MONTREAL PROTOCOL

ON SUBSTANCES THAT DEPLETE

THE OZONE LAYER

UNEP

REPORT OF THE
TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL

JUNE 2015

VOLUME 1

PROGRESS REPORT

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Foreword

The May 2015 TEAP Report

The June 2015 TEAP Report consists of three volumes:

***Volume 1**: Progress Report:*

- *June 2015 TEAP Essential Use Nominations Report*
- *TOC Progress Reports*
- *Response to Decision XXVI/7*
- *Other TEAP matters*
- *List of TEAP and TOC members at June 2015*
- *Matrix of Expertise*

***Volume 2**: May 2015 TEAP Critical Use Nominations Report*

***Volume 3**: Report of the TEAP Task Force on Decision XXVI/9: on Additional Information on Alternatives to ODS*

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PROGRESS REPORT

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1 Introduction

This is volume 1 of 3 of the June 2015 TEAP Report and contains:

The CTOC progress report and the EUN evaluation report

The FTOC progress report;

The HTOC progress report;

The MBTOC progress report;

The MTOC progress report;

The RTOC progress report;

TEAP's response to Decision XXVI/7

TEAP and TOC organisational issues; and

An annex of the TEAP and TOC membership list, as at June 2015, which includes each member's terms for re-appointment and an annex of the matrix of needed expertise on the TEAP and its TOCs.

The TEAP and its TOCs only recently completed and published their quadrennial Assessment Reports. Therefore, the above progress reports provide only brief updates and/or any new information that may not have been included in the Assessment Reports for the information of Parties.

TEAP would like to express its sincere gratitude for the voluntary service of the TOC members and their contributions to the work of completing the 2014 Assessment Reports. We look forward to future contributions of both continuing and new members to the TOCs.

2 Chemicals TOC (CTOC) Progress Report

2.1. CTOC Progress

In view of the publication of the CTOC 2014 Assessment Report occurring simultaneously with this Progress Report, CTOC provides no further updates and looks forward to presenting its Assessment Report to Parties at the July OEWG.

2.2. Essential Use Nomination of CTC Laboratory and analytical uses ("testing of oil, grease and total petroleum hydrocarbons in water") by China

2.2.1. Introduction

China is requesting a continued use of carbon tetrachloride (CTC) for laboratory and analytical uses of testing of oil, grease and total petroleum hydrocarbons in water (hereinafter referred as "oil in water"). Decision XXIII/6 specifies that after 31 December 2014, the use of CTC for the testing of oil, grease and total petroleum hydrocarbons in water would only be allowed under an essential-use exemption. In accordance with this Decision, last year, the Ministry of Environment Protection of China (hereinafter referred as "MEP") sent a request for an Essential Use Exemption for 90 metric tonnes CTC in 2015. However, according to information submitted by China, consumption of CTC increased by 20 MT between 2010 and 2012. An explanation was requested from China for this increase. In a bilateral consultation during the 34th OEWG, China submitted the supplemental information requested by CTOC, and subsequently reduced the nomination amount of CTC from 90 MT to 80MT for 2015, which was approved at the 26th MOP. In 2015, China has nominated 70 metric tonnes of CTC for use in 2016:

The oil-in-water test in China observes the national standard "*HJ 637-2012 Water quality-Determination of petroleum oil, animal and vegetable oils- Infrared photometric method"*, in which CTC is used as the extracting agent to extract oil substances which are then determined with the infrared photometric method.

It is a fundamental requirement to test oil in water in monitoring water quality in China. The scope of the water monitoring includes headwater, lake water, river water, surface water, groundwater, seawater, potable water, domestic sewage, industrial effluent, etc. The related stakeholders are diverse, which involve governmental monitoring departments for environmental and water affairs, detecting agencies of enterprises in petrochemical, chemical and agricultural industries, and testing agencies in universities, research institutes and social public testing organizations.

2.2.2. Explanation on EUN for CTC in 2015-2016 by China

A. Steps to Minimise Use

The MEP launched the revision of the standard "*HJ 637-2012 Water quality— Determination of petroleum oil, animal and vegetable oils—Infrared photometric method"* in February, 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. Currently the revision of above-mentioned standards is in process. China indicates its intention to complete the revision and approve and promulgate the new standards by the end of 2016. To achieve this, activities to support the implementation of the standards will be carried out, including training of technicians and management staff, updating/replacing testing apparatus, equipment and reagents and raising public awareness. . With the revised standard in 2016, it is highly unlikely that China would need to seek a future EUN for CTC in this use.

China has been promoting non-ODS standards in different water systems and testing ranges. "*Water quality- Determination of petroleum oil- Molecular fluorescence spectrometry (SL366-2006)"* was released by the Ministry of Water Resources, which takes n-hexane as the extracting agent. "*The specification for marine monitoring Part 4: Seawater analysis (GB/T17378.4-2007)*" was implemented in 2008, which targets at the oil pollution in marine, offshore and estuary waters. The standard uses spectrofluorimetry, UV spectrophotometry and gravimetric method, whose extracting agents are petroleum ether and cyclohexane.

In order to promote the replacement of CTC in laboratory and analytical uses, the technical assistant institutions will conduct technical exchange and trainings among institutional users, which can help them better aware of domestic and international policies, standards and amendments, and substitute reagents and methods.

Awareness raising activities are launched through public and professional media as well as the management website. Brochures and compact discs about lab-use ODS replacement are being developed too, which will be distributed to reagent producers, dealers and users.

B. Steps to Minimise Emissions

The environmental monitoring departments recycle the CTC, which approximately accounts for 20% of the total usage. For many of the other testing and analysis organizations and university laboratories, the used CTC will be collected and destroyed. The amount of this part roughly makes up 50% of the total usage.

C. The acquisition of carbon tetrachloride

CTC is one of the by-products of the methylene chloride production. Since 2007, China has been managing the CTC with "zero production quota" i.e., a company could only purchase carbon tetrachloride from legitimate producers or distributors when its feedstock use or exempted use has been approved by the MEP. Any remaining carbon tetrachloride resulting as a by-product must be converted into non-ODS substances or disposed by the producers. Therefore although China nominates an essential use, there will be no newly produced CTC even if the exemption is approved. The exempted use of CTC for laboratory and analytical use for testing oil in water will be effectively supervised under the existing management system.

2.2.3 CTOC Comments on EUN for CTC in 2016-2017 by China

CTOC acknowledges that China has developed a new standard, and is now in a transition period to replace CTC use as the extracting solvent. CTOC also acknowledges the effort made by China in its endeavor to reduce the use of CTC, and to promote the replacement of CTC in laboratory and analytical uses.

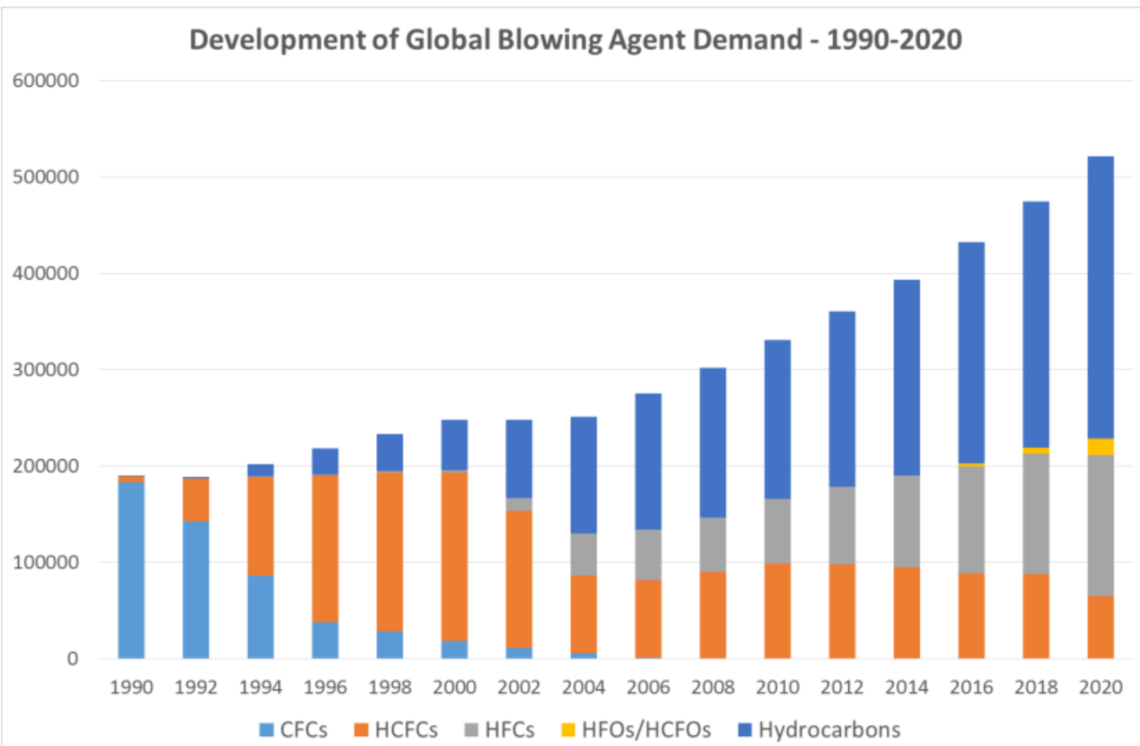
2.2.4. Conclusion

After careful review, CTOC recommends the Essential Use Exemptions of 70 metric tonnes CTC in 2016 for "testing of oil, grease and total petroleum hydrocarbons in water" for China. The global exemption of the use of ODS for laboratory and analytical purposes has been further extended for another 7 years to 31 December 2021 by Decision XXVI/5.1 taken in 2014. However, CTOC anticipates that China will implement the new standard and phase out the use of CTC for analytical uses as soon as possible. With the revised standard in 2016, it is highly unlikely that China would need to seek a future EUN for CTC in this use.

3 Foams TOC (FTOC) Progress Report

The FTOC 2014 Assessment Report has been published and is accessible at the Ozone Secretariat website http://ozone.unep.org/Assessment_Panels/TEAP/Reports/FTOC/FTOC-2014-Assessment-Report.pdf. The Assessment Report has taken a slightly different approach to the characterization of trends in blowing agent consumption in 2014, with stronger links back to the underlying growth in foam markets. The Report has also assessed the progress made in transitioning from HCFCs in Article 5 parties and the challenges remaining, particularly in the PU Spray and Extruded Polystyrene (XPS) sectors. The continued emergence of low-GWP blowing agent options, such as unsaturated H(C)FCs (H(C)FOs) and oxygenated hydrocarbons is also documented, leading to the following assessment of blowing agent markets to 2020.

Figure 3.1 – Assessment of the historic, current and future development of global blowing agent demand by blowing agent type



The Assessment Report will be presented by the out-going FTOC Co-Chairs to parties at the July OEWG. This presentation will also include any further updates in the development of the blowing agent choices, with focus on the impact of the various F-Gas initiatives on the selections being made, especially in XPS sectors where HFC-152a is becoming more prevalent.

4 Halons TOC (HTOC) Progress Report

The HTOC 2014 Assessment Report has been published and is accessible at the Ozone Secretariat website: http://ozone.unep.org/Assessment_Panels/TEAP/Reports/HTOC/HTOC%202014%20Assessment%20Report.pdf. The assessment provides new or updated information only and focuses on the important messages for the Parties to consider such as the continued reliance on halons or high GWP alternatives in several important sectors, continued need for recycled halon for legacy uses, and lack of progress in civil aviation in implementing alternatives for new production aircraft and for new designs. In view of the recent publication of the HTOC 2014 Assessment Report, HTOC only provides brief updates below in its 2015 Progress Report. HTOC looks forward to presenting its Assessment Report to Parties at the July OEWG.

The United States, through its National Institute of Standards and Technology, hosted a workshop to try to determine why the currently available halon replacement agents have failed the Exploding Aerosol Can test, which is one of the required tests needed to meet the Minimum Performance Standard in civil aviation cargo bays. The intent is to be able to predict the behavior of any new agents that are developed. A small-scale screening test has been developed and is available through NIST.

The HTOC continues to strengthen or maintain key expertise. At the end of 2014, five members retired from service and two new members have been appointed by the HTOC co-chairs, in consultation with the relevant Parties. HTOC is still seeking additional expertise in civil aviation from Far East Asia, and halon banking expertise in Africa and South America.

The UNEP Regional Office for Asia and the Pacific (ROAP) arranged for HTOC representatives to meet with the Regional Director of the Asia and Pacific Office of International Civil Aviation Organization (ICAO) just prior to OEWG-35. On the margins of OEWG-35, HTOC and UNEP ROAP representatives also discussed the issue of halons and aviation uses with staff from the Thai Civil Aviation Authority. The HTOC developed a questionnaire for dissemination to airlines that ICAO then provided to the Director of Aviation Environment in the International Air Transport Association, based in Geneva. The HTOC may be asked to participate in an upcoming regional ICAO meeting in October in Manila, Philippines to continue to raise awareness on the issue of continued reliance on halons in civil aviation.

5 Methyl Bromide TOC (MBTOC) Progress Report

5.1 Introduction

The MBTOC 2014 Assessment Report has been published and is accessible at the Ozone Secretariat website: http://ozone.unep.org/Assessment_Panels/TEAP/Reports/MBTOC/MBTOC-Assessment-Report-2014.pdf. The assessment focuses on recent progress made in the development and adoption of alternatives to methyl bromide for pre-plant (soil), structures and commodities (SC) and quarantine and preshipment (QPS) treatments. It also updates trends in methyl bromide (MB) production and consumption for controlled uses in A5 and non-A5 Parties. The report further estimates the levels of emissions of MB to the atmosphere, and strategies to reduce such emissions. In addition, the document includes some case studies illustrating successful adoption of alternatives to MB.

In view of the substantive review provided in the MBTOC 2014 Assessment Report, this 2015 MBTOC Progress Report highlights the recent progress in the development and adoption of alternatives to MB mainly in the remaining sectors for which critical uses are requested: soils (strawberry fruits and runners, raspberries**,** tomato and ginger), commodities (dry cured pork) and structures plus any relevant developments with use of MB for QPS.

5.2. Chemical and non-chemical alternatives for soils, structures, commodities and QPS uses

5.2.1. General

- Technically and economically feasible chemical and non-chemical alternatives to MB have been found for virtually all previous soils, structures and commodities uses. A few cases have proven more difficult to replace (strawberry runners, ginger, raspberry nurseries and dry cured ham) especially where it comes to implementing alternatives at a commercial scale.
- By the end of 2013 (the last date for which officially reported information is available), about 99 % of the total consumption baseline for non-A5 Parties had been replaced with alternatives or recategorised to QPS. About 85 % of the total consumption baseline for A5 Parties had been replaced with alternatives, ahead of the January 2015 deadline.
- A recent survey, which was responded by about 20 Parties (largest remaining MB users), identified specific categories for QPS for which MB is presently used. MBTOC considers that there are technically and economically feasible alternatives for about 40% of such QPS applications, particularly in the largest usage sectors of timber and wood packaging materials, grain, and logs.

5.2.2 Soil sector

- The use of grafted plants (combined with other relevant treatments) has continued to increase as a MB alternative in tomato, eggplant, pepper and cucurbits in A5 and non-A5 countries (Kunwar *et al.* 2015; Penella *et al.*2015; Rysin and Louws, 2015, Silverman *et al*. 2014).
- The use of low-cost substrates for protected vegetables, strawberries, ginger and flowers has increased in both A5 and non-A5 countries, including for open field crops in certain situations. Soilless culture of ginger seed is widely used in Hawaii and it is considered a suitable alternative to MB (Kratky and Bernabe 2009).
- Anaerobic Soil Disinfestation (ASD) is receiving increasing attention as a potential alternative to MB in developed and developing countries for strawberry, vegetables and other

crops. This technology has been evaluated in diverse cropping systems, however still with variable results (Shennan *et al* 2014). More work is needed to evaluate factors influencing the effectiveness of ASD treatments and to adapt this procedure to diverse cropping systems and environments (Momma and Kobara 2014; Shesta *et al.* 2014).

- Biofumigation with materials such as palmarosa (*Cymbopogon martini*), lemon grass (*C. citratus*) and eucalyptus oils (*Eucalyptus globulus*) is being trialed for controlling *Ralstonia solanacearum* race 4 and reducing bacterial wilt disease of edible ginger (*Zingiber officinale*) (Paret *et al.* 2010).
- Recent research 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). The beneficial microorganisms identified and commercially used include both bacteria and fungi (Loganathan *et al*. 2014).
- Repeated biosolarisation treatments (mainly with chicken manure) are reported as effective for controlling *Macrophomina phaseolina* in soil and increasing yields of some crops to levels that were similar or higher than those previously reported for 1,3-D/Pic, a key alternative to MB (Chamoro *et al.* 2015).
- Integrated approaches continue to gain importance for managing root-knot nematodes. For example, applications of the bio-control agent *Pochonia chlamydosporia* in combination with crop rotation and organic amendments reduced the numbers of second-stage nematode juveniles on roots as well as the galling index, and resulted in increased yields (Nessie *et al.* 2015).
- In Europe, strawberry runner production for export continues to increase even though MB use has been banned for five years (Meszka and Malus, 2014; Wu *et al.* 2012).
- Co-formulations of 1,3-D and Pic are commonly used for preplant fumigation of high-value crops. Pic emissions were significantly lower when co-applied in this fashion than when used alone (Ashworth *et al.* 2015).

5.2.3 Structures and commodities sector

In the past year, the state of the art and new developments of technologies in this sector have mostly been reported in the recent International Working Conference on Stored Product Protection and some journal articles.

- **Phosphine adoption and resistance issues-:** 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 phosphine resistant stored product pests (Jagedeesan *et al*. 2015; Konemann *et al*. 2015).
- **Phosphine generators** are now more widely available commercially. The generated gas is most often conveyed in a stream of CO_2 as a fire suppressant and diluent. Some MLF funded MB phaseout projects implemented in A5 countries have trialled and demonstrated such generators, for example for treatment of stored bagged grain in Syria and of stored maize in silo bins in Kenya.
- A recent MLF funded project in Tunisia has used phosphine generators to control *Ephestia kuehniella* and *Ectomylois ceratoniae* attacking dates. An optimum rate of 3 g/m^3 was identified for use during 12h, 16h and 24h exposure times at respectively, 30°C, 25°C and 20°C, with a resulting mortality of 100%. These results confirm that phosphine can be considered an efficient alternative to MB for date disinfestation (Dhouibi *et al.* 2015, Dhouibi and Hammami, 2015).

- **Ethyl formate (EF)** was studied in Tunisia, as an alternative to methyl bromide (MB) for date fruit disinfestations. Date fruits 'Deglet Nour' with different initial moisture content (16% for dry dates, 20% for semi dry dates, and a mixture of the two types) were separately fumigated with EF at different concentrations: Experimental EF sorption during fumigation was evaluated using the Peleg's model. This model allows the prediction of the effects of date moisture content and EF concentration on sorption behavior. A 2-h fumigation with 114.6 g/m3 EF provided complete control of all the carob moth stages (*Ectomyelois ceratoniae*) (Bessi *et al*, 2015)
- **Ham mites**: Results of studies on the control of mold mites *Tyrophagus putrescentiae* have been updated; food-grade coatings and IPM offer encouraging results (Phillips *et al*. 2015; Schilling 2014).
- **Inert gases and hermetic storage**: The potential of inert gases, hermetic storage and reduced partial air pressure implemented within an integrated approach has gained wider interest and adoption (Chigoverah *et al.* 2015; Murdock 2015; Navarro 2015; Prasantha *et al*. 2015).
- **Museum pests:** The detection and control of museum pests with alternatives has been a focus of several recent publications: Strang 2015; Arthur and Kelly 2015; Mendez and Ryder 2015.
- **Biological control:** The 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 (Athanassiou2015; Thakur and Renuka, 2015).
- **Other fumigants and contact insecticides:** Additional research on fumigant alternatives to MB, have focused on the development of new phosphine treatments and 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 USA, given that with robust IPM in place, infested sites needing treatment within a mill can be specifically identified (Campbell *et al.* 2014).
- **Extreme temperatures:** Extreme temperatures are being adopted in various sectors for protection of stored product and materials against arthropod pests (Arlene-Christina *et al.* 2015; Loganathan *et al.*2015; Braunbeck 2015; Fields and Abdelghany 2015).
- **Scrubbing of fumigants:** Mueller *et al.* (2015) described the disposal and scrubbing of several fumigants.

5.2.4 QPS sector

- As reported previously, MBTOC believes that between 31 and 47% of the MB used for QPS purposes in key consumption categories (WPM, grain, logs and soil fumigation) could be phased out and replaced with immediately available alternatives.
- 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 9 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).

- 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).
- Indonesia has projects for replacing MB used for QPS (reported usage is >150 tons per year) with the phosphine + CO_2 mix known as $ECO_2FUME^{®}$. This is used to treat exported woodchips as well as coffee, cocoa beans and other exported commodities requiring QPS treatments (Tumambing 2013). Indonesia has developed a QPS phosphine fumigation protocol manual (Salazar, 2014).
- $ECO_2FUME^{®}$ has recently been registered in Morocco (ONSSA 2015) for grain fumigation.
- In Turkey, $ECO_2FUME^{®}$ efficacy trials have been conducted to establish QPS fumigation protocols for export cut flowers (carnation, gerbera and roses) against thrips (*Frankliniella occidentalis*) and mites (*Tetranychus cinnabarinus*) at 4°C.Trials with $ECO_2FUME^{®}$ for dried fruits have been also conducted to control saw-toothed grain beetle (*Oryzaephilus surinamensis*) and raisin moth (*Ephestia figulilella*), where100% mortality of all stages of these pests was achieved using 1000 ppm PH_3 (70 g $ECO_2FUME^{®}/m^3$) for 24 h at 23°C or higher (Salazar, 2014).
- In Korea, efficacy trials with$ECO_2FUME^{®}$ have been conducted to control eggs and adults of various insects on strawberries (1,100 ppm, 24 h, 2°C or 600 ppm, 24h, 10°C), cherry tomato (25 ppm, 24 h, 13°C), paprika (30 ppm, 24 h, 13°C), cut flowers (1,400 ppm, 24 h, 8°C) and nursery trees (1,400 ppm, 48 h, 15°C) (Salazar, 2014)
- A controlled atmosphere system that uses nitrogen to lower O_2 levels below 1% and is combined with high temperatures (38°C) is an efficient treatment used in Indonesia for commodities such as tobacco (exposure time 4 days), which can also be used on grains with good results. Forty-six similar facilities are reported in 18 countries (Mahmudi, 2014).
- Trials with EDN achieved 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).
- Three cold treatments for controlling *Bactrocera tryoni* for different citrus species and an irradiation treatment for mealybugs were adopted by the IPPC CPM (Commission of Phytosanitary Measures) during its 10th Session(end of 2014). These will be included in the appropriate ISPMs (International Standards of Phytosanitary Measures) and can replace MB in some instances (Willink 2015, personal communication)
- Ethyl formate (EF) has been categorised as a full control fumigant with action against citrus mealybugs, adults of the Californian red scale and all stages of Fuller's rose weevil within 6 h, at dose rates of 20 g/m^3, 61.8 g/m^3 and 60.1 g/m^3, respectively at 15°C and a fill rate of 40%. Eucalyptus weevils attacking Pink Lady apples did not survive a 24 h treatment with 30g/m^3 of EF at 25°C or 50 g/m^3 at 4-8°C (Agarwal *et al.* 2015).
- Sulfuryl fluoride was subject of investigations as a suitable quarantine treatment fumigant against the khapra beetle *Trogoderma granarium* (Myers and Ghinmire, 2014).

5.2.5Critical uses

- Of over 140 nominations submitted for critical use of over 18,000 tonnes by non-Article 5 Parties for 2005, only three remain for less than 300 tonnes in 2016.
- In 2014, six critical use nominations were received and approved for use of MB in 2015 by the Parties at the MOP. This year eight nominations were received for use in 2016. CUE's are

now possible for A5 Parties since the phase-out deadline of January 1st 2015 has now passed, however nominations have to meet the specific criteria established under Decision IX/6.

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6 Medical Technical Options Committee Progress Report (MTOC)

The MTOC 2014 Assessment Report has been published and is accessible at the Ozone Secretariat website: http://ozone.unep.org/Assessment_Panels/TEAP/Reports/MTOC/MTOC-Assessment-Report-2014.pdf. The assessment presents recent progress in the phase-out of ODS used in medical uses such as MDIs, medical aerosols and sterilants, and the technical and economic assessment of alternatives.

The global phase-out of CFCs in the manufacture of MDIs is imminent with only one essential use exemption authorized by Parties, for China for 217 tonnes CFCs in 2015. This exempted quantity represents less than 3 percent of the annual maximum of CFCs used in MDIs under essential use exemptions, which was nearly 9,000 tonnes in 1997. No nominations were received for 2016, and it appears likely that 2015 will be the final year of essential use exemptions for CFCs for MDIs. The transition away from CFC MDIs to CFC-free alternatives is illustrated in the following Figure 6-1, which charts the trajectory of inhaled medicine from before the marketing approval of the first salbutamol HFC MDI in September 1996 until now.

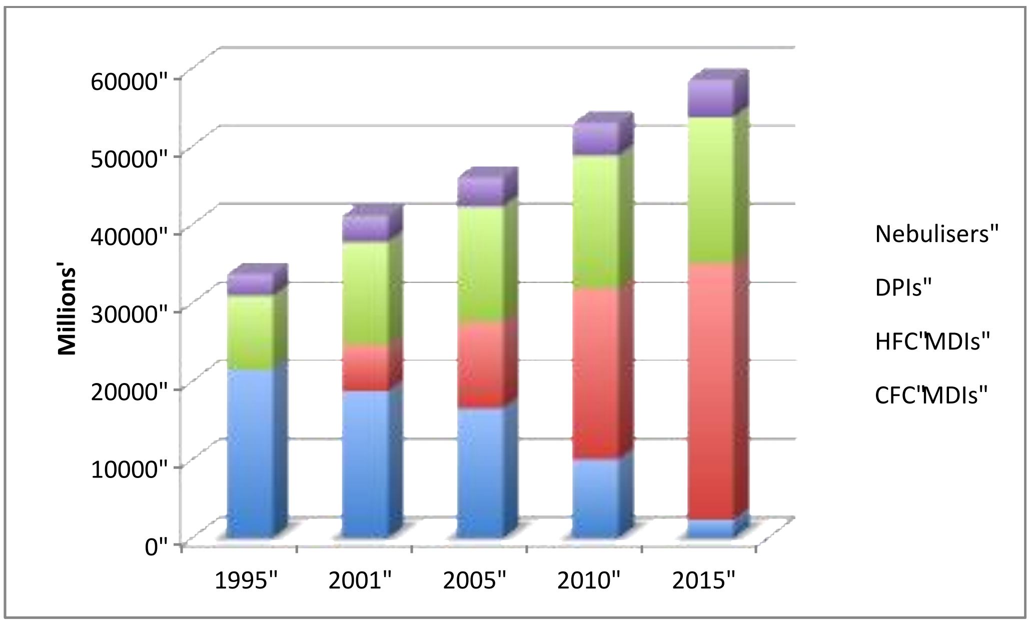

Figure 6-1. Transition from CFC MDIs to CFC-free alternatives according to the estimated number of doses of inhaled medicines, 1995-2015[1]

6.1. Reporting Accounting Frameworks for Essential Use Exemptions

MTOC has reviewed reporting accounting frameworks submitted by Parties for essential use exemptions of CFCs for the manufacture of metered dose inhalers (MDIs).

[1] Figure 6-1 is compiled from an analysis of a range of data sources including Assessment Reports of the ATOC and MTOC from 2002, 2006, 2010, 2014, and IMS Health market data of global inhaler usage from 2007-2012, data which was provided previously by IPAC with the permission of IMS MIDAS

Relevant to reporting accounting frameworks for essential use exemptions is Decision VIII/9(9), which states, "*To approve the format for reporting quantities and uses of ozone-depleting substances produced and consumed for essential uses as set out in annex IV to the report of the Eighth Meeting of the Parties and beginning in 1998 to request each of the Parties that have had essential-use exemptions granted for previous years, to submit their report in the approved format by 31 January of each year*".

MTOC understood this decision to mean that, from 1998 onwards, in each year by 31 January, Parties that had essential use exemptions granted in previous years would submit an accounting framework. When CFCs produced/imported and accumulated under essential use exemptions were consumed and reached zero, annual submission of reporting accounting frameworks would no longer be necessary. Each year, the Ozone Secretariat has made requests of Parties with essential use exemptions to report accounting frameworks pursuant to Decision VIII/9(9) and have forwarded such reports to MTOC to enable a review and reporting of this information to Parties in TEAP's Progress Report.

In practice, some Parties with essential use exemptions and on-going MDI manufacture have not submitted accounting frameworks on January 31 each year. This has made it increasingly difficult for MTOC to report to Parties on the status of CFCs authorised by Parties for production under the Montreal Protocol's essential use exemptions. CFCs produced under authorised essential use exemptions have the potential to be used in end-uses for which CFC production was neither authorised nor considered essential under the Montreal Protocol and were subjected generally to the control measures that phased out CFC production in 1996.

The Ozone Secretariat has informed MTOC that the way in which the Implementation Committee under the Non-Compliance Procedure had been dealing with accounting frameworks was that Parties with essential use exemptions would submit accounting frameworks by 31 January for the preceding year for which they had an exemption approved. Thus, even if a Party reported that there was an amount left over at the end of the year, if that Party was no longer nominating for exemptions, it was considered that the accounting framework was not "legally" required. The Secretariat has therefore only been requesting such Parties to report, without being able to quote a legal basis for doing so.

Having information on stockpiles, accumulated under CFC essential use exemptions granted by Parties for previous years, allows Parties to track the management and deployment of CFCs produced under authorised essential use exemptions until exhausted. Information on stockpiles is particularly important in the last stages of global CFC MDI phase-out and can be valuable in avoiding new production.

The following section describes the information provided in those reporting accounting frameworks submitted by Parties relevant to authorised essential use exemptions for 2014. This section also provides updates on Parties with authorised essential use exemptions in previous years that have or have not reported accounting frameworks.

6.1.1. Argentina

Argentina originally expected to nominate essential CFC uses until 2014. However, the transition proceeded faster than expected, with the result that Parties last authorised an essential use exemption in 2011; Argentina has not made any essential use nominations since. Argentina's accounting framework for 2012 showed CFC stocks on hand at the end of 2012 of about 5 tonnes. Argentina has not submitted an accounting framework in subsequent years.

All the companies except one in Argentina opted for technologies using HFC-134a as the excipient. Laboratorio Pablo Cassará initially converted its salbutamol MDI production to HFCs, but is implementing an MLF project to use iso-butane as the propellant. MTOC understands that Laboratorio Pablo Cassará plans to launch a salbutamol iso-butane MDI in 2016.

6.1.2. China

Parties authorised an essential use exemption of 235.05 tonnes of CFCs for the manufacture of MDIs in China for 2014. An accounting framework for 2014 was received from China in late May 2015. At the end of 2013, China reported a stockpile of 476.60 tonnes of CFCs, a year in which it produced no CFCs, and sourced its CFCs for MDI manufacture (with a total use of 165.16 tonnes CFCs) out of its existing stockpile. In 2014, China produced 176.67 tonnes CFCs, of which 106 tonnes was originally produced and intended for export to the Russian Federation under its essential use exemption but were not exported owing to administrative issues with the Russian importer. China used only 137.37 tonnes CFCs for domestic MDI manufacture, which was less than the tonnage of CFCs used in 2013 for MDI manufacture in China. At the end of 2014, China's CFCs on hand had increased to 515.9 tonnes (including 106 tonnes CFCs intended for the Russian Federation), compared with the total of 476.6 tonnes of CFCs on hand at the start of 2014. Given consumption trends, the CFCs on hand at the end of 2014 reported by China are equivalent to 4 years strategic reserve (2015-2018).

The actual consumption trend differs from China's projections when nominating CFCs for MDI manufacture for 2015, when this nomination stated that "*Demand is expected to grow for CFC MDIs in 2014 and 2015 due to an increased emphasis on inhaled therapy*". Demand in 2014 declined, and was less than the CFC quantity authorized by Parties for China for 2015 (182.62 tonnes), and continuing a previous downward trend.

China has stated that 2015 will be the last year in which there will 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. 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. After 2015, CFC demand for MDI manufacture will decline rapidly in China. Given reported and projected trends in CFC manufacturing, the stockpile of 515.9 tonnes appears to exceed significantly the overall essential use requirements in 2015 through to the completed phase-out. This arises in part because CFCs were produced in China for export to the Russian Federation that will now not be exported.

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.*"

In 2014, China produced more CFCs than were used in that year for MDI manufacture and therefore added to a substantial stockpile. Given that the CFC stockpile reportedly on hand at the end of 2014 is nearly enough for four years when only two more years of CFC MDI manufacture is planned under China's own phase-out strategy, new CFC production under China's authorized essential use exemption appears unnecessary in 2015. The quantity of CFCs in the current stockpile may lead to:

- CFC MDIs being manufactured and supplied for longer than is projected by China's agreed 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.

6.1.3. Egypt

Parties authorised an essential use exemption of 227.4 tonnes of CFCs for the manufacture of MDIs in Egypt for 2010. Egypt has not made any essential use nomination since 2010. No accounting framework was reported for authorised essential uses in 2010. However, in Egypt's Country Programme Report for 2010, Egypt reported that it imported and used 172.49 tonnes CFCs for MDI manufacture. MTOC understands that Egypt had been manufacturing CFC MDIs until third quarter 2011 using the existing CFC stockpile, and that the CFC MDI manufacturing conversion to CFC-free alternatives was completed by the end of 2011. MTOC understands that CFC stockpiles have been depleted.

6.1.4. European Union

The European Union has not had any authorised essential use exemptions since 2009. An accounting framework was received from the European Union in 2014 showing that it had completely depleted its CFC stockpile at the end of 2013. During 2013, Italy ceased using CFCs to manufacture a combination inhaler containing salbutamol sulphate and ipratropium bromide sold into that market. CFCs used by an Italian company in the manufacturing process for valves supplied to CFC MDI manufacturers also ceased during 2013. This indicated that those countries historically receiving MDI valves from the Italian manufacturer (Egypt, Pakistan, Russian Federation and Syria) would no longer be supplied with those valves.

6.1.5. India

Accounting frameworks on available stockpiles have not been received from India since 2011. In 2011, India reported CFC stocks of 226.295 tonnes, including 24.402 tonnes of non-pharmaceutical grade CFCs manufactured during start-up of CFC manufacturing. It is understood that India has converted its MDI manufacturing to be CFC-free. There is no information available on remaining CFC stockpiles in India. India has a wide range of CFC-free inhalers, including dry powder in a variety of devices.

6.1.6. Mexico

Parties authorised an emergency essential use of 6 tonnes CFCs for the manufacture of MDIs in Mexico in 2011 under an arrangement where Mexico agreed to destroy an equivalent ODP weighted amount of ODS. Mexico originally planned to destroy CFC-11 to compensate the emergency essential use acquired by import. Mexico has now completed conversion of CFC MDI manufacturing to CFC-free MDIs. Last year, MTOC reported that 18 tonnes of remaining stocks of mixed CFC-11, -12, and -114 would be destroyed or deployed for essential use. A local producer, Laboratorios Salus, had about 15 tonnes of out of specification CFC stockpile remaining, which was intended for destruction, and a small additional amount that might have been suitable for MDI production but was to be destroyed if necessary.

6.1.7. Pakistan

Parties authorised an essential use exemption of 24.1 tonnes of CFCs for the manufacture of MDIs in Pakistan for 2012. In its accounting framework for 2012, Pakistan reported 12 tonnes of CFCs in stockpile at the end of the year. No further accounting frameworks have been received from Pakistan.

One company, Mactor, is producing HFC MDIs locally in Pakistan. GSK Pakistan is in the testing phase for a locally produced salbutamol HFC MDI; it currently imports a more expensive salbutamol HFC MDI from GSK Australia. Zafa, despite having successfully applied to receive funding, is not proceeding with plant conversion.

Until the end of 2013, Pakistan was also receiving imported CFC MDIs manufactured in China, which made up to 70 per cent of unit sales. Regulatory authorities banned the import of CFC MDIs, as of December 2012. Highnoon Laboratories is importing HFC MDIs from Cipla India, and GETZ pharma is importing HFC MDIs from China. Chiesi also imports HFC MDIs from Europe, which are priced higher than locally manufactured or Chinese imported HFC MDI brands.

Imported DPIs are currently used by about 20 per cent of asthma and COPD patients, having been only 9 per cent one year previously. Single-dose DPIs imported by Highnoon Laboratories from Cipla India are more immediately affordable for patients because they contain fewer doses than pressurised MDIs. Macter has also launched a DPI for tiotropium.

6.1.8. Russian Federation

The Russian Federation has not submitted any nominations since 2013, in line with its announcement that its nomination for 2014 would be its last. The Russian Federation provided an accounting framework for 2014. The Russian Federation imported 106 tonnes CFCs from China in 2014, out of a total of 212 tonnes authorised by Parties under its essential use exemption. It reported 69.2 tonnes stockpile of CFCs 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.

Russia is in the final stages of manufacturing conversion to HFC MDIs, with completion likely in 2015. The filling equipment to produce HFC MDIs under the project sponsored by GEF, and implemented by UNIDO, was planned for delivery in November 2014. A full range of affordable imported CFC-free inhalers is available to Russian patients. With the possible completion of CFC MDI manufacturing in the Russian Federation, remaining CFC stockpiles will need to be destroyed.

6.1.9. Syria

Parties authorised an essential use exemption of 44.68 tonnes of CFCs for the manufacture of MDIs in Syria for 2010. However, no accounting framework was reported for authorised essential uses in 2010 or subsequently. Syria has not made any essential use nomination since 2010. Local manufacturers were investing in HFC MDI manufacturing facilities since 2011. MTOC understands that Syria had been importing valves to manufacture CFC MDIs. The Italian valve manufacturer ceased production during 2013.

6.1.10. United States

The United States has phased out CFC MDIs, with a wide range of CFC-free alternatives on the market. Under a US FDA rulemaking, the last CFC MDIs became non-essential on December 31, 2013. Primatene Mist, an over-the-counter CFC MDI for epinephrine, was withdrawn from sale in August 2013. On safety grounds, an epinephrine HFC MDI was not recommended for over-the-counter marketing by an FDA advisory committee in February 2014, and FDA has not approved epinephrine HFC MDI for prescription or over-the-counter marketing.

There were two separate types of CFC stockpile in the United States, one held by the MDI manufacturers, and one by the CFC manufacturer Honeywell on behalf of Boehringer Ingelheim. Some of the CFC surplus was manufactured pre-1996. For the MDI manufacturers, the United States previously reported a stockpile of 169 tonnes at the end of 2010, which was being run down in order to manufacture CFC MDIs. In 2013, the United States reported a stockpile of 280 tonnes of pharmaceutical-grade CFCs (owned by Boehringer Ingelheim and Honeywell). This was initially made available for export to Parties with approved essential-use exemptions, but this did not occur. MTOC understands from industry sources that about 160 tonnes of the CFC stockpile has been transferred for ultimate destruction.

7 Refrigeration, Air Conditioning and Heat Pumps TOC (RTOC)

Since the publication of the XXV/5 TEAP Task Force report in October 2014 and particularly the 2014 RTOC Assessment report in February 2015 (http://ozone.unep.org/Assessment_Panels/TEAP/Reports/RTOC/RTOC-Assessment-Report-2014.pdf) the options for replacing ODS and high GWP refrigerants have not changed. However, new information related to these options has been obtained through assessments of several additional reports and publications and the documents from the "2015 Workshop on Management of Hydrofluorocarbons (HFCs)"[2]. This new information is also presented in more detailed form in the XXVI/9 TEAP Task Force report, published the first part of June 2015. New information regarding the main refrigerants applications is presented in Table 7-1 (copied from Table 4-1 in the TEAP XXVI/9 Task Force Report) at the end of this chapter.

In summary, the following can be highlighted for the various R/AC subsectors:

7.1 Domestic appliances

Refrigerant migration from HFC-134a to HC-600a is expected to continue, driven either by local or regional regulations on HFCs or by the desire for reduced global warming impact from potential emissions, which is a driver for all the sub-sectors. Excluding any influence from regulatory interventions, it is projected that by 2020 about 75% of new refrigerator production will use HC-600a (possibly with a small share of unsaturated HFC refrigerant – HFOs, the HFC-1234 yf).

7.2 Commercial refrigeration

The commercial refrigeration sub-sector consists of three groups of equipment that are presented below.

7.2.1. Stand-alone Equipment

For this type of equipment, HFC-134a and R-404A can be expected to be phased-out progressively in developed countries. Lower GWP HFC (HFOs) and HFC blends, hydrocarbons such as HC-290, and R-744 are replacing R-404A and HFC-134a in new stand-alone equipment. Some plug-in units such as bottle coolers and vending machines are using R-744.

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[2] The "Workshop on Management of Hydrofluorocarbons (HFCs)" was convened in accordance with decision XXVI/9 and it was held in Bangkok, 20 and 21 April 2015. The workshop included issues in relation to HFC management, incorporating a focus on high-ambient temperature and safety requirements, as well as energy efficiency. The workshop involved wide participation of technical experts and industries as overview speakers, panellists. The sessions included all the relevant market and industry sectors and sub-sectors and all regions with a specific focus on high-ambient temperature conditions, where relevant. Fact sheets were developed for the refrigeration and air conditioning applications and were presented and discussed in the workshop. The panellists have been drawn from the "technology providers" and "implementers of technologies" groups from around the world, from both non-Article 5 and Article 5 countries.

7.2.2. Condensing Units

For new systems, R-404A is still the leading choice, and intermediate blends such as R-407A or R-407F are proposed as immediate options to replace this refrigerant. Global companies are now offering hydrocarbon based condensing units for smaller capacities. One can also expect lower GWP HFC and HFC blends and R-744 to grow in acceptance in this application in the future, where it should be mentioned that capital costs for small condensing units using R-744 are currently quite high.

7.2.3. Supermarket systems

Several thousands of supermarkets are already using R-744 systems, in both transcritical and cascade configurations. For supermarkets at low to medium ambient temperatures, the so-called "booster system" has been designed to use R-744 at the low and medium temperature level. For supermarkets at medium to high ambient temperature level, the cascade system is preferred with R-744 at the low temperature level and R-744 or HFC-134a at the medium temperature level. The efficiency of transcritical systems is very high in cold ambient conditions and new developments allow efficient operation in higher temperature conditions. In hot ambient conditions a cascade system is still more efficient. Capital costs were originally higher than those of HFC systems but are now decreasing. R-744 systems still require efficiency enhancements to achieve a competitive seasonal efficiency in hot climates.

Considering the amount of refrigerant charge, flammable or toxic refrigerants are not an option for supermarkets, but small plug-in HC-290 units cooled by a water circuit are used in some types of supermarkets. Non-flammable lower GWP HFCs can be an option for centralized systems.

Blends such as R-407A or R-407F as well as lower GWP HFC and HFC blends constitute options for retrofit and/or for new installations, because they offer an immediate possibility for a significantly lower GWP than R-404A and R-507A. Moderate and low GWP HFCs, HFCs/unsaturated HFCs (HFOs) blends and unsaturated HFCs (HFOs) have been recently introduced, but commercial experience is limited.

7.3. Industrial systems

The majority of large industrial systems use R-717 as the refrigerant. When R-717 is not acceptable in direct systems in these countries, options include R-744 or glycol in secondary systems or HCFCs or HFCs in direct systems. In countries where R-717 has not been the preferred solution, or in market segments with smaller systems, the transition from HCFC-22 has not been straightforward.

7.4. Transport refrigeration

Lower GWP HFC blends are likely to play a role as a replacement to R-404A, and HFC-134a systems: their GWP is significantly lower than R-404A and performances are relatively close. Candidates include but are not limited to R-407A, R-407F, R-448A, R-449A, R-450A, and R-452A.

R-744 has been field-tested since 2011. Its non-flammable characteristics make R-744 an attractive option, but the gap in efficiency at high ambient temperatures and the limited component supply base are limiting its market penetration. One also sees "non-conventional" solutions such as open loop systems or eutectic systems.

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

A wide range of different low GWP alternatives is described in the RTOC 2014 Assessment Report. Some of these alternatives are already becoming commercially established in certain countries, while others are in an earlier stage of development. There is currently less availability of lower GWP alternatives in Article 5 countries, although this is likely to change significantly during the next few years as technologies used in non-Article 5 countries will become more widely available.

Except for R-744, all of the medium and low GWP alternatives are flammable and should be applied in accordance with appropriate regulations and/or safety standards (that are continuously under development), considering refrigerant charge amount, risk measures and other special construction requirements. Some safety standards limit the quantity of the system of any refrigerant within occupied spaces.

HC-290 and HC-1270 are mainly considered for systems with smaller charge sizes. Split air conditioning systems using HC-290 have been available in Europe and Australia, are in production in India and certain HCFC-22 equipment production capacity is being converted to HC-290 in China (however, with limited output at present). R-744 is considered to have limited applicability for air conditioning appliances, due to the reduced efficiency when the ambient temperature approaches or exceeds about 30°C.

HFC-161 is currently under evaluation for systems with smaller charge sizes due to flammability. The operating pressure and capacity is similar to HCFC-22 and the efficiency is at least as high as HCFC-22, although there is concern over its stability.

HFC-32 is currently on the market for various types of air conditioners and has recently been applied in split units in several countries and some OEMs are also considering it for other types of systems. Its operating pressure and capacity are similar to R-410A and its efficiency is similar or better than that of R-410A.

There are various proprietary mixtures targeted for air conditioning applications, which comprise, amongst others, HFC-32, HFC-125, HFC-134a, HFC-152a, HFC-161, HFC-1234yf, HFC-1234ze, HC-600a, HC-600, H-1270 and HC-290. Some mixtures have been assigned R-numbers, such as R-444B, R-446A and R-447A, whilst most are still under development. These mixtures tend to have operating pressures and capacities similar to HCFC-22 or R-410A, with GWPs ranging from 150 to around 1000 and flammability class 1 (for higher GWPs) and class 2L (medium GWPs). Currently, most of these mixtures are not commercially available on a broad scale and adequate technical data is not yet in the public domain.

7.6. Water heating heat pumps

HCFC-22 replacements such as HFC-32 and other low-GWP HFC blends are becoming commercially available.

7.7. Chillers

Major efforts have been launched to propose and test new, lower GWP refrigerants. A number of candidates have been proposed and are in the early stages of testing as possible replacements for higher-GWP HFCs.

The new candidates generally are unsaturated HFCs or blends, which may contain HFCs, HCs, and/or unsaturated HFCs. Options for new equipment include: R-717, R-744, HC-290, HC-1270, HFC-1234ze(E), HCFC-1233zd(E), HFC-1336mzz(Z), HFC-32, R-444B, R-446A, R-447A, and R-450A.

District cooling could provide a high efficiency solution that would avoid the installation of multiple pieces of small equipment. Whilst it was agreed that such systems might be applicable under certain circumstances (e.g. when a major property development was being planned) it was not likely to be a solution for the majority of small systems.

7.8. Vehicle air conditioning

The increasingly rapid evolution of hybrid electric vehicles and electric vehicles with reversible air conditioning and heat pump cycles, which use semi hermetic electrically driven compressors introduces new challenges for any new alternative refrigerant.

It looks likely that more than one refrigerant will be used in the coming years for car and light truck air conditioning: HFC-134a will remain largely adopted worldwide, HFC-1234yf will continue its growth in the near future. At the end of 2014, three million cars are stated to be on the road using HFC-1234yf. R-744 is expected to be implemented on a commercial scale in certain regions by 2017. For large MAC systems using R-744 as an alternate refrigerant, ejector systems should be used to enhance the performance of the system at high ambient temperatures.

A few OEMs and suppliers have investigated hydrocarbons (HC-290, HC-600a) for direct expansion and HFC-152a in a secondary loop. These can provide good thermal performance, but car manufacturers are not willing to apply these, due to flammability concerns.

A few other new refrigerant mixtures for MACs have been developed (e.g. R-445A, GWP=120). Some OEMs and suppliers have conducted extensive testing with R-445A for performance, material compatibility, flammability and risk assessment. For electric vehicles and hybrid vehicles heat pump systems are needed for passenger heating - both R-744 and R-445A have shown good performance in heat pump mode.

Table 7-1. Application of ODS alternatives in the refrigeration and air conditioning sub-sectors

GWP	0	<1	<1	1	1	2	1 – 5	4	4	89	120	290	300	460
	R-717	HFC-1234yf	HFC-1234ze(E)	R-744	HCFC-1233zd(E)	HFC-1336mzz(Z)	HC-290, HC-1270	HC-600a	HFC-161	R-444A	R-445A	"L-40"	R-444B	R-446A
Domestic refrigeration		F						C						
Commercial refrigeration														
— Stand alone equipment		L	F	C			C	C				F	F	F
— Condensing units		F		L			L	F				F	F	F
— Centralised systems	L	F		C			L					F	F	F
Transport refrigeration		F		C			C					F	F	F
Large size refrigeration	C	F		C			L					F	F	F
Air conds and heat pumps														
— Small self contained		F		L			C		F				F	F
— Mini-split (non-ducted)				L			C		F				F	L
— Multi-split				L									F	L
— Split (ducted)				F			F						F	F
— Ducted split comm. &				F			L						F	F
— Hot water heating HPs	C	F	F	C			C	C				F	F	F
— Space heating HPs	C	F	F	L			C	L				F	F	F
Chillers														
— Positive displacement	C	L	L	C			C					F	F	L
— Centrifugal		L	L		L	F	L							
Mobile air conditioning														
— Cars		C		F			F	F		F	F			
— Public transport		L		F						F	F			

GWP	490	550	570	570	677	1300	1300	1370	1600	1820	1900	1900	2100	3900
	"DR-5"	R-450A	R-447A	R-513A	HFC-32	R-448A	R-449A	HFC-134a	R-407C	R-407F	R-452A	R-410A	R-407A	R-404A
Domestic refrigeration		F		F				C						
Commercial refrigeration														
— Stand alone equipment	F	F	F	F	F	L	F	C	F	F		F	F	C
— Condensing units	F	F	F	F	F	L	F	C	F	F		F	F	C
— Centralised systems	F	F	F	L	F	L	F	C	F	C		F	C	C
Transport refrigeration	F	F	F	F	F	F	F	C	F	F	F	C	F	C
Large size refrigeration	F	F	F	F	F	F	F	F	C	C		C	C	C
Air conds and heat pumps														
— Small self contained	F	F	F	F	L	F	F	C	C	F		C	F	F
— Mini-split (non-ducted)	F	F	L	F	C	F	F	F	C	F		C	F	F
— Multi-split	F	F	L	F	L	F	F	F	C	F		C	F	F
— Split (ducted)	F	F	F	F	L	F	F	F	C	F		C	F	F
— Ducted split comm. & non-	F	F	F	F	L	F	F	C	C	F		C	F	F
— Hot water heating HPs	F	F	F	F	L	F	F	C	C	F		C	F	F
— Space heating HPs	F	F	F	F	L	F	F	C	C	F		C	F	C
Chillers														
— Positive displacement	F	L	L	L	L	F	F	C	C	F		C	F	C
— Centrifugal								C						
Mobile air conditioning														
— Cars		F		F				C						
— Public transport		F		F				C	C			C		

C = Current use on a commercial scale. L = Limited use such as for demonstration trials, niche applications etc. F = use is potentially feasible, based on fluid characteristics

8 Response to Decision XXVI/7: Availability of recovered, recycled or reclaimed halons

Executive Summary

- Even though aviation applications of halon are among the most demanding uses, requiring suppression effectiveness at an acceptable toxicity level, civil aviation has not placed a high level priority on replacing halons. It is a disappointing fact that alternatives are used only in the lavatory fire extinguishing systems of in-production aircraft. It is especially disappointing given the research and testing efforts on aviation applications since 1993.

- The status of the alternatives in the various civil aviation applications of halons is as follows:

  - For lavatory trash receptacle systems, there are suitable alternative fire suppression systems (using HFC-227ea or HFC-236fa) available that meet the criteria for space, weight and toxicity, and cost the same or less than the halon 1301 systems being replaced. Reportedly, almost all new production aircraft are now installed with non-halon systems, and some airlines are retrofitting aircraft to these new systems during scheduled maintenance.

  - HFC-125 has been used successfully as an alternative to halon 1301 for engine nacelle fire protection on U.S. military aircraft developed since the early 1990s, and more recently HFC-125 is currently being developed for use on a U.S. military derivative of a large commercial aircraft. Owing to increased space and weight and its high Global warming Potential (GWP), civil aircraft airframe manufacturers have chosen not to pursue qualification and installation certification for HFC-125 in engines/auxiliary power units (APUs) of civil aircraft. The civil aviation industry has initiated a joint approach to identify a single agent for this application.

  - For halon 1301 systems in cargo compartments, testing of halocarbon agents has shown that they are not technically or economically feasible owing to the space and weight requirements of maintaining the necessary high concentrations of these agents. Commercial development of a water mist/nitrogen cargo fire suppression system is in the early stages, and industry has initiated a joint industry approach to finding an alternative for this application.

  - For halon 1211 in handheld extinguishers, three agents have passed the required testing and are commercially available. However, they have increased space and weight characteristics and some environmental concerns, so airframe manufacturers have chosen not to pursue qualification and installation certification for them. A new agent 2-BTP is currently under review with less space, weight and environmental concerns.

  - For halon 1211 used in some Aircraft Rescue and Fire Fighting (ARFF) or Crash Rescue Vehicles on airport ramps, one low-Ozone Depletion Potential (ODP) and low-GWP HCFC blend has proven to be an effective replacement.

- The estimated 2014 global halon 1301 bank is 41,500 metric tonnes while the estimated 2014 halon 1211 bank is 27,500 metric tonnes. However, there is likely to be a significant difference between the amount of halon that is estimated to exist, and the amount that could become available for civil aviation.

- At present, the halon demands of civil aviation are being met by recycling agent withdrawn from applications in other industries. This source of supply will be dramatically reduced, and may even be exhausted long before the aircraft now being built and fitted with halon systems are retired.

- The total amount of halon 1301 assumed to be available to meet aviation demands would come from commercial aviation stockpiles, computer/telecommunication facilities, and merchant shipping. It is estimated that the total amount of halon 1301 from these sources that could potentially come available to support civil aviation is 15,635 metric tonnes.

- Based on the potential amount of halon 1301 from ship breaking, those annual amounts could be sufficient to cover civil aviation needs until that source runs out - between 2023 and 2033. This assumes that all of the halon 1301 is fully recovered from shipbuilding and that all of it would be dedicated to civil aviation, both of which are likely not true today and, without significant effort, will not be true in the future.

- Scenarios modelling that estimate 1) the availability of halon 1301 to service the existing aviation fleet, 2) account for aviation growth through 2050, and 3) service existing non-aviation applications, provide that in the worst-case scenario, halon 1301 supplies for civil aviation would run out in 2036 and for the best-case scenario, would run out in 2045.

- While this may seem far out into the future, the reality is that civil aircraft have a 30+ year lifetime. Therefore, for aircraft that have been manufactured since 2009 there is not enough halon 1301 projected to be available to support them throughout their economic lifetime in the worst-case scenario. However, even in the best-case scenario, halon will only be available to support aircraft over their entire lifetime that are produced up until this year (i.e., 2015).

- As the supply of halons gets further reduced, the likelihood of a significant disruption in supply increases dramatically. If civil aviation does not stop producing new aircraft using halon 1301, they are already or soon will be producing aircraft that cannot be sustained over their economic lifetimes from existing supplies of recycled halon 1301. This may already be the case.

- Of all the halon use sectors, civil aviation is the least prepared to deal with diminishing halon supplies and, with the ultimate exhaustion of supplies, this sector will most likely be the one to request an Essential Use Nomination for production of new halon in the future.

8.1. Mandate and scope of the report

Decision XXVI/7 on the availability of recovered, recycled or reclaimed halons requests the Technology and Economic Assessment Panel, through its Halons Technical Options Committee:

(a) To continue to liaise with the International Civil Aviation Organisation to facilitate the transition to halon alternatives, to approach the International Maritime Organisation 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;

The full text of the decision is available in Annex 3 of this Report.

In response to the Decision XXVI/7, the co-chairs of the Halons Technical Options Committee (HTOC) assigned the effort to a working group amongst its members, with the addition of a co-chair of Technology and Economic Panel (TEAP) who previously served as a member of the HTOC.

Work was conducted initially by electronic communication, and several members were able to meet face-to-face in Bangkok on the margins of the TEAP and Open-ended Working Group (OEWG)-35 meetings, held 16-19 April, 2015 and 22-24, 2015, respectively, in Bangkok, Thailand.

The rest of this chapter is organised as follows:

Section 8. 2 - Background

Section 8. 3 – Status of Currently Available Alternatives to Halons for Civil Aviation

Section 8.4 – Estimated Civil Aviation Halon Installed Base

Section 8.5 – Estimates of Global Quantities of Halons

Section 8.6 - Halon Needs for Civil Aviation

Annex 3 - Decision XXVI/7: Availability of recovered, recycled or reclaimed halons

8.2. Background

8.2.1. The Montreal Protocol and the Phase-Out of Halons

The Montreal Protocol calls for the phase out of production and consumption of nearly 100 chemicals, including halons. In accordance with Protocol adjustments, production of halons in the United States and other developed countries ceased at the end of 1993 and halon production ceased in developing countries at the end of 2009. Although new production has been phased out globally since 2009, the Protocol allows the Parties to use and trade in previously used halons. To date, global supplies of previously used halons have been sufficient to supply residual important uses, including the use of halons in aviation.

Over the last two decades, the Halons Technical Options Committee (HTOC) has tracked the efforts that the Parties and their respective users have made in transitioning away from the use of halons. One area of continuing concern, however, has been the continued reliance on halons by the civil aviation community. Halon is used in four major aircraft on-board applications: lavatory trash receptacles, hand-held extinguishers, engine nacelles/auxiliary power units (APUs), and cargo compartments. In addition to on-board aircraft applications, halon is also used in some aircraft rescue and fire fighting (ARFF) or crash rescue vehicles on airport ramps. The Parties through a number of decisions under the Protocol have requested the Ozone Secretariat as well as the HTOC to work with the International Civil Aviation Organisation (ICAO) on the transition to alternatives to halons for aviation uses. Towards that end, the HTOC worked for several years with the ICAO Secretariat and ICAO stakeholders through the ICAO Halons Working Group. After several years of discussion, that group agreed that proposed timelines for halon replacement should be incorporated into ICAO Standards and Recommended Practices (SARPs), and ultimately be adopted by States in their national frameworks.

8.2.2. ICAO Assembly Resolutions and EU Regulations on Halon Replacement

Formed in 1944 with the signing of the Convention on International Civil Aviation (the "Chicago Convention"), ICAO's mission is to promote the safe and orderly development of all aspects of international civil aeronautics, and provides the forum for issues affecting civil aviation to be discussed. It is headquartered in Montreal, Canada, with seven regional offices throughout the world. At present, the Organisation is comprised of 191 Contracting States.

In collaboration with Contracting States and industry, ICAO first introduced proposed actions for the international aviation community regarding halon replacement in 2007 at the 36th ICAO Assembly. This was done with the strong support of the U.S., which presented several formal working papers endorsing collaboration and cooperation throughout the aviation community to affect the transition beyond halon reliance. This resulted in a series of Assembly Resolutions from the past three ICAO Assemblies directing specific action to the ICAO Council based on the progress of developing and identifying halon replacements and implementing such replacements into aircraft fire suppression systems.

ICAO Resolution A37-9, adopted at the 37th Assembly in September 2010, mandates halon replacement in ICAO standards in lavatory trash receptacle fire extinguishing systems used in aircraft produced after December 30, 2011; in handheld extinguishers used in aircraft produced after December 30, 2016; and in engine and auxiliary power unit fire extinguishing systems used in aircraft for which application for type certification will be submitted after December 30, 2014. However, these are not requirements that States must follow. Instead, States including the U.S. can and have filed "differences" indicating that they will not meet these standards and will continue to use halons or allow the use of halons past these dates. On the basis of this decision, ICAO adopted amendments to the international SARPs in two Annexes of the Chicago Convention. Annex 6 ("Operation of Aircraft") and Annex 8 ("Airworthiness of Aircraft") were amended to include the related dates and requirements for halon replacements for lavatory trash receptacle, hand held, and engine and auxiliary fire extinguishing fire suppression systems. None of these requirements calls for the retrofit of any halon systems in the current fleet. A timeline for the replacement of halon in cargo compartments for new design aircraft is expected to be proposed and considered for adoption at the 39th ICAO Assembly in September 2016.

Within the European Union, all current on-board uses of halons in aviation are listed as critical uses in the current Annex VI to Regulation (EC) No. 1005/2009. Annex VI was revised in 2010 as per Commission Regulation (EU) No 744/2010 of 18 August 2010 and contains "cut-off dates" for the use of halons in new designs of equipment or facilities and "end dates" when all halon systems or extinguishers in a particular application must be decommissioned. Other States have proposed or are considering regulations.

Table 8-1 below outlines a listing of international requirements for both new design and new production aircraft. This listing includes cutoff dates and end dates for halon use in civil aviation as directed by the EU and specified dates in the ICAO SARPs.

Table 8-1. Comparison of EU and ICAO halon Phase-out Requirements

	Requirement	Lavatory	Handheld Extinguisher	Engine / APU	Cargo
New Design Aircraft	EC Cutoff Date	2011	2014	2014	2018
	ICAO	2011	2016	2014	NA
Current Production Aircraft	EC End Date (includes retrofit)	2020	2025	2040	2040
	ICAO	2011	2016	NA	NA

8.3. Status of Currently Available Alternatives to Halons for Civil Aviation

Aviation applications of halon are among the most demanding uses of the agents, requiring fire suppression effectiveness at an acceptable toxicity level. For these reasons, it would be expected that civil aviation would place a high level of need on replacing halons for aviation uses. However, that is not evidenced in their efforts to date. The fact that alternatives are used only in the lavatory trash receptacle fire extinguishing systems of in-production aircraft is a remarkably disappointing result given the research and testing efforts on aviation applications since 1993.

Below is a summary of the status of the available alternatives for the four on-board and one flightline halon uses:

- Halon 1301 in lavatory trash receptacle extinguishing systems;
- Halon 1301 in engine nacelle/auxiliary power unit (APU) protection systems;
- Halon 1301 in cargo compartment extinguishing systems;
- Halon 1211 handheld extinguishers; and
- Halon 1211 in crash rescue vehicles.

8.3.1. Lavatory Trash Receptacle

Research and testing has shown that there are suitable alternative suppression systems (using HFC-227ea or HFC-236fa) available for lavatory trash receptacle applications that meet the criteria for space, weight and toxicity, and cost the same or less than the halon systems being replaced. Both have Ozone Depletion Potentials (ODPs) of zero but have high Global Warming Potentials (GWPs); HFC-227ea has a 100-year GWP of 3140 and HFC-236fa has a 100-year GWP of 8060. Data from one lavatory extinguisher manufacturer shows that the vast majority of new production aircraft are now installed with non-halon systems. In addition, some airlines are replacing existing halon 1301 in this application with systems using these halon-free alternatives during scheduled maintenance operations and have previously reported that they are cheaper than the halon 1301 system.

8.3.2. Engine Nacelle and APU

HFC-125 has been used successfully as an alternative to halon 1301 for engine nacelle fire protection on U.S. military aircraft developed since the early 1990s. In addition, HFC-125 is currently being developed for use on a military derivative of a large commercial aircraft (Boeing 767; military derivative KC-46).

HFC-125 has increased space and weight characteristics as compared to halon 1301 that present installation concerns to civil aviation airframe manufacturers. HFC-125 has a zero ODP but has a 100-year GWP of 3450. Based on these facts, civil aviation airframe manufacturers have chosen not to pursue qualification and installation certification for HFC-125 in engine nacelles/APUs of civil aircraft.

Both of the low/zero-GWP fire-fighting agents that have been tested by approval authorities for engine nacelle and APU applications have failed required fire suppression tests. One failed the low-temperature, live-fire test and the other failed the large-scale, live-fire test. The civil aviation industry has now come to the conclusion that they need to take a different approach to finding a halon 1301 replacement for engine nacelle and APUs. They have pooled their resources to develop a single agent/approach and formed the Halon Alternatives for Aircraft Propulsion Systems (HAAPS) consortium in 2015. The HAAPS consortium is an international collaboration among aircraft manufacturers, fire extinguishing system suppliers, engine/auxiliary power unit/nacelle companies, and other key stakeholders that aims to identify a common environmentally acceptable non-halon fire extinguishing solution(s) for use in engine and APU fire zones. They recently selected the Ohio Aerospace Institute (OAI) in Cleveland, Ohio to manage the activities of the consortium.

8.3.3. Cargo Compartments

In passenger aircraft, the cargo compartments are typically located below the passenger cabin, or occupy both the main and lower deck on freighter aircraft. In the latter, fire control on the main deck is effected by depressurising the main deck cargo compartment, reaching the landing site, and landing as quickly as possible before the fire re-establishes itself. In the case of a fire in the lower deck cargo compartment or below the passenger compartment, a rapid discharge of halon 1301 is deployed into the protected space to suppress the fire, which is followed by a discharge that is released slowly to maintain a concentration of halon 1301 to prevent re-ignition. The slow discharge is maintained until the plane has landed to protect against any reduction in the concentration of halon 1301 caused by ventilation or leakage.

Cargo compartment fire suppression systems must be able to meet the requirements of four fire tests: 1) the system must be able to suppress a Class A (ordinary combustibles) deep-seated fire for at least 30 minutes, 2) suppress a Class A fire inside a cargo container for at least 30 minutes, 3) extinguish a Class B fire (Jet-A fuel) within 5 minutes, and 4) prevent the explosion of a hydrocarbon mixture, such as found in aerosol cans. In addition, the system must have sufficient agent/suppression capability to be able to provide continued safe flight and landing from the time a fire warning occurs, which could be in excess of 350 minutes, depending on the aircraft type and flight route planned.

To date, there have been no cases of halon 1301 replacement with an alternative agent in cargo compartments of civil aircraft. Testing of halocarbon agents has shown that they are not technically or economically feasible due to the space and weight requirements of maintaining the necessary high concentrations of these agents. A combination of water mist and nitrogen has been tested to and shown to meet the current performance requirements. Commercial development of a water mist/nitrogen cargo fire suppression system is in the early stages.

The International Coordinating Council of Aerospace Industries Associations (ICCAIA) formed the Cargo Compartment Halon Replacement Working Group (CCHRWG) in 2014 to provide a recommendation to ICAO on a date for requiring the use of a halon replacement in the cargo compartments of newly designed aircraft. The CCHRWG has documented the requirements for a cargo compartment fire suppression system, created a technology development and implementation timeline, and is developing a generic scenario for a non-halon cargo compartment system. The CCHRWG is also exploring potential mechanisms for further technology development such as a consortium or joint research agreement.

8.3.4. Handheld Extinguishers

Two non-ODS alternatives, HFC-227ea and HFC-236fa, and one ODS - HCFC Blend B (>96% HCFC-123, <4% Ar and <2% CF_4) have successfully completed all of the required Underwriters Laboratories (UL) and MPS handheld tests and are commercially available. As shown in Table 8-2, these alternatives have increased space and weight characteristics compared to the use of halon 1211 extinguishers and, in some cases, environmental concerns. Based on these issues, airframe manufacturers have chosen not to pursue qualification and installation certification for these particular alternatives, a necessary requirement prior to airline use.

Table 8-2. Potential Portable Extinguishers for Civil Aviation

Type	Agent Charge	Total Weight	Atmospheric Lifetime	ODP	GWP
Halon 1211	1.14 kg	1.79 kg	161[1]	6.9[1] (3)[2]	1750[1]
	2.50 kg	4.23 kg			
HCFC	>96% HCFC-123		1.3[3]	0.01[3] (.02)[2]	79[3]
Blend B	<4% Ar		n/a	0	0
	<2% CF_4		50,000[3]	0	6630[3]
HFC-227ea	2.61 kg	4.45 kg	36[1]	0	3140[1]
HFC-236fa	2.16 kg	4.32 kg	242[3]	0	8060[3]
2-BTP	1.70 kg	2.55 kg	.02 (7 days)[2]	.0028[2]	0.26[4]

1. WMO, 2014 2. Official values used by the Montreal Protocol 3. IPCC, 2013 and 4. Patten, et al., 2012

ICAO, in working paper A37-WP/67, reported that the airframe manufacturers and the International Air Transport Association (IATA) requested additional time (until 2016) to thoroughly test and validate a potential halon replacement agent for hand-held fire extinguishers, which was reported to be neither a greenhouse gas nor a regulated ODS. Testing of this low GWP, unsaturated HBFC, known as 3,3,3-trifluoro-2-bromo-prop-1-ene or 2-BTP that has the potential of lower space and weight impact compared to other alternatives, has been completed. In early 2014, the agent manufacturer made a submission under the U.S. Significant New Alternatives Policy program and a Pre-manufacturing Notice under the Toxic Substances Control Act, both of which are required before commercialisation can begin within the U.S. As of March 2014, the agent is registered via the European Chemicals Agency under the European Union Regulation Registration, Evaluation, Authorisation and Restriction of Chemicals in the 10 – 100 metric tonnes per annum range. If approved in the U.S., this agent could be commercialised in the next few years to meet aviation needs for a handheld extinguisher replacement for in production aircraft after December 31, 2016, and may be a possible candidate for evaluation in engine nacelles/APUs as well. ICCAIA and IATA also indicated that should 2-BTP not be available by 2016, the aircraft manufacturers have agreed to put into service one of the current, approved hand-held halon fire extinguishing agents in order to meet the 2016 timeframe. In working paper A37-WP/197, ICCAIA agreed with the dates presented by ICAO in working paper A37-WP/67.

8.3.4.1. Use of HCFC-123 in fire protection

HCFC-123 is a unique case within civil aviation fire protection because while it is an ODS, it is also a low-GWP alternative to halon 1211 when formulated with other chemicals. As such, it deserves special discussion. It is important to note that while the primary component of HCFC clean agents commercialised for use in streaming applications is HCFC-123, e.g., HCFC Blend B (96% HCFC-123) and HCFC Blend E (90% HCFC-123), it is only HCFC Blend B that has gained appropriate approvals for civil aviation use.

When considering options to replace halon 1211 for handheld use on civil aircraft, one must compare the overall environmental impacts of the agents. Of concern are the typical ODP, GWP, and Atmospheric Lifetime but also for aircraft applications the total extra weight that aircraft will need to carry. The ODP of HFC-227ea and HFC-236fa is 0 and that of HCFC-123 is now considered to be 0.01. According to Wuebbles, 2009, the 2006 worldwide installed bank for HCFC Blend B and HCFC-123 for fire extinguishing is estimated as 1800 metric tonnes. Further, Wuebbles, 2009 opined that "given the short atmospheric lifetime of HCFC-123, in a realistic situation, the emissions are expected to remain small enough that the equivalent chlorine would never get anywhere close to a level of concern relative to other forcings on ozone."

8.3.4.2. Impact of the Use of HCFC-123 in fire protection

HCFC-123 has a 100-year integrated GWP of 79. This value is much less than the value of 3140 for HFC-227ea and 8,060 for HFC-236fa. However, the HCFC Blend B formulation contains a small percentage of CF_4, a high GWP gas with a very long atmospheric lifetime. According to Wuebbles, 2009, accounting for the CF_4 content, however, one could emit over 40 times the amount of HCFC Blend B before having the same impact on climate as using HFC-236fa, using the latest GWPs at the time of that publication. Using similar logic with the GWPs listed in Table 2, one could emit more than 15 times of HCFC-Blend B than HFC-227ea and more than 38 times of HCFC Blend B than HFC-236fa before having the same impact on climate. However, CF_4 lasts in the atmosphere for many thousands of years, so its effects on climate would continue for a very long time. The amount of CF_4 emissions worldwide from HCFC Blend B was estimated in 2009 to be less than 1 metric tonne annually, but its long atmospheric lifetime and strength as a greenhouse gas make it a concern.

From a weight standpoint, all the alternative extinguishers weigh more than an equivalent halon 1211 extinguisher at 1.8 kg. 2-BTP has the lowest weight increase of about 0.75 kg. All three of the existing alternatives have similar weight increases, with HFC-227ea as the highest at nearly 2.5 kg. Should HCFC Blend B become of interest for use on board aircraft, the manufacturer has indicated that they have a reduced weight aluminum cylinder version that could be made available. The aluminum extinguisher contains 2.27 kg of agent and weighs 3.32 kg.

The extra weight from non-halon 1211 extinguishers would also cause increased fuel consumption during flight. For every 1 kg increase in weight of a typical commercial aircraft, it is estimated that fuel consumption is increased by an average of 0.15 liters per hour, with a potential average cost impact of less than $100 per aircraft per year (assuming jet fuel costs $3.25 per gallon and an average of 1300 flights per year averaging 2 hours per flight). Per extinguisher replaced, this would equate to an annual increased cost due to additional fuel consumption of $60 per year for 2-BTP, $115 per year for HCFC Blend B in the lower weight aluminum cylinder, and about $200 per year for HFC-236fa and HFC-227ea. Should 2-BTP receive final approvals, it would be an effective substitute for halon 1211, although it would be more expensive. Should 2-BTP not prove acceptable, the next best choice when considering all environmental and cost implications for aviation portable fire extinguishers is HCFC Blend B. In addition, HCFC Blend B is available in larger portable systems and is approved for use in ARFF vehicles by the U.S. (see next section).

8.3.4.3. Crash Rescue Vehicles

In addition to onboard civil aircraft applications, halon 1211 is used in some Aircraft Rescue and Fire Fighting (ARFF) or Crash Rescue Vehicles on airport ramps. U.S. Federal Aviation Administration (FAA) CERT Alert 95-03 approved HCFC Blend B as a halon 1211 replacement for this application in the U.S. Since 1995, more than 100 U.S. airports and some airports outside of the U.S. have installed such systems. These systems have between 208 and 227 kg net charge weight. There are multiple manufacturers who sell ARFF vehicles with HCFC Blend B systems. Since 1997, the documented aviation related fires extinguished with HCFC Blend B include several engine fires on commercial passenger aircraft, APUs, and in one instance a hydraulic fluid fire on a helicopter. HCFC Blend B has been shown to be effective in knocking down and controlling lithium ion battery type fires. However, because HCFC Blend B is an ODS, national regulations may limit its use for the ARFF application in other countries.

8.4. Estimated Civil Aviation Halon Installed Base

With the minor exception of the use of PBr_3 in one business jet, all new installations of fire extinguishing systems for engines and cargo compartments continue to use halon 1301, and all new installations of handheld extinguishers continue to use halon 1211. With the exception of lavatory trash receptacles, there has been no retrofit of halon systems or portable extinguishers with available alternatives.

8.4.1. Civil Aviation Fleet Estimates

The halon 1301 and halon 1211 installed base estimates for mainline and regional aircraft were developed using activity data for each use and assumptions on the growing size of the global fleet. Estimates of the current and projected fleet were made based on information contained in Airbus' and Boeing's Global Market Outlook reports and adjusted based on feedback provided from Airbus and Boeing representatives. Fleet estimates from Bombardier's global forecast and Flight International's business aircraft census were used to estimate the business jets and turboprop fleets. It was assumed that the remaining portion of the estimated 2014 fleet consists of regional aircraft. The market breakdown of the mainline versus regional fleet after 2014 is assumed to be proportionate to the number of mainline versus regional deliveries in 2013. Table 8-3 below outlines the current and projected worldwide fleet.

Table 8-3. Civil Aviation Fleet Estimates

Year	2014	2020	2025	2030
Total Mainline Fleet	18,313	23,509	27,839	32,170
Total Regional Fleet	2,699	3,465	4,103	4,741
Total Business Jets Fleet	15,680	20,510	24,535	28,560
Total Turboprops Fleet	10,520	8,777	7,324	5,872

8.4.2. Estimate of Halon 1301 Installed

The number of installed halon 1301 systems per aircraft and the installed base of halon over the entire commercial aviation fleet were estimated using activity data and manufacturer feedback for engine nacelles, cargo compartments, APUs, and lavatory trash receptacle systems. The engine nacelle application assumes one halon bottle per engine. The baggage/cargo application varies according to flight distance and estimated cargo space. The installed halon in the baggage/cargo section of the aircraft varies according to the maximum Extended-range Twin-engine Operational Performance Standards (ETOPS) distance that the aircraft was certified for. For business jet fleet, it was assumed that half an additional halon 1301 system in the baggage/cargo compartment. The APU application assumes one bottle per aircraft and the lavatory trash receptacle application assumes one bottle per regional aircraft. Using this bottom-up approach, there is approximately 2,236 metric tonnes of halon 1301 currently installed across the civil aviation fleet, as presented in Table 8-4. Based on the growth trend observed through 2030, the installed base of halon was projected out to 2050 at 5,993 metric tonnes.

Table 8-4. Estimated Installed Base of Halon 1301 in Commercial Aircraft (metric tonnes), (EPA, 2015)

	2014	2020	2030	2040	2050
Total Installed in Halon 1301 Applications	2,236	2,862	3,906	4,949	5,993

8.4.3. Estimate of Halon 1211 Installed on Civil Aircraft

A halon 1211 handheld extinguisher is assumed to be located in the cockpit of all civil aircraft (i.e., including mainline aircraft, regional aircraft, business jets, and turboprops), in addition to the minimum number of extinguishers required in the passenger cabin. Furthermore, a handheld extinguisher must be readily accessible in accessible baggage compartments. Therefore, it was assumed that half of the business jet fleet is equipped with an additional handheld extinguisher. The assumption for the halon 1211 application is the following:

- 7 – 8 bottles per very large mainline and intermediate twin aisle mainline aircraft,
- 4 – 6 bottles per intermediate twin aisle mainline aircraft,
- 4 – 5 bottles two bottles per small twin aisle and single aisle mainline aircraft,
- 3 – 4 bottles per single aisle mainline aircraft,
- 2 - bottles per regional aircraft,
- 2 - bottles per business jet, and
- 2 - bottles per turboprop aircraft.

Due to the uncertainty surrounding the use of halon 1211 in handheld fire extinguishers beyond 2016, the halon 1211 analysis in Table 8-5 considers two scenarios: a business as usual scenario and a best-case scenario. The business as usual scenario assumes the continued use of halon 1211 in handheld fire extinguishers through 2030. The best-case scenario assumes that mainline airframe manufacturers will implement halon-alternative handheld fire extinguishers in all aircraft new deliveries by December 31, 2016, and in the European Union retrofit of all existing aircraft by December 31, 2025.

Table 8-5. Estimated Quantities of Halon 1211 on Commercial Aircraft (metric tonnes)

	2014	**2020**	**2025**	**2030**
Total Installed: Business As Usual Scenario	164	204	237	270
Total Installed: Best-Case Scenario	164	173	171	166

8.5. Estimates of Global Quantities of Halons

The 2014 HTOC Assessment report provided the most current estimates of global inventories of halon 1211 and halon 1301 based on modeling of reported production and estimated emissions. For halon 1301, the HTOC model emissions and bank estimates compare quite well with emissions derived from mixing ratios reported by the Scientific Assessment Panel (SAP). For halon 1301, the estimated cumulative emissions derived from mixing ratios through 2014 are 108,000 metric tonnes, which would provide a remaining bank of 41,000 metric tonnes versus the HTOC model estimate of 106,000 metric tonnes of cumulative emissions and a remaining bank of 43,000 metric tonnes. Taking an average of the two approaches provides a 2014 halon 1301 bank of 42,000 metric tonnes. For halon 1211, the two estimates do not compare as well as for halon 1301. The estimated halon 1211 cumulative emissions derived from mixing ratios through 2014 are 291,000 metric tonnes and a remaining bank of 22,000 metric tonnes versus the HTOC model estimate of 280,000 metric tonnes of cumulative emissions and a remaining bank of 33,000 metric tonnes. Taking an average of the two approaches provides a 2014 halon 1211 bank of 27,500 metric tonnes.

8.5.1. Limitations of Global Modeling Data for Use in Civil Aviation Planning

Over the years, the Parties have asked the Ozone Secretariat to request the International Civil Aviation Organisation (ICAO) Secretariat to send halon reserves data reported to it to the Ozone Secretariat. Few countries have provided detailed information. As a consequence, with the exception of information provided by Japan, the modeled data is based on a very limited amount of direct, quantified, national input. Furthermore, the HTOC bottom-up and SAP top-down estimates do not provide any direct information on the quantities of halon that could become available for use in civil aviation now or in the future. None-the-less, there is often the temptation to compare the total global inventories against the annual quantities of halons needed to support aviation and come to a conclusion that aviation is a small user of the existing halon bank. However, this approach does not recognise that the total inventories of halons are not necessarily going to be available to civil aviation. First, some of the halon thought to exist may be inaccessible due to physical constraints and/or national restrictions on exports. In addition, a portion of the existing halon bank is owned by users whose fire protection applications have equipment that still relies on halons, and they have continuing long-term needs. Examples of these situations include the following:

- Approximately 1 metric tonnes of halon 1301 in China,
- 17,000 metric tonnes of halon 1301 that is currently installed or stockpiled and reserved for future use in ground-based fire protection systems in Japan,
- About 4,600 metric tonnes of halon 1301 and 700 metric tonnes of halon 1211 stockpiled by the U.S. military for use in existing critical weapons systems, and
- About 1,500 metric tonnes of halon 1301 installed in oil facilities on the North Slope of Alaska and other places around the world.

Furthermore, the amount of halon currently installed in aviation applications (i.e., 2,236 metric tonnes, from Table 4) is accounted for in the worldwide supply, but is also assumed not to be available for future aviation needs. Therefore, there is likely to be a significant difference between the amount of halon that is predicted to exist, and the amount that could become available to civil aviation. At present, the halon demands of civil aviation are being met by recycled agent withdrawn from applications in other industries. This source of supply will be dramatically reduced, and may even be exhausted, long before the aircraft now being built and fitted with halon systems are retired. The total amount of halon 1301 assumed to be available to meet aviation demands would come from commercial aviation stockpiles, computer/telecommunication facilities, and merchant shipping. It is estimated that the total amount of halon 1301 from these sources that could potentially become available to support civil aviation is 15,635 metric tonnes.

8.5.2. Sources of Recycled Halon 1301 for Civil Aviation

Since production of halon ceased in 1993 in non-Article 5 Parties, most, if not all, of the halon needed to support civil aviation has come from recycled supplies. This has been the case for more than 20 years now. With one known exception, where contaminated halons were purposefully provided for civil aviation use, there have been no problems reported in supporting global civil aviation fleets or any other long-term legacy user. Some users such as the U.S. military built their own long-term bank but, for the most part, other users report either no bank of their own or one that is sufficient for a few years only and is replenished on a routine basis. Most of the halon for existing legacy users comes from just a few recycling corporations around the world. What is not well understood but is reported by the halon recycling community is that they only have a few months supply on hand at any one time and only know where they will be getting additional halon from for perhaps as much as a year out but often less. This living “hand-to-mouth” has worked so far in meeting past and current demand. There always seems to be enough halon found to provide for existing users. Over the last few years, prices for recycled halon 1301 have increased significantly (including doubling in some markets) indicating there is some concern over future availability. However, supplies are still being found, albeit perhaps at a slower pace. Even with the knowledge that halon supplies may be available for only a few months of stock, most users, including civil aviation, have to date expressed no real concerns with this situation. Some long term users and suppliers, however, are beginning to express concern. The HTOC has previously stated that perhaps halon banking has worked until now because of routine ship breaking of vessels that had been designed with halon 1301 systems. A concern is that if true, then when that source dries up, there could be a disruption and potential shortage of halon 1301 to support users dependent on the routine supplies in order to maintain their existing system operations.

8.5.3. Estimated Halon 1301 Installed on Merchant Ships

In order to estimate the amount of halon 1301 that may still be installed in merchant shipping, five questions need to be answered:

1) What types of ships had halon 1301 installed?
2) Over what time period was the halon installed?
3) How much halon would be installed per ship?
4) How many ships were built during the time period?
5) What is the average lifetime of those ships?

For the first two questions the HTOC could provide answers based on direct experience or other information available. Halon1301 was primarily used for the protection of machinery spaces on passenger ships and machinery spaces and cargo pump rooms on tankers. The International Maritime Organisation (IMO) banned the use of halons in new constructions in 1992, so it is assumed that the last ships would have been constructed in 1993 and it is estimated the first ships were constructed with halon 1301 beginning in 1975. Data on quantities of halon 1301 by ship size, quantities of ships constructed during 1975 – 1993 and the average lifetime were still needed.

It had been hoped that the IMO would provide two of the missing pieces of information to the HTOC: 1) quantities of ships constructed during 1975 – 1993 and 2) year of ship breaking so that average lifetimes could be established. The Ozone Secretariat provided a Point of Contact at IMO who informed the HTOC that they were not allowed to provide such information owing to a contractual agreement with the ship registry company and that access to the data would need to be discussed with commercial providers. The Ozone Secretariat subsequently directed HTOC to a partially open access website, http://www.world-ships.com/, which contained information on year and sizes of ships constructed. Additional information on year of ship breaking was reported as being available through this registry but was not able to be obtained in time for this report. For the purposes of this report, the useful lifetime of all ships is estimated to be between 30 - 40 yrs.

Data on passenger ships and tankers were extracted from the World Shipping Register including ship name, ship type, deadweight tonnage (DWT), year built, and flag. The database constructed only includes ships that were built between 1975 and 1993. The database includes approximately 4,000 tankers (i.e., asphalt tankers, chemical/oil tankers, crude oil tankers, LNG tankers, LPG tankers, water tankers, and other tankers) and approximately 2,700 passenger ships (i.e., cruise ships, ferry ships, and other passenger ships).

The average charge size of halon 1301 systems on passenger ships and tankers was assumed to vary by the ship's DWT. These charge sizes are listed in Table 8-6 below for each size range of passenger ships and tankers taken.

Table 8-6. Halon 1301 Charge Sizes for Passenger Ships and Tankers of Various Sizes (ICF, 2015)

Ship Type	**Deadweight Tonnage (DWT)**	**Halon 1301 Charge Size (kg)**
Passenger Ship	< 1,000	100
Passenger Ship	1,000 – 10,000	750
Passenger Ship	10,001 – 20,000	1,500
Passenger Ship	> 20,000	2,000
Tanker	< 1,000	100
Tanker	1,000 – 50,000	2,000
Tanker	50,001 – 100,000	2,500
Tanker	100,001 – 200,000	3,000
Tanker	200,001 – 300,000	7,000
Tanker	> 300,000	8,000

Figure 8-1, below, shows the number of passenger ships and tankers built between 1975 and 1993 and Figure 8-2 shows the estimated total residual amount of halon 1301 remaining in service for an assumed 30 year and 40 year lifetime. In 2014, approximately 2,628 metric tonnes is estimated to remain in service for a 30-year lifetime of ships. This would provide on average a little less than 300 metric tonnes annually through 2023. For a 40-year lifetime of ships, 3,775 metric tonnes of residual halon 1301 is estimated to remain in service in 2014. This would provide on average a little less than 200.

Figure 8-1. Total Number of Passenger Ships and Tankers Built Between 1975 and 1993 (ICF, 2015) metric tonnes annually through 2033

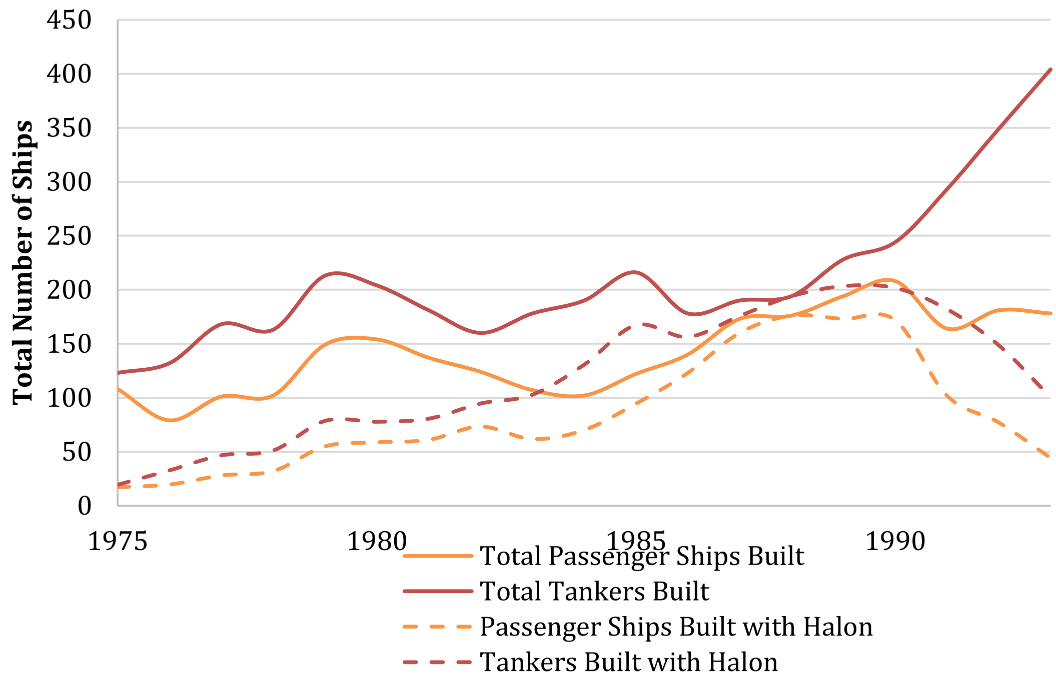
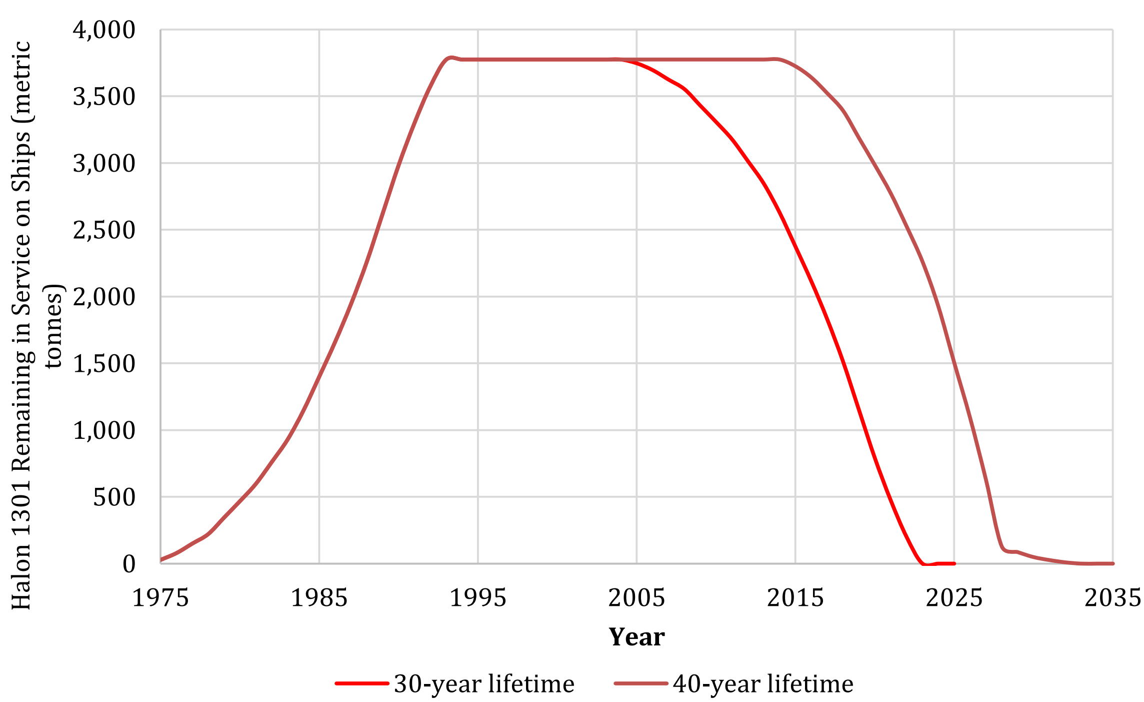


Figure 8-2. Total Residual Amount of Halon 1301 Remaining in Service (ICF, 2015)



8.6. Halon Needs for Civil Aviation

Typically, the estimates of the annual needs of halon 1301 to support civil aviation have been developed by applying an assumed emission factor of 2-3% per year to the estimated installed on aircraft. That emission factor is based on estimated, annual, average global emissions of halons developed from the HTOC and SAP models. It is not specific to civil aviation. Experience from other halon users such as military, and oil and gas production has shown that emission rates are typically higher than this until there is management emphasis to identify and reduce activities or failures that lead to unnecessary emissions. Emission rates of 5% or more were not uncommon. For example, in looking at their emissions in the early 1990s, the U.S. military found that a particular aircraft was experiencing an unusually high halon 1301 emission rate. It was determined that the cause of the higher emissions was an unwritten procedure used by aircraft maintenance workers. It was learned that when working on or in the engine area, an easy way to turn off power to the fuel pump was to press the engine fire indicator button in the cock pit. In addition to killing the power to the fuel pump, pressing it once would cause this button to light up. If another maintainer looked into the cock pit, they would see the button lit up and do what is common in that circumstance; they would press the button to see if they could make the light go out. Unfortunately, pressing the button a second time would discharge the halon system. This is one example, but there were others that needed to be looked into and resolved in order to reduce emissions as much as possible, which are currently likely below 2%. One Party reports that their annual emissions are well below 1% because they have placed a very high value on minimising unnecessary emissions. Based on experience to date with the civil aviation industry, HTOC sees little evidence of a strong sense of urgency in the industry to find halon replacements, or any concerted effort by the industry to look into the cause of or minimise unnecessary use and emissions. The working group believes applying the current global emission factor likely underestimates the actual emissions from civil aviation. Therefore, a second scenario is also included that assumes a higher annual emission rate of 5% of the installed base on civil aviation.

Six scenarios were modeled to estimate the availability of halon 1301 resources needed to service the existing aviation fleet, account for aviation growth through 2050, and service existing non-aviation applications. These scenarios do not consider uptake of any further halon 1301 alternatives. The scenarios model the initial total available worldwide supply of halon 1301 of 15,635 metric tonnes as well as +/- 10% of this value (i.e., 14,071 metric tonnes and 17,198 metric tonnes). Each scenario assumes a low, 2 to 3% and high, 5%, annual emission rate from all halon 1301 aviation applications and a constant emission rate for non-aviation sources of 3%. It must be noted that the emission rates for civil aviation applications could potentially be even larger than 5% while the emission rate for non-aviation sources (i.e., oil and gas production, military, and nuclear facilities) could be even lower and the global averages in the 2 to 3% would still be obtained. Description of scenarios and the resulting years in which halon 1301 would no longer be available to meet demand are summarised in Table 8-7. Under the worst case assumptions in Scenario 2b, halon 1301 supplies for civil aviation would run out in 2036 and for the best case Scenario in 3a, would run out in 2045.

Table 8-7. Characteristics of Six Scenarios Modeled (ICF, 2015)

Scenario	Annual Emission Rate (Aviation)	Annual Emission Rate (Non-Aviation)	Total Available Worldwide Supply[a] (metric tonnes)	Estimated Year to Meet Demand
1a	2.3 – 2.8%	3%	15,635	2042
1b	5%	3%	15,635	2039
2a	2.3 – 2.8%	3%	14,071	2040
2b	**5%**	**3%**	**14,071**	**2036**
3a	**2.3 – 2.8%**	**3%**	**17,198**	**2045**
3b	5%	3%	17,198	2041

[a] Estimated amount of material that will be decommissioned and repurposed for aviation applications from commercial aviation stockpiles, computer facilities, and maritime.

While this may seem far out into the future, the reality is that the aircraft have a 30+ year lifetime. Therefore, for aircraft that have been manufactured since 2006, there is not enough halon 1301 projected to be available to support them throughout their economic lifetime in the worst-case scenario. Even in the best-case scenario, halon is only projected to be available to support aircraft over their entire lifetime that are produced up until this year (i.e., 2015).

Based on the potential amount of halon 1301 from ship breaking in the previous section, annual amounts from ship breaking could be sufficient to cover civil aviation needs until that source runs out between 2023 and 2033. This assumes that all of the halon 1301 is fully recovered from shipbuilding and that all of it would be dedicated to civil aviation, both of which are likely not true today and, without significant effort, will not be true in the future. Further, as the supply of halons gets further reduced the likelihood of a significant disruption in supply increases dramatically. If civil aviation does not stop producing new aircraft using halon 1301, they are already or soon will be producing aircraft that cannot be sustained over their economic lifetimes with existing supplies of recycled halon 1301. Of all the halon use sectors, civil aviation is the least prepared to deal with diminishing halon supplies and, with the ultimate exhaustion of supplies this sector will most likely be the one to request an Essential Use Nomination in the future.

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9. Other TEAP matters

9.1 Status of TOC reappointments

As required by Decision XXIII/10, TEAP and its TOCs completed reappointments of members in 2014. The TOCs membership sizes, geographical, and gender balance in the period beginning 1 January 2015 follows the configurations reported to the Parties in TEAP's Decision XXIV/8 Task Force Report (May 2013). In that report, TOCs membership numbers in the 2014-2018 period were anticipated to remain the same or decrease from the 2013-2014 period due to anticipated attrition during the 2014 reappointment process; the exception to this was RTOC which was anticipated to retain its previous membership numbers based on anticipated workload. Annex 1 of this report provides updated TOC membership lists, which include the start dates and current terms of appointment for all members. Where possible, TEAP is aligning appointment start dates to begin on Jan 1^{st} coinciding with the start of the next quadrennial Assessment Reporting period. TEAP is grateful for the service of the TOCs members, past and present, and their contributions to the work of completing the 2014 assessment reports, and looks forward to the contributions of continuing and new members to the TOCs in the next assessment report period.

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

9.1.1 CTOC

Recent reorganisation and the retirement of an experienced co-chair has presented CTOC with some important shortfalls in expertise in the membership, for example with respect to laboratory and analytical uses of ODS, destruction technologies and solvents. CTOC was not able to complete its 2014 CTOC Assessment Report within the timeframe required by Decision XXIII/18. This required TEAP to post an "Advance" 2014 Assessment Report with placeholders for CTOC issues. The CTOC 2014 Assessment Report is now available and posted, as is the TEAP 2014 Assessment Report. TEAP is however working with CTOC to ensure this situation does not arise again in the future.

9.1.2 FTOC

FTOC co-chairs Paul Ashford (UK) and Miguel Quintero (Colombia) resigned their positions at the start of 2015. Both cited the increasing workload and short timelines for TEAP reports, in the context of their own full-time occupations. TEAP is grateful for their expertise, extraordinary time and effort over the years in managing the work of the FTOC, and long dedication to the Panel and the goals of the Protocol. They will be missed as friends and colleagues on the TEAP. TEAP has sought, but has not been able to make, interim co-chair appointments as allowed under its TOR. TEAP will consider candidates to recommend for nomination by Parties and for appointment at the 27^{th} MOP.

9.1.3 RTOC

The current RTOC membership has adequate expertise in all sub-sectors, although some strengthening would be helpful increasing the emphasis on addressing HCFC-22 and HFCs use in stationary AC and commercial refrigeration.

The RTOC has experts nominated from seven Parties. RTOC co-chairs have been matching the CVs to the desired additional emphasis in relation to certain expertise. Final decisions on appointments will be taken this month (June 2015), in advance of the OEWG-36 meeting and in time for the next RTOC meeting, planned for Paris 27-28 July 2015.

9.2 Continuing challenges

As noted in the TEAP 2014 Assessment Report, the role of TEAP and its TOCs continues to evolve in meeting the current needs of Parties. Where, originally, the three Panels were considered as the bodies that should carry out assessments pursuant to Article 6 under the Montreal Protocol (at least every four years), TEAP, in particular, has become a "standing advisory group" to the Parties on a large number of technology related Protocol issues. The evolving role of the TEAP, its TOCs and other Temporary Subsidiary Bodies, can be explained by the fact that the focus of the Montreal Protocol has shifted from introducing and strengthening control schedules (based upon assessment reports) to managing the use of controlled chemicals and to compliance with the Protocol. This role could again evolve with any future change to the current phaseout scenario under the Protocol. TEAP continues to work so that its TOCs are structured in size and expertise to support future efforts of the Parties, but takes the opportunity in this report to address ongoing challenges and bring them to the attention of the Parties.

- TEAP has been challenged in this period with a significant transition in leadership as well as attrition through retirement of its members. Members of TEAP are generally also co-chairs of TOCs and thus have a broader role and greater expectation to bring their long-time understanding of the history of the Protocol, its decisions, its issues, and its processes into the technical outputs developed by their committees, and by the Panel. This is in addition to the particular technical expertise each member brings to the Panel. The challenge to TEAP and TOC leadership is to identify candidates with adequate history and experience as well as technical expertise in order for TEAP to continue to meet the significant demands of delivering outputs to support the deliberations of Parties, without loss of continuity.

- Similarly, the TOCs have also been challenged with attrition through retirement of members and increasing loss of expertise. The absence of funding for non-Article 5 members makes participation increasingly difficult. This is of growing concern to the consensus process of the committees where a range of independent expert opinions is necessary. Increasingly, absence of funding has extended to TOC co-chairs making uncertain travel to meetings and participation in other activities essential to the role of a co-chair.

- There is a significant workload related to the work of TEAP and its TOCs that has grown in recent years with the responses to various requests of the Parties; this situation if unaddressed will increasingly affect the delivery and timeline of TEAP's outputs. Members of TEAP and TOC often concurrently serve on TEAP Task Forces adding to the workload and making it difficult to meet deadlines.

- The members of TEAP and its TOCs provide their expertise and work on a voluntary basis and many are finding the increasing time commitment difficult/impossible to manage in the context of a full- time occupation.

- TEAP is determined to re-invigorate its membership and leadership, but at the same time maintain involvement of members with substantial experience to ensure the continuity of its work for Parties. This might be achieved through an expanded number of Senior Expert positions, at least for a period.

- To ensure the functioning of the TEAP and its TOCs to continue to provide timely assessments to support the discussions of Parties, TEAP and Parties may need to consider the overall annual workload and support for TEAP at the time of or soon after decisions requesting this work.

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

ANNEX 1: TEAP and TOC membership list status June 2015

The disclosure of interest (DOI) of each member can be found on the Ozone Secretariat website at: http://ozone.unep.org/Assessment_Panels/TEAP/toc-members-disclosures.shtml. 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 specifies 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.

Technology and Economic Assessment Panel (TEAP)			
Co-chairs	**Affiliation**	**Country**	**Appointment through**
Bella Maranion	U.S. EPA	USA	2016
Marta Pizano	Consultant	Colombia	2018
Ashley Woodcock	University Hospital of South Manchester	UK	2018
Senior Expert Members	**Affiliation**	**Country**	
Marco Gonzalez	Consultant	Costa Rica	2015
Masaaki Yamabe	National Inst. Advanced Industrial Science and Technology	Japan	2015
Shiqiu Zhang	Sen Yat Sen University	China	2017
TOC Chairs	**Affiliation**	**Country**	**Appointed through**
Mohamed Besri	Institut Agronomique et Vétérinaire Hassan II	Morocco	2017
David V. Catchpole	Petrotechnical Resources Alaska	UK	2016
Sergey Kopylov	All Russian Research Institute for Fire Protection	Russian Federation	2017
Lambert Kuijpers	Technical University Eindhoven	Netherlands	2015
Kei-ichi Ohnishi	Asahi Glass	Japan	2015
Roberto de A. Peixoto	Maua Institute (IMT), Sao Paulo	Brazil	2017
Fabio Polonara	Universitá Politecnica delle Marche	Italy	2018
Marta Pizano	Consultant	Colombia	2017
Jose Pons-Pons	Spray Química	Venezuela	2017
Ian Porter	La Trobe University	Australia	2017
Helen Tope	Energy International Australia	Australia	2017
Daniel P. Verdonik	Hughes Associates	USA	2016
Ashley Woodcock	University Hospital of South Manchester	UK	2016
Jianjun Zhang	Sen Yat Sen University	PRC	2017

Decision XXII/10 paragraph 9 specified that *"the terms of all the members of the…technical options committees shall otherwise expire at the end of…2014…in the absence of reappointment.*" 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.*" TOC member re-appointments start as of 1st January of the calendar year following appointment and end as of 31st December of the final year of appointment, as indicated in the last column of the following TOC tables.

New appointments to a TOC would 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.

TEAP Chemicals Technical Options Committee (CTOC)

Co-chairs	**Affiliation**	**Country**	**Appointment through**
Kei-ichi Ohnishi	Asahi Glass	Japan	2015
Jianjun Zhang	Sen Yat Sen University	China	2017
Members	**Affiliation**	**Country**	**Appointed through**
D. D. Arora	The Energy and Research Institute	India	2018
Steven Bernhardt	Honeywell	USA	2018
Olga Blinova	Russian Scientific Centre for Applied Chemistry	Russia	2018
Nick Campbell	Arkema	France	2018
Jianxin Hu	College of Environmental Sciences & Engineering, Peking University	China	2018
Claudia Paratori	Coordinator Ozone Programme -CONAMA	Chile	2018
Hans Porre	Teijin Aramids	Netherlands	2018
Surinder, Singh, Sambi		India	2018
Fatemah Al-Shatti	Kuwait Petroleum Corporation	Kuwait	2018
Nee Sun Choong Kwet Yive (Robert)	University of Mauritius	Mauritius	2018

TEAP Flexible and Rigid Foams Technical Options Committee (FTOC)

Co-chairs	Affiliation	Country	Appointment through
Paul Ashford	Caleb Management Services	UK	Resigned 2015
Miguel Quintero	Consultant	Colombia	Resigned 2015
Members	**Affiliation**	**Country**	**Appointed through**
Samir Arora	Industrial Foams	India	2016
Terry Arrmitt	Hennecke	UK	2018
Roy Chowdhury	Foam Supplies	Australia	2018
Rick Duncan	Spray Polyurethane Association	USA	2018
Koichi Wada	Bayer Material Science/JUFA	Japan	2018
Mike Jeffs	Consultant	UK	2015
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
Christoph Meurer	Solvay	Germany	2018
Sascha Rulhoff	Haltermann	Germany	2018
Enshan Sheng	Huntsman Co	China	2018
Helen Walter-Terrinoni	DuPont	USA	2018
Dave Williams	Honeywell	USA	2018
Allen Zhang	Consultant	China	2018

TEAP Halons Technical Options Committee (HTOC)

Co-chairs	Affiliation	Country	Appointed through
David V. Catchpole	Petrotechnical Resources Alaska	UK	2016
Sergey N. Kopylov	All Russian Research Institute for Fire Protection	Russian Federation	2017
Daniel P. Verdonik	Jensen Hughes	USA	2016
Members	**Affiliation**	**Country**	**Appointed through**
Tareq K. Al-Awad	King Abdullah II Design & Development 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
John J. O’Sullivan	Bureau Veriitas	UK	2015
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 trhough**
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	All Russian Research Institute for Fire Protection	Russian Federation	
David Liddy	Consultant – Retired	UK	
Steve McCormick	United States Army	USA	
John G. Owens	3M Company	USA	
Mark L. Robin	DuPont	USA	
Joseph A. Senecal	Kidde-Fenwal Inc.	USA	
Ronald S. Sheinson	Consultant - Retired	USA	

TEAP Medical Technical Options Committee (MTOC)			
Co-chairs	**Affiliation**	**Country**	**Appointed through**
Jose Pons Pons	Spray Quimica	Venezuela	2017
Helen Tope	Energy International Australia	Australia	2017
Ashley Woodcock	University Hospital of South Manchester	UK	2016
Members	**Affiliation**	**Country**	**Appointed through**
Emmanuel Addo-Yobo	Kwame Nkrumah University of Science and Technology	Ghana	2018
Paul Atkins	Oriel Therapeutics Inc.	USA	2018
Jorge Caneva	Favaloro Foundation	Argentina	2018
Davide Dalle Fusine	Chiesi Farmaceutici	Italy	2018
Eamonn Hoxey	Johnson & Johnson	UK	2018
Javaid Khan	The Aga Khan University	Pakistan	2018
Robert Meyer	Virginia Center for Translational and Regulatory Sciences	USA	2018
Gerald McDonnell	STERIS	UK	2018
Hideo Mori	Private Consultant	Japan	2018
Tunde Otulana	Boehringer Ingelheim Pharmaceuticals Inc.	USA	2018
John Pritchard	Philips Home Healthcare Solutions	UK	2018
Rabbur Reza	Beximco Pharmaceuticals	Bangladesh	2018
Roland Stechert	Boehringer Ingelheim	Germany	2018
Kristine Whorlow	National Asthma Council Australia	Australia	2018
You Yizhong	Journal of Aerosol Communication	P.R. China	2018

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	The Netherlands	2018
Aocheng Cao	Chinese Academy of Agricultural Sciences	China	2018
Raquel Ghini	EMBRAPA	Brasil	2016
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	National Institute for Agriculture 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	Ministry of Food, Agriculture and Livestock	Turkey	2016

TEAP Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee

Co-chairs	Affiliation	Country	Appointed through
Lambert Kuijpers	A/genT Consultancy (TUE Eindhoven)	Netherlands	2015
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 Republic	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
Richard Lawton	CRT Cambridge	UK	2018
Tingxun Li	Guangzhou University	China	2018
Petter Nekså	SINTEF Energy Research	Norway	2018
Horace Nelson	Consultant	Jamaica	2018
Carloandrea Malvicino	Fiat Ricerche	Italy	2018
Tetsuji Okada	JRAIA	Japan	2018
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

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 2015.

Body	Required Expertise	A5/ Non-A5
Chemicals TOC	Experts on destruction technologies Experts on Laboratory and analytical uses Experts on solvents	A5 or non-A5 A5 or non-A5 A5 or non-A5
Foams TOC	Additional polyurethane foam expertise in the appliance sector Representation of smaller XPS producers XPS representation Representation on PU foams	Particularly North America From Europe From Japan From South East Asia and Sub-Saharan Africa
Halons TOC	Civil aviation Halon Banking	A5, South East Asia A5, Africa and A5, South America
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 TOC	Expert on sterilants Expert on dry powder inhalers	A5 or non-A5 A5 or non-A5
Refrigeration TOC	Additional experts not currently required (ssee note under section "Other TEAP issues")	
Senior Experts]	Economic analysis Emissions analysis and modeling ODS alternatives chemistry and production expertise Legal expertise and experience with Montreal Protocol	A5 and 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;