MONTREAL PROTOCOL
ON SUBSTANCES THAT DEPLETE
THE OZONE LAYER

UNEP

REPORT OF THE
HALONS TECHNICAL OPTIONS COMMITTEE

DECEMBER 2014

VOLUME 1

2014 ASSESSMENT REPORT

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Dedication

Since the last Assessment Report, a founding member of the Halons Technical Options Committee has passed away. This report is dedicated to the memory of:

Philip J. DiNenno

Acknowledgements

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The opinions expressed are those of the Committee and do not necessarily reflect the views of any sponsoring or supporting organisations.

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Preface

The December 2014 HTOC Report consists of three volumes:

Volume 1: 2014 Assessment Report

Volume 2: 2014 Supplementary Report #1 – Civil Aviation

Volume 3: 2014 Supplementary Report # 2 – Global Halon 1211, 1301, and 2402 Banking

The HTOC has taken a different approach to the reporting of its 2014 Assessment than in previous years. In the past, the report was an accumulation of all the information that the HTOC had gathered – some that had not changed over the years - plus new, updated information. This made the report large and unwieldy to some readers, and the important messages that the HTOC wanted to convey were getting lost.

For 2014, the HTOC has decided to slim down the report so that the main body will concentrate on new/changed information and important messages for the Parties to consider. The background information for two topics that may be of particular interest to some Parties are included as Supplementary Reports, with only new and important information in the main body of this report. These are Civil Aviation, and Global Halon 1211, 1301 and 2402 Banking. In addition, information that has been reported on in the past, which has been updated, and which is considered useful reference material, will be found in one of five Technical Notes: Fire Protection Alternatives to Halons; Halon Emission Reduction Strategies; Explosion Protection – Halon Use And Alternatives; Recommended Practices For Recycling Halon and Halocarbon Alternatives; and Halon Destruction. These technical notes may be further updated on an annual basis in conjunction with HTOC Progress Reports.

Executive Summary

The HTOC is of the opinion that despite the introduction of new halon alternatives and the remarkable progress in switching to them, there is still an on-going need for halons for service, in particular legacy systems. As such, halon recycling is becoming even more important to ensure that adequate stocks of halons are available to meet the future needs of the Parties.

Inventories of Halons

1. The rates of halon emissions based on atmospheric measurements of halon concentrations are similar to the rates of emissions based on model estimates. The estimated size of the global halon banks in 2014 are: halon 1211 - 33,000 MT; halon 1301 - 43,000 MT; and halon 2402 - 9,000 MT.
2. The total quantities of inventories of halons are not necessarily available for redeployment for multiple reasons, e.g.:
    a. It is often the case that the quantities, locations and availability of halons stocks are not known either within countries or regions;
    b. Where halon quantities and locations are known it is because owners want to preserve these materials for their own use.
    c. Many countries have no halon bank management programme for connecting recyclable halon to users.
    d. Numerous reports have indicated halon quality is suspect due to lack of controls and infrastructure.

    Thus, while the actual quantities of halons may be substantial, their use is jeopardized by political borders, suspect quality, and uncertain quantities in specific locations.

3. The 2010 HTOC report projected a 2014 halon 1211 bank of approximately 50,000 MT, while the 2014 HTOC report estimates a bank of 33,000 MT. This is because the HTOC has raised its assumed emission rates for halon 1211, based on a recent assessment of the likely emissions from retired portable extinguishers, particularly in A5 Parties.
4. Although the regional disparity in the distribution of halon itself does not constitute necessarily a regional problem, it is anticipated that regional imbalances may result in shortages in one country or region with excesses in other countries and regions.
5. The HTOC has a serious concern that many users are relying on halon imports for their most important uses, such as civil aviation and military.
6. Some A5 users are now encountering difficulties obtaining sufficient quantities of halon, with potential serious consequences.
7. Parties may wish to revisit the global strategic approach to halon bank management in order to avoid a severe supply disruption that would lead to an Essential Use Nomination. This could include development of updated training and awareness materials and programs, which address the harmonization of import and export regulations, purity and other halon bank management needs.

Civil Aviation

1. The fact that alternatives are used only in the lavatory fire extinguishing systems of in-production aircraft is a remarkably disappointing result, especially given the extensive research and testing efforts on aviation applications since 1993.
2. To date, the two low GWP candidates for engine nacelles have not passed all required tests by the civil aviation safety authorities. Airframe manufacturers have chosen not to pursue qualification and installation certification for HFC-125 owing to weight penalties and more recently, growing controls by individual jurisdictions.
3. The civil aviation industry has decided to develop a single agent/approach and has formed the Engine/APU Halon Alternatives Industry Consortium (IC).
4. The International Coordinating Council of Aerospace Industries Associations (ICCAIA) has formed the Cargo Compartment Halon Replacement Working Group (CCHRWG) to begin to coordinate a single industry effort to find an alternative to halon 1301 in cargo bays.
5. While the halon requirements of civil aviation initially appear modest in comparison to the total inventory available today, civil aviation neither owns nor controls the ever reducing quantities of halons needed to support existing aircraft, much less new aircraft, for an additional 30 or more years.
6. Of all the 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.

Military

1. Generally speaking, halon is only required to support legacy systems and their variants, and new military aircraft based on commercial designs with airworthiness certifications. Alternatives are available for all other new system designs.
2. The ultimate requirement of the military sector for halons cannot be calculated owing to the obvious uncertainty of future mission requirements.
3. It is unclear how many military organizations have made provisions to secure long-term supplies of halons.
4. Some military organizations are known to be completely reliant upon sources of halons outside of their own countries.
5. Adverse geopolitical events might lead to increased rates of depletion of known halon stocks and loss of access to out-of-country supplies.
6. Unlike the civil aviation sector, the military sector has incorporated alternatives to halons on many of its newer platforms, reducing its future demand for the diminishing supplies of halons.

Oil & Gas Operations

1. Generally speaking, halon is only required to support legacy facilities; all new facilities are halon-free.
2. Legacy facilities in the far north will continue to require the use of halons in occupied spaces owing to severe ambient (very low temperature) conditions.
3. Facility owners neither own nor control the quantities of halons needed to support operations over the continually extended time horizons. This situation will continue to

place demands on the level of available halon stocks. However, owing to the adoption of alternatives in new facilities, this sector has reduced its future demand for the diminishing supplies of halons.

Alternatives Technologies

1. While no single alternative has been commercialized that covers the wide range of applications of halons, there are a multitude of alternatives that collectively can be used to meet the fire protection requirements of all non-aviation future applications, although with technical or economic penalties, or both and likely civil aviation future applications also with technical or economic penalties. Civil aviation has yet to try to validate and implement technically viable solutions with weight and/or space penalties.
2. Some applications, including those in the military, aviation, and oil & gas sectors, require use of high-GWP chemical alternatives or the original halon to meet the fire protection requirements.
3. Five new low-GWP chemicals are in various stages of evaluation as alternatives for halons; none of these prospective alternatives are expected to be commercially available for years, if at all.

1.0 Global Estimated Inventories of Halons

As in previous assessment reports, the HTOC is providing the most current estimates of inventories for halon 1211 and halon 1301 based on modelling of reported production and estimated emissions. These models have been updated to reflect quantities that have been reported as destroyed and new emission patterns based on the latest information available. For halon 2402, open literature information has been found on production in the former Soviet Union. Based on that information, and other estimates, the HTOC has now developed a model for halon 2402 similar to the halon 1211 and 1301 models.

1.1 Emissions and Inventories of Halon 1301

Table 1-1 provides the HTOC 2014 Assessment of estimates of total production, annual emissions, cumulative emissions and resulting inventories (bank) for halon 1301 from 2014 - 2044. The HTOC model emissions and bank estimates compare quite well with emissions derived from mixing ratios reported by the Science Assessment Panel (SAP) in Scientific Assessment of Ozone Depletion: 2014. The SAP estimated cumulative emissions through 2014 of 108,000 MT, which would provide a remaining bank of 41,000 MT versus the HTOC model estimate of 106,000 MT of cumulative emissions and a remaining bank of 43,000 MT. The emissions and bank for Japan are consistent with those reported by the Japanese Fire and Environment Protection Network. The emissions for Europe are consistent with the latest estimates from O'Doherty et al., (2014) of North West Europe emissions from 1995 – 2013. This implies that a significant amount of halon 1301 is still contained within Europe. Figure 1-1 provides the regional distribution of the global inventory of halon 1301 and shows that according to the HTOC Model for halon 1301, at the end of 2014 nearly 40% of the current inventory of halon 1301 is projected to be in Japan and 33% in North America. Although the regional disparity in the distribution of halon itself does not constitute necessarily a regional imbalance, it is anticipated that regional imbalances may result in shortages in one country or region with excesses in other countries and regions.

Table 1-1: HTOC 2014 Assessment of Current Estimates of Inventories for Halon 1301 in MT

	2014	2019	2024	2029	2034	2039	2044
CUMULATIVE PRODUCTION							
North America, Western Europe and Japan	135,783	135,783	135,783	135,783	135,783	135,783	135,783
former Countries with Economies in Transition	1,385	1,385	1,385	1,385	1,385	1,385	1,385
Article 5	11,643	11,643	11,643	11,643	11,643	11,643	11,643
TOTAL CUMULATIVE PRODUCTION	**148,781**	**148,781**	**148,781**	**148,781**	**148,781**	**148,781**	**148,781**
ANNUAL EMISSIONS							
North America	477	402	338	285	240	195	165
Western Europe and Australia	238	201	170	143	121	99	83
Japan	25	25	25	24	24	24	24
former Countries with Economies in Transition	69	56	45	36	29	22	18
Article 5	393	235	140	83	50	27	16
TOTAL ANNUAL EMISSIONS	**1,203**	**918**	**718**	**572**	**464**	**367**	**306**
CUMULATIVE EMISSIONS							
North America	29,402	31,556	33,370	34,898	36,185	37,232	38,114
Western Europe and Australia	24,511	25,589	26,499	27,267	27,916	28,445	28,892
Japan	10,366	10,490	10,614	10,737	10,859	10,979	11,099
former Countries with Economies in Transition	6,613	6,916	7,161	7,358	7,516	7,638	7,736
Article 5	35,263	36,721	37,590	38,109	38,418	38,585	38,684
TOTAL CUMULATIVE EMISSIONS	**106,154**	**111,272**	**115,234**	**118,369**	**120,893**	**122,879**	**124,525**
INVENTORY (BANK)							
North America	13,654	11,500	9,686	8,158	6,871	5,824	4,942
Western Europe and Australia	6,916	5,838	4,928	4,159	3,511	2,982	2,535
Japan	16,888	16,764	16,640	16,517	16,396	16,275	16,155
CEIT	1,556	1,252	1,008	811	653	531	433
Article 5	3,613	2,155	1,285	766	457	291	192
GLOBAL INVENTORY (BANK)	**42,627**	**37,508**	**33,546**	**30,412**	**27,887**	**25,902**	**24,256**

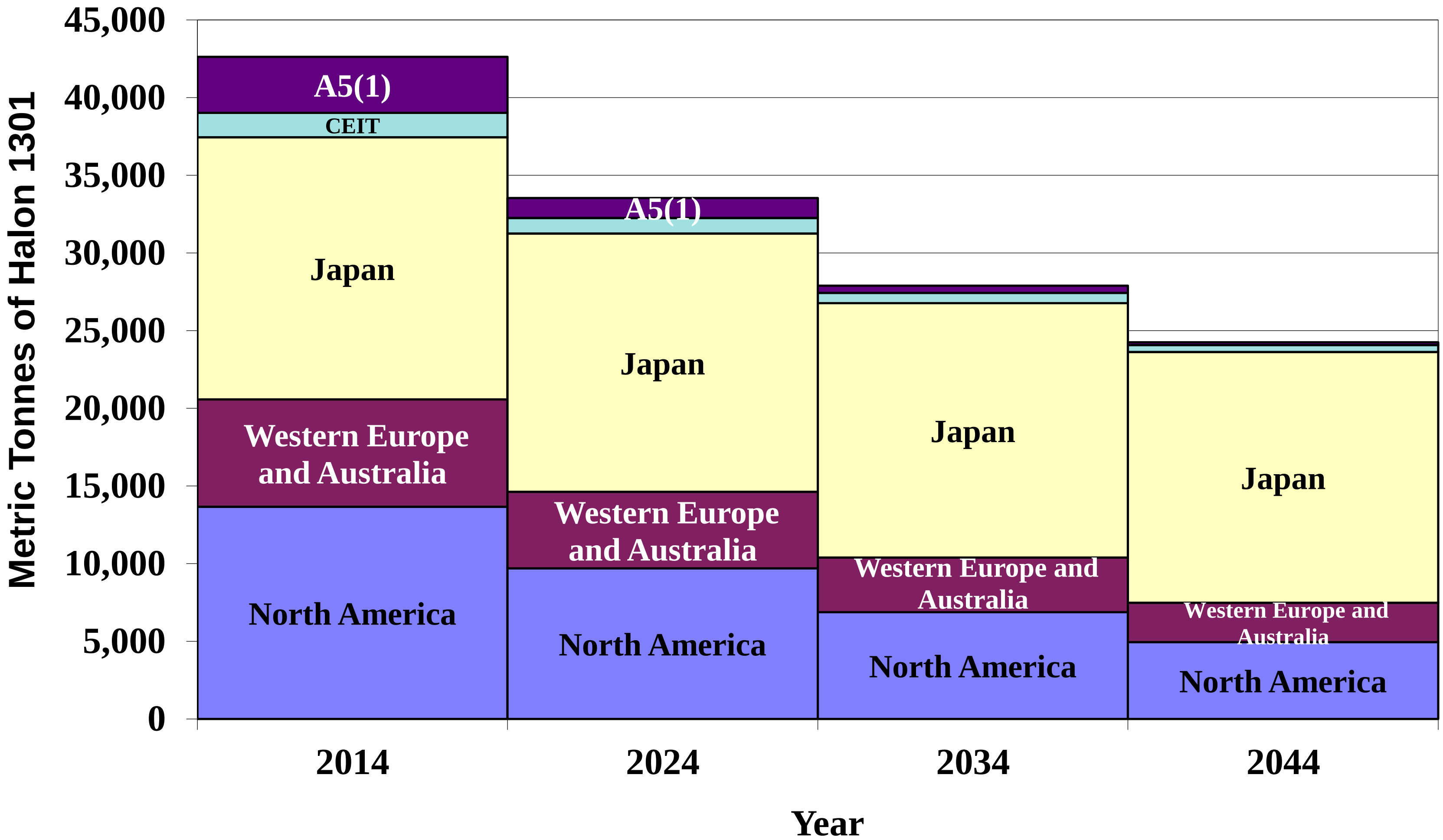

Figure 1-1: Breakout of Global Inventories (Bank) of Halon 1301 by HTOC Model Regions

1.2 Emissions and Inventories of Halon 1211

Table 1-2 provides the HTOC 2014 Assessment of estimates of total production, annual emissions, cumulative emissions and resulting inventories (bank) for halon 1211 from 2014 - 2044. The HTOC is concerned with the status of banking capabilities in some regions of the world and the handling of halon 1211. As a result, the HTOC is changing its assumptions on emissions as a percentage of the bank. It is believed that global emissions of halon 1211 are higher than previously proposed. The HTOC 2014 Assessment has increased the emissions, which results in a significantly smaller inventory (bank) as compared with the 2006 and 2010 Assessments. The HTOC 2010 Assessment projected a 2014 halon 1211 bank of approximately 50,000 MT while the HTOC 2014 Assessment estimates a bank of 33,000 MT. These lower estimates are consistent with emissions derived from mixing ratios reported by the Science Assessment Panel (SAP) in Scientific Assessment of Ozone Depletion: 2014. This is particularly true in light of the very large uncertainty in atmospheric measurement derived emissions and the sensitivity of atmospheric lifetime in estimating emissions. Newland et al., (2013) showed that changing the atmospheric lifetime of halon 1211 from 16 years to 14 years would reduce their 2010 bank estimates from 37,000 MT to 10,000 MT. Conversely, increasing the atmospheric lifetime would reduce the amount of resulting emissions and would increase the size of the bank. The SAP estimated cumulative emissions through 2014 of 291,000 MT and a remaining bank of 22,000 MT versus the HTOC model estimate of 280,000 MT of cumulative emissions and a remaining bank of 33,000 MT. The HTOC emission estimates for North America are consistent with 600 MT average from 2004 – 2006 estimated by Millet et al. (2009) using aircraft measurements. The emissions and bank for Japan are consistent with those reported by the Japanese Fire and Environment Protection Network. The emissions for Europe are consistent with the latest estimates from O’Doherty et al., (2014) of North West Europe emissions from 1995 – 2013, which implies that a significant amount of halon 1211 is still contained within Europe.

Figure 1-2 provides the regional distribution of the global inventory of halon 1211 and shows that according to the HTOC model approximately 25% of the current inventory of halon 1211 is projected to be in Article 5 Parties at the end of 2014. This is significantly lower than the more than 50% projected in the 2010 Assessment, which again is a reflection of HTOC concerns with halon 1211 bank management. Although the regional disparity in the distribution of halon itself does not constitute necessarily a regional imbalance, it is anticipated that regional imbalances may result in shortages in one country or region with excesses in other countries and regions.

Table 1-2: HTOC 2014 Assessment of Current Estimates of Inventories for Halon1211 in MT

	2014	2019	2024	2029	2034	2039	2044
CUMULATIVE PRODUCTION							
North America, Western Europe and Japan	196,601	196,601	196,601	196,601	196,601	196,601	196,601
CEIT	1,040	1,040	1,040	1,040	1,040	1,040	1,040
Article 5(1)	115,817	115,817	115,817	115,817	115,817	115,817	115,817
TOTAL CUMULATIVE PRODUCTION	**313,457**	**313,457**	**313,457**	**313,457**	**313,457**	**313,457**	**313,457**
ANNUAL EMISSIONS							
North America	457	375	308	253	207	170	140
Western Europe and Australia	538	436	371	301	258	211	160
Japan	12	10	8	6	5	4	3
CEIT	61	41	27	18	12	8	6
Article 5(1)	1,024	582	331	189	107	61	33
TOTAL ANNUAL EMISSIONS	**2,092**	**1,445**	**1,045**	**767**	**591**	**454**	**342**
					591	454	342
CUMULATIVE EMISSIONS							
North America	47,774	49,808	51,477	52,847	53,971	54,894	55,651
Western Europe and Australia	74,064	76,446	78,396	80,021	81,351	82,508	83,405
Japan	1,700	1,754	1,798	1,833	1,861	1,883	1,900
CEIT	10,163	10,403	10,564	10,672	10,745	10,793	10,826
Article 5(1)	146,654	150,350	152,453	153,649	154,329	154,717	154,931
TOTAL CUMULATIVE EMISSIONS	**280,355**	**288,761**	**294,688**	**299,021**	**302,257**	**304,795**	**306,713**
INVENTORY (BANK)							
North America	11,342	9,308	7,639	6,270	5,145	4,223	3,466
Western Europe and Australia	12,186	9,804	7,853	6,229	4,899	3,741	2,845
Japan	271	216	173	138	110	88	70
CEIT	730	490	329	221	148	99	67
Article 5(1)	8,573	4,878	2,775	1,579	898	511	297
TOTAL INVENTORY (BANK)	**33,102**	**24,696**	**18,769**	**14,436**	**11,200**	**8,663**	**6,744**

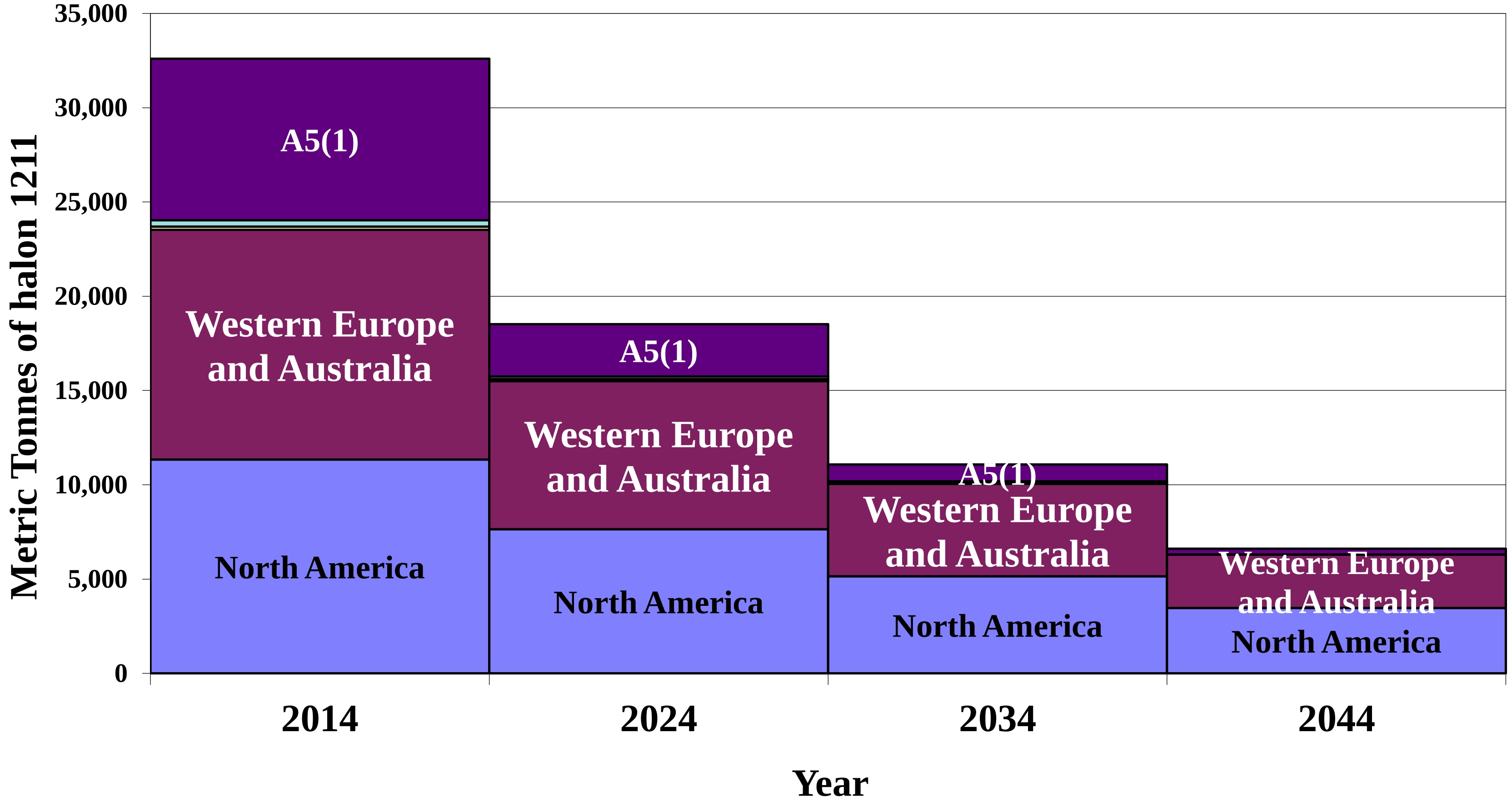

Figure 1-2: Breakout of Global Inventories (Bank) of Halon 1211 by HTOC Model Region

1.3 Emissions and Inventories of Halon 2402.

Table 1-3 provides the HTOC 2014 Assessment of estimates of total production, annual emissions, cumulative emissions and resulting inventories (bank) for halon 2402 from 2014 - 2044. The HTOC model emissions are within about 20% of those derived from mixing ratios reported by the Science Assessment Panel (SAP) in Scientific Assessment of Ozone Depletion: 2014. The SAP estimated cumulative emissions through 2014 of 41,000 MT versus the HTOC model estimate of 50,000 MT of cumulative emissions. It should be noted that this new assessment for halon 2402 was not completed in time for consideration by the SAP and is not included in Scientific Assessment of Ozone Depletion: 2014. The SAP did not have any information on the cumulative production of halon 2402.

The HTOC estimated cumulative production of halon 2402 from Kopylov N.P., Nikolayev V.M., Zhevlakov A.F., Pivovarov V.V., Tselikov V.N., Russian National Strategy for Halon Management, Chimizdat, StPetersburg-Moscow, 2003, 39 pp. (in Russian) and by assuming the difference between total Article 7 production data for halon in non-Article 5 and the halon 1211 and 1301 quantities used in the HTOC models, represents additional halon 2402 production outside of the former Soviet Union from the years 1986 - 2010. This difference represented 7% of the total quantity of halon produced over that period. To estimate the 1963 – 1985 production, the 7% factor was applied to the halon 1211 and 1301 production quantities per year. The resulting bank of halon 2402 in 2014 was 9,000 MT.

Table 1-3: HTOC 2014 Assessment of Current Estimates of Inventories for Halon2402

	2014	2019	2024	2029	2034	2039	2044
CUMMULATIVE PRODUCTION							
North America, Western Europe and Japan	23,333	23,333	23,333	23,333	23,333	23,333	23,333
CEIT	35,558	35,558	35,558	35,558	35,558	35,558	35,558
Article 5(1)	-	-	-	-	-	-	-
TOTAL CUMMULATIVE PRODUCTION	**58,891**	**58,891**	**58,891**	**58,891**	**58,891**	**58,891**	**58,891**
ANNUAL EMISSIONS							
North America	57	42	31	23	17	12	9
Western Europe and Australia	134	94	66	47	33	23	16
Japan	12	10	8	7	6	5	-
CEIT	391	275	193	136	96	67	47
Article 5(1)	45	30	21	14	10	6	4
TOTAL ANNUAL EMISSIONS	**639**	**451**	**319**	**227**	**162**	**113**	**76**
CUMMULATIVE EMISSIONS							
North America	4,930	5,168	5,344	5,473	5,568	5,638	5,690
Western Europe and Australia	8,662	9,208	9,591	9,861	10,050	10,184	10,278
Japan	860	915	959	996	1,026	1,051	1,064
CEIT	30,202	31,792	32,909	33,696	34,248	34,637	34,910
Article 5(1)	5,278	5,456	5,577	5,659	5,715	5,753	5,779
TOTAL CUMMULATIVE EMISSIONS	**49,932**	**52,539**	**54,380**	**55,685**	**56,607**	**57,263**	**57,721**
INVENTORY							
North America	903	665	489	360	265	195	143
Western Europe and Australia	1,838	1,292	909	639	449	316	222
Japan	306	252	207	171	140	116	103
CEIT	5,356	3,766	2,649	1,862	1,310	921	648
Article 5(1)	556	377	256	174	118	80	54
TOTAL INVENTORY	**8,959**	**6,352**	**4,510**	**3,206**	**2,282**	**1,628**	**1,170**

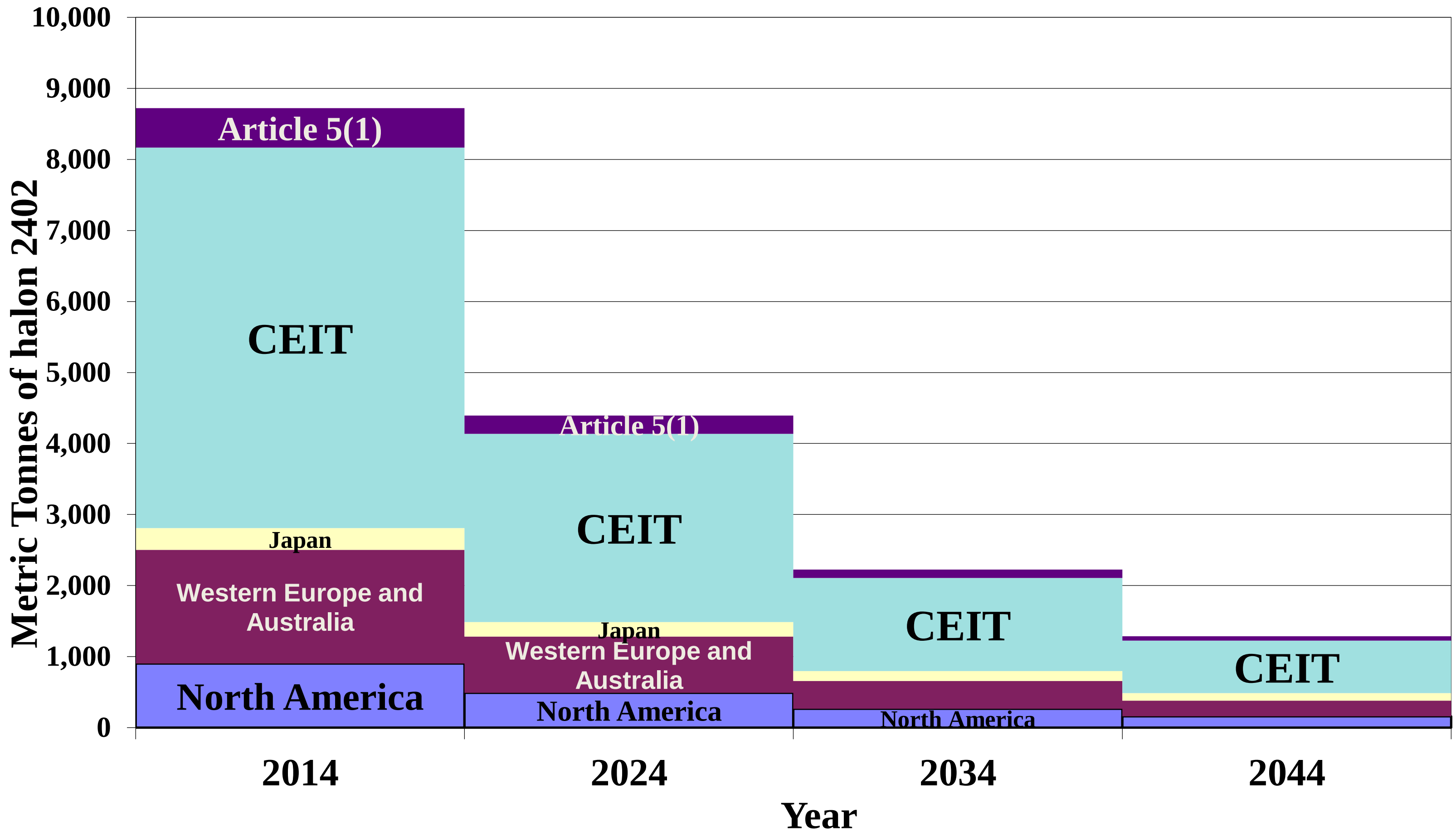

Figure 1-3: Breakout of Global Inventories (Bank) of Halon 2402 by HTOC Model Region

2.0 Civil Aviation

2.1 Introduction

Aviation applications of halon are among the most demanding uses of the agents, requiring their suppression effectiveness at an acceptable toxicity. 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. Given the anticipated 25–30 year lifespan of a newly produced civil aircraft, halon 1301 dependency could continue beyond the time when recycled halon is readily available. A separate Supplementary Report on the status of halon and its alternatives in use in civil aviation has been produced, and is summarised below.

2.2 Estimated Halon Installed Base and Emissions

The halon 1301 and halon 1211 installed base estimates for mainline and regional aircraft were developed using activity data and fleet assumptions. The total worldwide fleet for 2014 is estimated to be approximately 21,000. In order to estimate the installed halon base, activity data for engine nacelles, cargo compartments, APUs, lavex systems, and handheld applications from previous analyses was used, as well as feedback from airframe manufacturers. It is estimated that for 2014, there is approximately 1,500 MT of halon 1301, and approximately 200 MT of halon 1211 installed across the mainline and regional fleet.

HTOC Supplemental Report #1: *Civil Aviation*, details the calculations used for these estimates, and also provides estimates for the years 2020, 2025 and 2030.

2.3 Halon Banks

At present, the halon demands of aviation are being met by recycling agent being withdrawn from applications in other industries and decommissioned aircraft. This source of supply will be dramatically reduced long before the aircraft now being built and fitted with halon systems are retired. Of all sectors, civil aviation is the least prepared to deal with diminishing halon supplies.

Civil aviation has only instituted a halon replacement for its smallest use, lavatory trash receptacle extinguishing systems (lavex), estimated to be less than 0.5% of its total installed base on aircraft. Its two largest uses, engine nacelles/APUs and cargo compartments, continue to have no alternatives available to be approved by aviation authorities. With the ultimate exhaustion of supplies, this sector will most likely be the one to request an Essential Use Nomination in the future.

2.4 Status of Halon Replacement Options

With the exception of some lavatory trash receptacles, there has been no retrofit of halon systems or portable extinguishers with available alternatives in the existing worldwide fleet of aircraft.

2.4.1 Lavatory Trash Receptacle

Research and testing has shown that there are suitable alternative suppression systems (using HFC-227ea or HFC-236fa).

2.4.2 Handheld Extinguishers

As of 2003, three halon alternatives, HFC-227ea, HFC-236fa and HCFC Blend B, have successfully completed all of the required Minimum Performance Standard (MPS) tests and handheld extinguishers are commercially available. One other halon alternative, 2-BTP, is in the process of being commercialized. Qualification is needed prior to airline use, however, and to date this has not happened.

2.4.3 Engine and APU Compartment

HFC-125 has been used successfully as an alternative to halon for engine fire protection on US military aircraft developed since the early 1990s. In addition, HFC-125 is currently being specified for use on a military derivative of a large commercial aircraft currently under development (Boeing 767; military derivative KC-46). HFC-125 has increased space and weight characteristics that present installation and environmental concerns. Based on these issues, airframe manufacturers have chosen not to pursue qualification and installation certification for HFC-125 in engines/APUs.

The civil aviation industry has now decided to develop a single agent/approach and has formed the Engine/APU Halon Alternatives Research Industry Consortium (IC). The IC has mapped out a 3 phase multi-year approach for alternatives development.

2.4.4 Cargo Compartments

The International Coordinating Council of Aerospace Industries Associations (ICCAIA) has formed the Cargo Compartment Halon Replacement Working Group (CCHRWG) to begin to coordinate a single industry effort to find an alternative to halon 1301 in cargo bays. Current best estimates are that it will take somewhere between 3½ and 6 years to transition from proof of concept to a point where a type certificate can be applied for.

2.5 Regulatory Timelines

ICAO Resolution A37-9 mandates halon replacement in ICAO standards in lavatory fire extinguishing systems used in aircraft produced after December 30, 2011; in hand-held fire 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 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.

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.

2.6 New Generation Aircraft

The civil aviation regulatory authorities should closely monitor and ensure that the testing and approval of alternatives for engine nacelle and cargo compartment applications is completed in the near-term for new airframe designs. New airframe designs should take into account these tested and approved alternative fire suppression agents and systems. However, this is not happening to date. The timing of the inclusion of the available halon alternatives in new aircraft designs remains uncertain, and unless the processes of designing, conforming, qualifying and certifying new extinguishing systems on civil aircraft are made a priority by the airframe manufacturers and approval authorities – and expedited accordingly – these are significant barriers to the transition away from halons and will place an increasing burden on the diminishing supplies of halons.

As reported in the 2010 HTOC Assessment, it is markedly disappointing that, given the extensive research and testing efforts that have been expended on aviation applications since 1993, alternatives are used only in the lavatory fire extinguishing systems of new Airbus, Boeing and Embraer aircraft systems and not yet for any engine/APU, cargo bay, or hand-held extinguisher applications.

2.7 Crash Rescue Vehicles

In addition to on-board civil aircraft applications, halon 1211 is used in some Aircraft Rescue and Fire Fighting (ARFF) or Crash Rescue vehicles on airport ramps. Since 1995 a significant number of airports in the United States have used HCFC Blend B as an alternative to halon 1211 for this application. However, because HCFC Blend B is an ODS, national regulations may limit its use for this application in other countries.

The HTOC Supplementary Report #1: *Civil Aviation*, can be found on the Ozone Secretariat website at:

http://montreal-protocol.org/new_site/en/assessment_panels_bodies.php?committee_id=6

under the HTOC reports.

3.0 Military Applications

Many Parties' defence ministries and military organisations have invested substantial resources to minimize the inadvertent release of halons, recover and recycle these chemicals, and stockpile them for future use where alternatives cannot be implemented. These reserves are, in many cases, being carefully managed to support a number of weapon system applications for the remainder of their service lives or until alternatives can be fitted. At a time when many military budgets are decreasing in real terms, service life extension programmes are commonly being planned and implemented to maintain many of these weapon systems and equipment well past their originally intended design lives. This means that much of today's fielded equipment will remain in operation, and their halon mission-critical fire protection systems will need to be supported, to 2050 and potentially beyond.

Military fire protection systems are unique in that, besides protecting against 'peacetime' fires from routine use, including equipment failures, they must protect military personnel and platforms from the consequences of combat damage. Fires due to combat events are generally very fast-growing and relatively large and military fire protection systems are required to counter these, including in some cases also providing explosion protection for normally-occupied spaces.

Table 3-1 summarises where halons are being used in military applications and where and which alternatives have been implemented by various Parties, or could potentially be suitable, in new designs and to convert existing equipment and facilities. The status of alternatives remains largely unchanged from the 2010 HTOC Assessment report.
There are no universal fire protection requirements for military applications. For example, some navies rely on halons as a key element of their fire protection strategies for submarines while others prohibit their use for this equipment due to the potential hazard from combustion by-products (for example, acid gases including HF, HBr, and/or HCl as well as carbonyl species such as COF_2, depending on the particular halon used) that are inevitably generated by thermal breakdown of the agent during fire suppression. Similarly, levels of these toxic combustion by-products are a key consideration for agent selection for ground vehicle crew compartment fire extinguishing systems for some militaries while others have not established any limits for these potentially toxic compounds. These examples illustrate the fact that a suitable alternative for one Party may not be acceptable to another.

3.1 Ground Vehicle Applications

In 2010 the US Army reported on an extensive research program that, among other results, demonstrated that drop-in replacements for halon 1301 and hybrid HFC-227ea / Sodium Bicarbonate (HFC-227BC) based crew protection systems were not feasible with currently available extinguishing agents and systems. These results were based on tests conducted in a vehicle mock-up. In 2011 the US Army completed that research with tests on a legacy vehicle protected by halon 1301 and similar results were obtained.

In 2013 the US Army reported the development of a drop-in replacement unit for its halon 1301 handheld fire extinguisher that is based on HFC-227ea in combination with nanoparticulate sodium bicarbonate, and has developed Military Specifications for the units. However, to date none have been deployed.

Some Parties have made considerable progress since the 2010 HTOC Assessment Report. For example, the UK has converted the engine compartment fire protection systems of all its in-service armoured fighting vehicles to HFC alternatives and replaced halon portable extinguishers in the vehicle crew compartments. Additionally, several Parties have considered conversion programs that would replace halon 1301 in crew protection systems with a more environmentally friendly agent based upon an HFC/powder blend. Some continue to pursue this alternative because its performance has been shown to be comparable to halon 1301, while others have reservations about its use due to the short-term reduction in visibility and powder residue. Although this agent has a high-GWP, the Parties that have adopted it are not likely to be able to replace it in the foreseeable future due to the lack of other viable alternatives and the significant additional investment that would be required.

In general, vehicle halon replacement programmes have, to date, not proceeded further for a number of reasons including:

- There is concern that production or use of high-GWP HFCs may be limited in the future.
- An HFC or other alternative system generally requires more space and is heavier than the halon 1301 system it replaces.
- Potentially unacceptable levels of toxic combustion products may result from systems utilising fluorinated halocarbon alternatives.
- Converting a fielded platform to a new extinguishing system may be very expensive and demand considerable resources for a significant period of time.

3.2 Military Aviation Applications[1]

Halon replacement can only be achieved when there are technically and economically feasible alternatives available. To date, many military aviation applications have continued to rely on halons as the only viable option. As an example, the A400M military cargo aircraft has been ordered by eight European and Asian countries (Germany, France, Spain, United Kingdom, Turkey, Belgium, Luxembourg, and Malaysia) and entered service in late 2013 using halon 1301 for its engine nacelle fire extinguishing system. The extinguishers are installed at the back of each engine nacelle using the very limited space available. Halon 1301 is used due to its fire extinguishing capability under the wide range of operating conditions that are likely to be experienced. The A400M and its halon 1301 extinguishing system are expected to have a minimum service life of 30 years; a retrofittable alternative is unlikely to be available for the foreseeable future due to the complex technical issues associated with the current aircraft design.

On the other hand, after substantial development effort, the halon systems initially used in the protection of engines and auxiliary power units (APUs) in the prototype US F-22 stealth fighter have been replaced with an HFC-125 system for the production aircraft. The aircraft is designed to have a minimum service life of 30 years so support for the current system will be required beyond 2040; it is not likely this system will be converted to a lower-GWP agent in the foreseeable future.

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[1] Note: This section should be read in conjunction with Supplementary Report #1 on civil aviation.

3.3 Naval Applications

The halons are no longer required or being installed in new designs of naval vessels. However, they continue to be used in critical legacy applications, including on some submarines and in certain ship areas.

- In naval vessels, HFC-227ea, fine water spray, hybrid HFC-227ea/water spray, foam or carbon dioxide systems are being used for the main machinery and other spaces of new vessels operated by some Parties. However, carbon dioxide systems are prohibited in all spaces on all new US naval vessels due to crew safety considerations.
- On existing naval vessels operated by some Parties, conversion programs continue for normally-unoccupied spaces such as paint lockers and diesel or gas turbine modules. In these applications, carbon dioxide or HFC extinguishants have been found acceptable. Australia and Germany have converted some main machinery space halon systems to HFC-227ea and carbon dioxide, respectively. In Denmark, where HFCs are not acceptable because of national legislation, inert gas systems have been installed to protect the engine compartments of some surface ships. When considering inert gas systems for naval vessels, the weight and space occupied by the system must be considered. For the protection of identical spaces, inert gas systems require agent storage cylinders weighing over three times the cylinders' weight of an HFC-227ea or FK-5-1-12 system. For those same systems, the inert gas storage cylinders occupy over three times the deck space of HFC-227ea or FK-5-1-12 cylinders.

3.4 Conclusion

Since the 2010 Assessment Report, the pace of research and development to evaluate and implement halon alternatives in military applications has slowed significantly. This is attributable, in large part, to the lack of potentially viable new alternatives being developed and marketed by industry. Most, if not all, commercially available extinguishing agents have been assessed against the range of unique military fire protection requirements. Alternatives have been adopted in some cases where they have been found to be technically and economically feasible, but applications remain where halons, and several of the high-GWP HFCs, are the only viable fire and explosion protection solution to maintain Parties' levels of national security and the safety of their military personnel and equipment. This is likely to be the case for the foreseeable future.

While no blanket conclusions can be drawn regarding the viability of more environmentally benign replacement agents for these unique military fire protection applications, it is clear that, without major progress in the development of better alternatives, there will continue to be a need for recycled halons and high-GWP HFCs for a substantial number of military critical uses at least until the middle of the century. However, unlike the civil aviation sector, the military sector has incorporated alternatives to halons on many of its newer platforms, reducing its future demand for the diminishing supplies of halons.

Table 3-1: Continuing Uses of Halons and Examples of Implemented and Potential Alternatives in the Military Sector

Application	Protected Space	Primary Protected Risk	Halon	Implemented & Potential Alternatives (1)	
				In conversions of Existing Equipment	In New Designs and Major Modifications of Equipment
Armoured Fighting Vehicle	Engine Compartment	Class B	1301, 1211, 2402	HFC-227ea, HFC-236fa, 2-BTP, Dry Chemical, Inert Gas	HFC-227ea, HFC-236fa, HFC-125, 2-BTP, Dry Chemical
	Crew Compartment	Class B (explosion)	1301, 2402	HFC-227BC, HFC-236fa	HFC-227BC HFC-236fa
	Portable Extinguisher	Class A, B, electrical	1211, 1301, 2402	CO_2, 2-BTP, Dry Chemical, Water/Potassium Acetate, HFC-236fa, HFC-227ea	CO_2, 2-BTP, Dry Chemical, Water/Potassium Acetate, HFC-236fa, HFC-227ea
Aircraft	Engine Nacelle	Class B	1301, 1211, 2402	None	HFC-125, 2-BTP, FK-5-1-12, Powdered Aerosol F
	APU	Class B	1301, 1211, 2402	None	HFC-125, 2-BTP, FK-5-1-12, Powdered Aerosol F
	Dry Bay	Class B (explosion)	1301, 2402	None	IGG, Dry Chemical
	Cargo Bay	Class A (deep-seated)	1301, 2402	None	Water Mist plus nitrogen (2)
	Fuel Tank Inerting	Class B	1301, 2402	None	OBIGGS, Fire Suppression Foam
	Cabin Portable Extinguisher	Class A, B, electrical	1211, 1301, 2402	HFC-227ea, HFC-236fa, 2-BTP, HCFC Blend B (3)	HFC-227ea, HFC-236fa, 2-BTP, HCFC Blend B (3)
	Lavatory (waste bin)	Class A	1301	HFC-227ea, HFC-236fa, FK-5-1-12, 2-BTP	HFC-227ea, HFC-236fa, FK-5-1-12, 2-BTP
Airfield	Hardened Aircraft Shelter	Class B	1301	Foam	Foam
	Crash Rescue Vehicle	Class B	1211	Dry Chemical, HCFC Blend B (3)	Dry Chemical, HCFC Blend B (3)
	Fight Line (Portable) Extinguisher	Class B	1211	CO_2, Dry Chemical, Foam, HCFC Blend B (3)	Dry Chemical, Foam, HCFC Blend B (3)

Note 1: The listed alternatives are indicative only and may not be suitable for the applications in all examples of the equipment or facility concerned. Circumstances vary and the suitability of any alternative for any particular equipment or facility must be assessed by competent personnel on a case-by-case basis. Other unlisted alternatives may also prove to be suitable and the full range of options, as outlined in UNEP HTOC Technical Note #1, should be considered at the outset of any halon replacement activity.

Note 2: Water mist plus nitrogen has met the applicable FAA Minimum Performance Standard and a system is in the early stages of commercialization.

Note 3: HCFC Blend B is not an acceptable halon alternative under some jurisdictions because as an ODS it is being phased out under the Montreal Protocol.

Application	Protected Space	Primary Protected Risk	Halon	Implemented & Potential Alternatives (1)	
				In conversions of Existing Equipment	In New Designs and Major Modifications of Equipment
Naval Vessel (Surface Ship)	Main Machinery Space (Normally Occupied)	Class B	1301, 2402	HFC-227ea, CO_2, HFC-227ea/Water Spray	HFC-227ea, CO_2, HFC-227ea/Water Spray, Water Mist, Foam
	Engine Space/Module (Normally Unoccupied)	Class B	1301, 1211	HFC-227ea, 2-BTP, CO_2, Dry Chemical	HFC-227ea, 2-BTP, CO_2, PGA
	Flammable Liquid Storeroom	Class B	1301, 2402	Dry Chemical	HFC-227ea, HFC-227ea/Water Spray, FK-5-1-12
	Electrical Compartment	Class A, Electrical	1301, 2402	HFC-227ea, HFC-236fa, FK-5-1-12, Inert Gas	HFC-227ea, HFC-236fa, FK-5-1-12, Inert Gas
	Fuel Pump Room	Class B	1301	None	Foam, HFC-227ea FK-5-1-12
	Command Centre	Class A, Electrical	1301, 2402	None	HFC-227ea, FK-5-1-12
	Flight Line/Hangar (Portable Extinguisher)	Class B	1211, 2402	Foam, Dry Chemical	Foam, Dry Chemical
Naval Vessel (Submarine)	Machinery Space	Class B	1301, 2402	None	Foam, Water Mist
	Diesel Generator Space	Class B	1301, 2402	None	Foam, Water Mist
	Electrical Compartment	Class A, Electrical	1301, 2402	None	None
	Command Centre	Class A, Electrical	1301	None	None
Facilities	Command Centre	Class A, Electrical	1301, 2402	HFC-227ea, FK-5-1-12, CO_2	Water Sprinkler, Inert Gas, HFC-227ea, FK-5-1-12, CO_2
	Research Facility	Class A, B, Electrical	1301	Water Sprinkler, CO_2, Inert Gas, HFC-227ea, FK-5-1-12	Water Sprinkler, Inert Gas, HFC-227ea, FK-5-1-12, CO_2
	Computer Centre	Class A	1301, 1211, 2402	Water Sprinkler, CO_2, Inert Gas, HFC-227ea, FK-5-1-12	Water Sprinkler, Inert Gas, HFC-227ea, FK-5-1-12, CO_2
	Portable Extinguisher	Class A, B, Electrical	1211, 2402	CO_2, Dry Chemical, Foam, FK-5-1-12, HFC-236fa, 2-BTP, HCFC Blend B (3)	CO_2, Dry Chemical, Foam, FK-5-1-12, HFC-236fa, 2-BTP, HCFC Blend B (3)

4.0 Pipelines / Oil and Gas

In its 2010 Assessment, the HTOC detailed the status of the use of halons and their alternatives in pipelines and the oil and gas industry. The primary need for halons is for the maintenance of legacy systems used to prevent explosions and to suppress fires in inhospitable locations such as the Alaskan North Slope in the United States and parts of the former Soviet Union. Essentially the situation remains unchanged.

In most cases, existing facilities were designed and constructed with halon 1301 fixed systems as an integral part of the safety system design as well as the physical layout of the facility. As with civil aviation, after extensive research, it has been determined that in some cases the retrofit of such facilities with currently available alternative systems is not economically feasible, and that current research is unlikely to lead to an economic solution. Thus, these facilities will likely rely on existing halon banks for their operating lifetimes.

For new facilities, companies are adopting an inherently safe design approach to the protection of their facilities. This means preventing the release of hydrocarbons and eliminating the availability of flammable or explosive materials. Only when all such measures have been considered, and a residual risk of the hazard still remains, are other risk reducing measures considered. In most cases, new technology detection systems are employed to shut-down and blow-down processes, and turn on high rate ventilation systems rather than closing up the space and trying to inert it with an extinguishing agent. However, where an inerting agent is still required in occupied spaces, halon 1301 has been replaced by HFC-23 or FK-5-1-12, if temperatures permit. Currently, HFC-23 is the only alternative that can be used in very cold climatic conditions.

Halon 1301 is also used for fire and explosion suppression systems that protect offshore oil exploration platforms in the tropical climatic zone in Asia.

Article 5 Parties in the Asia pacific region, including India, use halon 1301 systems in refineries, gas pumping stations and offshore oil platforms. Refineries and oil pumping stations have/are gradually switching over to dry powders in pumping stations, HFC-227ea, FK-5-1-12, and inert gases in refineries where it is technically feasible given space and weight concerns. For offshore oil platforms, space and weight are still a big concern and thus the replacement of old legacy systems and those systems on new platforms have been delayed. Thus for such applications halon requirements still exist. Oil companies are obtaining this halon from local sources of recovered halon, which they use to refill existing cylinders. However, there is no halon recycling, banking or quality testing facility for such recovered halon in this part of Asia. Therefore the quality and effectiveness of such recovered halon is currently a major concern. In land based halon 1301 systems, where a clean agent is important, some oil companies are hesitating to switch over to HFCs because of their high GWP as they do not want to switch over twice. HFC-23 has never been used in this region by the oil industry.

Owing to the adoption of alternatives in new facilities, this sector is reducing the burden on the ever reducing current supplies of halons.

5.0 Global/Regional Supply and Demand Balance

As of January 1, 2010, all halon production and consumption, as defined by the Montreal Protocol, for fire protection ceased. Additionally, there has been no essential use halon production since 2000 (as authorised by Decision VIII/9). Nevertheless, halon 1301 (CF_3Br) continues to be produced for use as a feedstock in the manufacture of the pesticide Fipronil.

With no global production of halons for fire protection uses, management of the remaining stock remains crucial for ensuring sufficient halons for applications that need them. There is currently no demand for new halons, which has been made possible through the availability of substitute fire extinguishing agents and alternatives for new systems, halon recycling programs to support mainly existing systems, and implementation of Best Practices to minimise emissions. Based on a review of the situation in a large number of Parties, with the exception of aviation and military, it has been concluded that generally halons have been replaced by substitutes for all new applications where halons were traditionally used. Even so, the demand for recycled halons remains high for existing applications in some Parties. The global trade in recycled halons is robust, but difficulties have been reported in obtaining quantities beyond a few months' supply by some Parties, and in obtaining the necessary government permits for import and export of halons.

In Decision XXI/7 the Parties were requested to report their projected needs for, and shortages of, halons to the Ozone Secretariat for use by the HTOC. To date the Parties have not indicated to the Ozone Secretariat that they are unable to obtain halons to satisfy their needs, although some Parties have expressed cost concerns to HTOC members. There are also indications that there are stocks of halons in some countries and regions that are not being recycled on the global market.

Based on current data reported to the Ozone Secretariat, and information from industry, the HTOC has concluded that there is no global halon imbalance at this time, i.e., demand is being satisfied by the available supply. Nevertheless, with many important halon users such as military and civil aviation relying on month to month supplies, the possibility of a supply disruption increases with time as the available supplies are depleted.

It has become apparent that for several uses, ready-to-use halons can only be obtained from a few countries in the world. However, without additional data on projected needs/shortages/surpluses, especially for civil aviation and military, from the Parties, the HTOC cannot quantify potential imbalances beyond noting that demand seems to remain steady and supply seems to remain available, but is only adequate for current needs. Therefore the HTOC is concerned that the likelihood of a supply disruption is increasing for those who must rely on halons for their most important uses. The lack of progress in implementing halon alternatives for the three largest (out of 4) civil aviation uses is troubling to the HTOC as the installed quantities of halon 1301 in civil aviation as a percentage of the available global quantities continues to increase annually.

6.0 Global Halon 1211, 1301, and 2402 Banking

A Halon bank is defined as all halons contained in fire extinguishing cylinders and storage cylinders within any organisation, country, or region. Likewise, the 'global halon bank' is all halon presently contained in halon fire equipment plus all halon stored at halon recycling centres, at fire equipment companies, at halon users' premises, etc., i.e., it is all halon that has been produced but has yet to be emitted or destroyed. The collection, reclamation, storage, and redistribution of halons are referred to as "Halon Banking".

Many Parties have halon banking programs that are fully operational, but more Parties have not implemented any program nor planned for the needs of their remaining uses. Furthermore, it has become clear that historical knowledge has been lost and a significant number of individuals now responsible for halon management and phase out are unfamiliar with the issues surrounding halon use, recycling, and banking. In short, there is currently a systemic failure in organizational memory that has become evident to HTOC members as we attempt to collect information on halon banking and this failure is being seen by fire protection consultants as they work with various countries/organizations on issues related to acquiring halons to meet their continuing needs.

Halon 2402 is still being used in Europe, central Asia, and Japan. Russia is the largest user of halon 2402. The 'market' appears to be balanced. Most critical uses are in the military sector. Data shows no increase in demand and no increases expected in the future. Contaminated agent and mixtures have entered the market.

The HTOC Supplementary Report #2: *Global Halon 1211, 1301, and 2402 Banking*, provides guidance on these matters, and can be found on the Ozone Secretariat website at:

http://montreal-protocol.org/new_site/en/assessment_panels_bodies.php?committee_id=6

under the HTOC reports.

7.0 Fire Protection Alternatives To Halons

Halons are fully-halogenated carbon-based molecules containing bromine. In a flame bromine atoms in a halon molecule readily detach to form bromine radicals (Br·). Bromine radicals have unique chemical reactivity characteristics that result in the efficient deactivation of other radicals (especially OH·, H·, and O·) that are essential to flame propagation. Reduction of the population of these flame-essential radicals from combustion gases leads to prompt flame extinguishment. For this reason some halon compounds were adopted into use, beginning in the 1950s, as fire extinguishing agents. Three halon compounds (halon 1301, halon 1211, and halon 2402) were adopted for use in a wide range of highly varied and critically important fire protection applications. Halon 1301, having a boiling point of -57.75 °C, and which has low toxicity at use concentrations, became the "total-flooding" extinguishing agent of choice wherever fire extinguishing systems, that did not use water, were required in occupied spaces. Halon 1211, having a boiling point of -3.7 °C, has acceptable toxicity characteristics that led to its wide adoption for use as an efficient "streaming" agent in portable or wheeled extinguisher units. Halon 2402, a liquid with a boiling point of 47.3 °C, is a potent fire extinguishing agent that found use in some military and industrial explosion protection applications.

The promulgation of the Montreal Protocol in 1987 meant that the manufacture of halons, which are potent ozone-depleting substances (ODSs), would eventually cease. By the 1980s the use of halons had become very important in fire protection applications world-wide. Manufacturers of halons promptly began research into new chemicals and gases that could serve as effective total-flooding and streaming fire extinguishants. An important attribute of halon alternatives was that they needed to have low toxicity to prevent injury to people who may be accidentally exposed to agent vapours.

The subject of fire protection alternatives to halons was addressed at length in earlier editions of the HTOC Assessment Reports. For the 2014 Assessment Report the Halon Technical Options Committee elected to move the contents of this chapter to Technical Note #1: *Fire Protection Alternatives to Halons*, where it can be continuously updated as new alternatives are developed.

Technical Note #1 can be found on the Ozone Secretariat website at:

http://ozone.unep.org/en/assessment_docs.php?committee_id=6&body_id=4&body_full=Halons Technical Options Committee&body_acronym=HTOC

under the HTOC reports.

8.0 Climate Considerations for Halons and Alternatives

Hydrofluorocarbons (HFCs) have been commercialised as replacements for halons. The development of these and other alternatives for use in fire and explosion suppression applications, as outlined in Technical Note #1, was instrumental in achieving the halon production phase out mandated by the Montreal Protocol.

Emissions of HFCs currently represent approximately 1-2% of total GHG emissions; however, there are projections that show emissions increasing to much higher levels in the future. Emissions of HFCs from fire protection are estimated at less than 1% of total HFC emissions from all sources. The impact on climate change of HFCs in fire protection is estimated to be 0.015% and 0.05% of the impact of all GHGs in the US[2] and EU[3], respectively.

The Technology and Economic Assessment Panel (TEAP) Decision XXIV/7 Task Force Report estimates that from 2008-2012 about 1% of global HFC sales were for fire protection applications[4]. Sales of HFCs in the fire protection sector are reported as growing in the Middle East and Asia regions, but are flat in North America, Latin America, and Europe.

The principal HFC used in total flooding fire protection systems is HFC-227ea, and annual emissions are estimated to be 3% of the installed base. Using HFC-227ea global emissions data reported by Laube et al. and Vollmer et al.[5], and subtracting the estimated non-fire protection emissions, the TEAP Decision XXV/5 Task Force estimated that the installed base of HFC-227ea in fire protection, from the period 2006 – 2010, is in the low tens of thousands of metric tonnes (30,000 – 50,000 MT range). However, it should be noted that there are a lot of uncertainties associated with the various estimates and thus ultimately this estimate should be considered order-of-magnitude only.

The principal HFC used in portable extinguishers is HFC-236fa, and annual emissions are estimated to be 4% of the installed base. As was the case for HFC-227ea, there are other non-fire protection uses of HFC-236fa. However, unlike HFC-227ea, there is little information available on the relative take-up of HFC-236fa in the fire protection market. The results of the total emissions of HFC-236fa provided in Vollmer et al. are only 160 MT in 2010 as compared with HFC-227ea total emissions of 2530 MT, more than one order of magnitude different. As it is not known how much of these emissions can be attributable to fire protection, the TEAP Decision XXV/5 Task Force decided the best that can be done is to bound the issue. If the fire protection installed base is responsible for 90% of these emissions, the fire protection installed base in 2010 would be in the low thousands of metric tonnes (3000 - 4000 MT range), which is an order of magnitude less than for the HFC-227ea fire protection installed base. If the fire protection installed base is responsible for only 10% of these emissions, the fire protection installed base in

[2] Inventory of U.S. GHG Emissions and Sinks: 1990-2012, U.S. EPA, April 15, 2014

[3] Annual European Union GHG Inventory 1990-2012 and Inventory Report 2014, 27 May 2014

[4] TEAP Decision XXIV/7 Task Force Report, September, 2013

[5] TEAP Decision XXV/5 Task Force Report, September 2014.

2010 would be in the low to mid hundreds of metric tonnes (300 - 500 MT range), which is two orders of magnitude less than for the HFC-227ea fire protection installed base.

In its response to Decision XXIV/7, the TEAP concluded that if an environmentally sound alternative agent works in any specific application there is no barrier to its adoption other than economic considerations. However there are a small number of fire protection applications that may still require halons, HCFCs, or HFCs such as oil and gas production facilities in very cold climates, crew bays of armoured vehicles, military and civilian flight lines, aircraft rescue and fire fighting vehicles, and systems/extinguishers on civil aircraft. Thus, from a total environmental impact perspective, is it better to reuse an already produced, recycled, halon or produce a high-GWP HFC for the application? This is a challenge that the Parties may wish to consider.

9.0 Recommended Practices for Recycling Halon and Halocarbon Agent Alternatives

With the halt in production of halons, recycled halon became the sole replenishment source for the recharge of halon extinguishers and extinguishing systems. Indeed, the use of recycled halocarbons has emerged as the preferred source to recharge other halocarbon systems and extinguishers, even though these halocarbons continue to be manufactured.

Faced with this high reliance on recycled agents for the replenishment of agent in extinguishers and extinguishing systems, it is essential that "used" agents be properly processed in order to remove impurities and return the agent to a purity level consistent with newly manufactured agent. Furthermore, the participants in the agent resupply industry must have the technical ability to test and certify that the agents being offered for replenishment are indeed free of impurities. Without that ability rigorously applied, there can be no credible halon or halocarbon clean agent resupply industry.

Guidance on the practices for recycling halon was addressed in earlier editions of the HTOC Assessment Reports. For the 2014 Assessment Report the Halon Technical Options Committee elected to move the contents of this chapter to Technical Note #4: *Recommended Practices for Recycling Halon and Halocarbon Agent Alternatives*, where it can be continuously updated as necessary.

Technical Note #4 can be found on the Ozone Secretariat website at:

http://montreal-protocol.org/new_site/en/assessment_panels_bodies.php?committee_id=6

under the HTOC reports.

10.0 Halon Emission Reduction Strategies

Historically, less than 5% of all halon emissions have been a result of using halons to extinguish fires. While most (*it is presumed all*) countries have discontinued system discharge testing and discharge of extinguishers for training purposes, additional significant reductions of halon emissions can be realised by improving maintenance procedures, detection, and control devices, recovery and recycling, recordkeeping, proper training, utilizing standardized procedures for halon transfers and storage, and implementation of policies and awareness campaigns.

In many cases, it has been found that an automatic halon fire suppression system would not have been necessary had a full risk assessment been performed, good fire protection design practices implemented, and the fire risks minimized or removed from the location being protected. There are many halon alternatives both in-kind and not-in-kind available to the designer; however, they should be considered only after the aforementioned "good practices" have been followed. The same strategies for halon emissions reductions should be employed with the halon alternatives.

The subject of halon emission reduction strategies was addressed at length in earlier editions of the HTOC Assessment Reports. For the 2014 Assessment Report the Halon Technical Options Committee elected to move the contents of this chapter to Technical Note #2: *Halon Emission Reduction Strategies*, where it can be continuously updated as necessary.

Technical Note #2 can be found on the Ozone Secretariat website at:

http://montreal-protocol.org/new_site/en/assessment_panels_bodies.php?committee_id=6

under the HTOC reports.

11.0 Destruction

With the worldwide end of halon production for fire protection uses at the end of 2009, global inventory management and responsible disposal practices become important considerations to prevent emissions during a critical period of ozone layer recovery. The options for avoiding emissions of unwanted stockpiles of halons include destruction and transformation (also referred to as conversion) to useful chemical products. Halons, more than some of the other ODSs, are readily accessible for collection, storage, and disposal or reuse. Owing to the continued global demand in applications such as aviation, the HTOC has recommended that destruction as a final disposition option should be considered only if the halons are cross-contaminated and cannot be reclaimed to an acceptable purity. Approved ODS destruction technologies and facilities can be found in many countries, and some already have experience destroying some types of ODS including, to a very limited extent, halons.

The subject of halon destruction was addressed at length in earlier editions of the HTOC Assessment Reports. For the 2014 Assessment Report the Halon Technical Options Committee elected to move the contents of this chapter to Technical Note #5: *Halon Destruction*, where it can be continuously updated as necessary.

Technical Note #5 can be found on the Ozone Secretariat website at:

http://montreal-protocol.org/new_site/en/assessment_panels_bodies.php?committee_id=6

under the HTOC reports.

Appendix A: List of Acronyms and Abbreviations

A5	Article 5 Party
APU	Auxiliary Power Unit
2-BTP	Bromotrifluoropropene
CFC	Chlorofluorocarbons
CO_2	Carbon Dioxide
EC	European Commission
EU	European Union
EUN	Essential Use Nomination
FIC	Fluoroiodocarbon
FK	Fluoroketone
GHG	Green House Gas
GWP	Global Warming Potential
HBr	Hydrogen Bromide
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbons
HTOC	Halons Technical Options Committee
ICAO	International Civil Aviation Organisation
IGG	Inert Gas Generator
kg	kilogrammes
MPS	Minimum Performance Standards
MT	Metric Tonnes
OBIGGS	On-board Inert Gas Generating Systems
ODP	Ozone Depletion Potential
ODS	Ozone Depleting Substance
PFCs	Perfluorocarbons
PGA	Pyrotechnically Generated Aerosols
TEAP	Technology and Economic Assessment Panel
UK	United Kingdom
UNEP	United Nations Environment Programme
US	United States
USA	United States of America

Appendix B: Definitions

Article 5 Parties: Parties to the Montreal Protocol whose annual calculated level of consumption is less than 0.3 kg per capita of the controlled substances in Annex A, and less than 0.2 kg per capita of the controlled substances in Annex B, on the date of the entry into force of the Montreal Protocol, or any time thereafter. These countries are permitted a ten year "grace period" compared to the phase out schedule in the Montreal Protocol for developed countries. The Parties in this category are known as "countries operating under Article 5 of the Protocol".

Atmospheric Lifetime: The total atmospheric lifetime or turnover time of a trace gas is the time required to remove or chemically transform approximately 63% (i.e., 1−1/e) of its global atmospheric burden as a result of either being converted to another chemical compound or being taken out of the atmosphere by a sink.

Consumption: Production plus imports minus exports of controlled substances.

Controlled Substance: Any ozone depleting substance that is subject to control measures under the Montreal Protocol. Specifically, it refers to a substance listed in Annexes A, B, C or E of the Protocol, whether alone or in a mixture. It includes the isomers of any such substance, except as specified in the relevant Annex, but excludes any controlled substance or mixture which is in a manufactured product other than a container used for the transportation or storage of that substance.

Essential Use: In their Decision IV/25, the Parties to the Montreal Protocol define an ODS use as "essential" only if: "(i) It is necessary for the health, safety or is critical for the functioning of society (encompassing cultural and intellectual aspects) and (ii) There are no available technically and economically feasible alternatives or substitutes that are acceptable from the standpoint of environment and health". Production and consumption of an ODS for essential uses is permitted only if: "(i) All economically feasible steps have been taken to minimise the essential use and any associated emission of the controlled substance; and (ii) The controlled substance is not available in sufficient quantity and quality from existing stocks of banked or recycled controlled substances, also bearing in mind the developing countries' need for controlled substances".

Essential Use Nomination (EUN): Decision IV/25 of the 4th Meeting of the Parties to the Montreal Protocol set the criteria and process for assessment of essential use nominations.

Feedstock: A controlled substance that undergoes transformation in a process in which it is converted from its original composition except for insignificant trace emissions as allowed by Decision IV/12.

Global Warming Potential (GWP): Global warming potential is defined as a cumulative radiative forcing effects of a gas over a specified time horizon resulting from the emission of a unit mass of gas relative to CO_2. The TEAP has proposed the following classification: High >1000, Moderate 300 – 1000, and Low < 300, which has been used in this Assessment report.

Halocarbons: Halocarbons are compounds derived from hydrocarbons, where one or several of the hydrogen atoms are substituted with chlorine (Cl), fluorine (F), bromine (Br), and/or iodine

(I). The ability of halocarbons to deplete ozone in the stratosphere is due to their content of chlorine, bromine, and/or iodine and their chemical stability). CFCs, HCFCs and HFCs are examples of halocarbons.

Halocarbon Fire Extinguishing Agents: Halogenated hydrocarbon chemicals, including HCFCs, HFCs, PFCs, and FICs, that are used for fire-fighting applications. Each of these chemicals is stored as a liquefied compressed gas at room temperature, is electrically non-conductive, and leaves no residue upon vaporisation.

Halon: The halon terminology system provides a convenient means to reference halogenated hydrocarbon fire extinguishants. Halogenated hydrocarbons are acyclic saturated hydrocarbons in which one or more of the hydrogen atoms have been replaced by atoms from the halogen series (that is, fluorine, chlorine, bromine, and iodine). By definition, the first digit of the halon numbering system represents the number of carbon atoms in the compound molecule; the second digit, the number of fluorine atoms; the third digit, the number of chlorine atoms; the fourth digit, the number of bromine atoms; and the fifth digit, the number of iodine atoms. Trailing zeros are not expressed. Unaccounted for valence requirements are assumed to be hydrogen atoms. For example, bromochlorodifluoromethane – CF_2BrCl - halon 1211.

Halons exhibit exceptional firefighting effectiveness. They are used as fire extinguishing agents and as explosion suppressants.

Halon 1211: A halogenated hydrocarbon, bromochlorodifluoromethane (CF2BrCl). It is also known as "BCF". Halon 1211 is a fire extinguishing agent that can be discharged in a liquid stream. It is primarily used in portable fire extinguishers. Halon-1211 is an ozone depleting substance with an ODP of 3.0.

Halon 1301: A halogenated hydrocarbon, bromotrifluoromethane (CF_3Br). It is also known as "BTM". Halon 1301 is a fire extinguishing agent that can be discharged rapidly, mixing with air to create an extinguishing application. It is primarily used in total flooding fire protection systems. Halon 1301 is an ozone depleting substance with an ODP of 10.

Halon 2402: A halogenated hydrocarbon, dibromotetrafluoroethane ($C_2F_4Br_2$). Halon 2402 is a fire extinguishing agent that can be discharged in a liquid stream. It is primarily used in portable fire extinguishers or hand hose line equipment, and fire protection for specialised applications. Halon 2402 is an ozone depleting substance with an ODP of 6.0.

Halon Bank: A halon bank is all halons contained in fire extinguishing cylinders and storage cylinders within any organisation, country, or region.

Halon Bank Management: A method of managing a supply of banked halon. Bank management consists of keeping track of halon quantities at each stage: initial filling, installation, "recycling", and storage. A major goal of a halon bank is to re-deploy halons from decommissioned systems. Halon banks can be managed by a clearinghouse, i.e. an office that facilitates contact between halon owners and halon buyers.

Halons Technical Options Committee (HTOC): An international body of experts established under the Technology and Economic Assessment Panel (TEAP) to regularly examine and report to the Parties on the technical options and progress in phasing out halon fire extinguishants (see TEAP).

Hydrochlorofluorocarbons (HCFCs): A family of chemicals related to CFCs that contains hydrogen, chlorine, fluorine, and carbon atoms. HCFCs are partly halogenated and have much lower ODP than the CFCs.

Hydrofluorocarbons (HFCs): A family of chemicals related to CFCs that contains one or more carbon atoms surrounded by fluorine and hydrogen atoms. Since no chlorine or bromine is present, HFCs do not deplete the ozone layer.

Inert Gases: Fire extinguishing agents containing one or more of the following gases: argon, carbon dioxide, and nitrogen. Inert gases have zero ODP and extinguish fires by reducing oxygen concentrations in the confined space thereby "starving" the fire.

Inert Gas Generator: A fire fighting technology that uses a solid material that oxidises rapidly, producing large quantities of carbon dioxide and/or nitrogen. The use of this technology to date has been limited to specialised applications such as engine nacelles and dry bays on military aircraft.

Montreal Protocol (MP): An international agreement limiting the production and consumption of chemicals that deplete the stratospheric ozone layer, including CFCs, halons, HCFCs, HBFCs, methyl bromide and others. Signed in 1987, the Protocol commits Parties to take measures to protect the ozone layer by freezing, reducing or ending production and consumption of controlled substances. This agreement is the protocol to the Vienna convention.

Non-Article 5 Parties: Parties to the Montreal Protocol that do not operate under Article 5 of the MP.

Ozone Depleting Substance (ODS): Any substance with an ODP greater than 0 that can deplete the stratospheric ozone layer. Most of ODS are controlled under the Montreal Protocol and its amendments, and they include CFCs, HCFCs, halons and methyl bromide.

Ozone Depletion Potential (ODP): A relative index indicating the extent to which a chemical product destroys the stratospheric ozone layer. The reference level of 1 is the potential of CFC-11 and CFC-12 to cause ozone depletion. If a product has an ozone depletion potential of 0.5, a given mass of emissions would, in time, deplete half the ozone that the same mass of emissions of CFC-11 would deplete. The ozone depletion potentials are calculated from mathematical models, which take into account factors such as the stability of the product, the rate of diffusion, the quantity of depleting atoms per molecule, and the effect of ultraviolet light and other radiation on the molecules. The substances implicated generally contain chlorine or bromine.

Ozone Layer: An area of the stratosphere, approximately 15 to 60 kilometres (9 to 38 miles) above the earth, where ozone is found as a trace gas (at higher concentrations than other parts of the atmosphere). This relatively high concentration of ozone filters most ultraviolet radiation, preventing it from reaching the earth.

Ozone Secretariat: The secretariat to the Montreal Protocol and Vienna Convention, provided by UNEP and based in Nairobi, Kenya.

Party: A country that has ratified an international legal instrument (e.g., a protocol or an amendment to a protocol), indicating that it agrees to be bound by the rules set out therein. Parties to the Montreal Protocol are countries that have ratified the Protocol.

Perfluorocarbons (PFCs): A group of synthetically produced compounds in which the hydrogen atoms of a hydrocarbon are replaced with fluorine atoms. The compounds are characterised by extreme stability, non-flammability, low toxicity, zero ozone depleting potential, and high global warming potential.

Phase Out: The ending of all production and consumption of a chemical controlled under the Montreal Protocol.

Production: The amount of controlled substances produced, minus the amount destroyed by technologies to be approved by the Parties and minus the amount entirely used as feedstock in the manufacture of other chemicals. The amount recycled and reused is not to be considered as "production".

Reclamation of Halons: To reprocess halon to a purity specified in applicable standards and to use a certified laboratory to verify this purity using the analytical methodology as prescribed in those standards. Reclamation is the preferred method to achieve the highest level of purity. Reclamation requires specialised machinery usually not available at a servicing company.

Recovery of Halons: To remove halon in any condition from an extinguisher or extinguishing system cylinder and store it in an external container without necessarily testing or processing it in any way.

Recycling of Halons: To extract halon from an extinguisher or system storage container and clean the halon for reuse without meeting all of the requirements for reclamation. In general, recycled halon is halon that has its super-pressurising nitrogen removed in addition to being processed to only reduce moisture and particulate matter.

Total Flooding System: A fire extinguishing system that protects a space by developing a critical concentration of extinguishing agent.

Water Mist: A fire fighting agent that uses relatively small water droplet sprays under low, medium, or high pressure to extinguish fires. These systems use specially designed nozzles to produce much smaller droplets than are produced by traditional water-spray systems or conventional sprinklers