons in new ships and noting that ships containing halons are now being decommissioned,

Recalling also the adoption by the Assembly of the International Civil Aviation Organization of resolutions A37-9 and A38-9, in which the Assembly expressed an urgent need to continue developing and implementing halon alternatives for civil aviation and called on manufacturers to use alternatives in lavatory fire extinguishing systems in newly designed and new production aircraft after 2011, in hand-held fire extinguishers in such aircraft after 2016, in engine and auxiliary power unit fire-extinguishing systems used in newly designed aircrafts after 2014 and in the cargo compartments of new aircraft by a date to be determined by the Assembly in 2016

Noting that the import and export of recovered, recycled or reclaimed halons is allowed under the Montreal Protocol and that the Technology and Economic Assessment Panel has found that the current distribution of recovered, recycled or reclaimed halon stocks potentially may not align with anticipated needs for such stocks,

Recalling paragraph 3 of decision XXI/7, concerning the import and export of recovered, recycled or reclaimed halons,

Taking note of the progress report of the Technology and Economic Assessment Panel provided to the parties before the thirty-fourth meeting of the Open-ended Working Group, including information on alternatives,

1. To encourage parties, on a voluntary basis, to liaise, through their national ozone officers, with their national civil aviation authorities to gain an understanding of how halons are being recovered, recycled or reclaimed to meet purity standards for aviation use and supplied to air carriers to meet ongoing civil aviation needs and on any national actions being taken to expedite the replacement of halons in civil aviation uses as called for by the Assembly of the International Civil Aviation Organization in its resolutions A37-9 and A38-9;

2. To also encourage parties, on a voluntary basis, to submit information provided in accordance with paragraph 1 of the present decision to the Ozone Secretariat by 1 September 2015;

3. To invite parties, on a voluntary basis, to reassess any national import and export restrictions other than licensing requirements with a view to facilitating the import and export of recovered, recycled or reclaimed halons and the management of stocks of such halons with the aim of enabling all parties to meet remaining needs in accordance with domestic regulations even as they transition to halon alternatives;

4. To request the Technology and Economic Assessment Panel, through its Halons Technical Options Committee:

(a) To continue to liaise with the International Civil Aviation Organization to facilitate the transition to halon alternatives, to approach the International Maritime Organization to estimate the amount and purity of halon 1211 and 1301 available from the breaking of ships and to report information on global stocks of recovered halons to the parties in its 2015 progress report;

(b) To report on existing and emerging alternatives for halons, including information on their characteristics and their rate of adoption, in particular for aviation uses;

5. To request the Ozone Secretariat to report to the parties, prior to the thirty-sixth meeting of the Open-ended Working Group, any information provided by parties in accordance with paragraph 1 of the present decision;