

**REVIEW OF AUSTRALIA'S
NON-DEFENCE HALON REQUIREMENTS**

**FINAL REPORT
APRIL 2020**

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Executive Summary

Halons are highly effective fire-fighting agents that were introduced into Australia in the early 1970s. Halon 1211 was commonly used in portable fire extinguishers, and halon 1301 was used for fixed fire protection systems. Halons are brominated halocarbons that are highly potent ozone-depleting chemicals.

The Australian Government Department of Agriculture, Water and the Environment (the Department) sought consultancy services to advise it on non-defence halon uses, including current and future trends in halon use, and likely future domestic halon demand until halon is no longer needed.

The Montreal Protocol on Substances that Deplete the Ozone Layer is a global agreement to protect the Earth's ozone layer by phasing out the chemicals that destroy stratospheric ozone. The Protocol phased out the production, import and export of ozone-depleting halons in non-Article 5 parties (developed countries) in 1994 and in Article 5 parties (developing countries) in 2000. The Montreal Protocol control measures relate to newly manufactured halon not to recycled or reused halon, which has been the source of all halon for remaining critical fire protection applications when alternatives to using halon have been unavailable since the phase-out.

The Department manages a strategic halon stockpile originating from surplus halons recovered from decommissioned halon equipment and systems in Australia. The National Halon Bank (NHB) was established in 1993 to maintain a bank of halons (halon 1211 and halon 1301) for Australia's future strategic non-defence requirements until the transition to halon alternatives is completed.

Globally, alternatives to halons are now available for most, but not all, halon applications. Since the mid-1990s, most halon equipment and systems in Australia have been replaced or decommissioned. The remaining major halon uses in Australia are in civil aviation and defence applications.

Civil aviation is the largest on-going non-defence application for halon. Progress has been made on halon replacements for handheld extinguishers and lavatory extinguisher (lavex) receptacles on aircraft. However, little progress has been made on engine nacelles/auxiliary power units (APUs) or cargo compartment halon fire protection systems, where still no practical alternatives have been found to be acceptable. In the last five years, transnational consortia of aircraft manufacturers and stakeholders have been established to accelerate the development of halon alternatives for the remaining aviation applications. Most maritime applications have been, or are in the process of being, replaced by alternatives to halons.

Defence halon usage and future halon requirements have been addressed

separately.

A key issue for the Department, and stakeholders still reliant on halons, is whether there will be adequate halon to supply Australia's future requirements until halon alternatives have replaced remaining halon uses.

Future halon requirements for non-defence uses have been estimated based on NHB halon sales data and an aviation halon inventory using methodology, scenarios and assumptions outlined in this report.

For halon 1211, based on NHB sales analysis, between 7.01 and 10.35 tonnes, depending on aircraft lifetime variables, are estimated to be needed to supply non-defence uses until halon 1211 is no longer required. Based on the aviation inventory analysis, between 4.12 and 6.17 tonnes halon 1211, depending on aircraft lifetime variables, are estimated to be needed to supply non-defence uses until halon 1211 is no longer required. These estimations can be compared with the available NHB inventory of 93.03 tonnes of halon 1211. There would appear to be a wide margin within the limit of the NHB's reserves of halon 1211, which minimises the risks of inadequate supply of halon 1211 until replacements are installed.

For halon 1301, based on the NHB sales analysis, between 35.05 and 96.81 tonnes are estimated to be needed to supply non-defence uses until halon 1301 is no longer required. The range of estimated quantities is dependent on the variables of new design aircraft dates, aircraft lifetime, and aviation industry growth rates. Based on the aviation inventory analysis, between 27.00 and 503.62 tonnes halon 1301 are estimated to be needed to supply non-defence uses until halon 1301 is no longer required. The range of estimated quantities is dependent on the variables of the starting level of consumption estimated for 2020 (which are based on different emission factors for the aviation inventory), new design aircraft dates, aircraft lifetime, and aviation industry growth rates. These estimations can be compared with the available NHB inventory of 165.87 tonnes of halon 1301.

The broad range of possible outcomes for halon 1301 indicates the potential impact of the different variables, including the risks associated with delays in implementing halon replacements. Longer delays will increase the total demand for halon 1301 and narrow the margin within the limit of the NHB's reserves of halon 1301, which increases the risks of inadequate supply of halon 1301 until replacements are installed. This underlines the on-going importance of active international aviation industry investigation and implementation of halon 1301 replacements at the earliest possible dates. Higher leakage rates also increase the risks of inadequate supply of halon 1301. From a risk perspective, this clearly underlines the importance of Australia's suite of halon management controls aimed at minimising emissions in fire protection applications.

Assuming the average annual sales of halon 1301 from the NHB represent total annual non-defence consumption, using the estimated halon 1301 aviation inventory, an annual emission rate of 3% can be derived for Australian aviation. Similarly, assuming the average annual sales of halon 1211 from the NHB represent total annual non-defence consumption, using the estimated halon 1211 aviation inventory, an annual emission rate of 10% can be derived for Australian aviation.

Uncertainties in the analysis surround unquantified industry activities (such as potential reuse of recovered halon by industry stakeholders that could add to overall halon consumption in non-defence uses) and reporting (such as NHB sales designated by purchasers into a certain halon end-use category potentially being used in a different end-use category). These uncertainties could increase or decrease the total halon requirements for non-defence uses estimated from NHB sales. Improved or validated reporting that more accurately captures halon usage activities would meaningfully inform future estimations of halon requirements.

Uncertainties also surround the available quantities of halon of appropriate quality for use in civil aviation. Civil aviation procedures specify halon certified to meet international standards (either ASTM D 5632 Type 2 for halon 1301 or ISO 7201 for halon 1211), essentially the same specification as newly manufactured halon. Halon recovered and recycled from equipment may not necessarily meet international standards because of contamination or non-condensable gas content. A small number of service providers have indicated that they are able to reclaim halon to ISO 7201 or ASTM D5632 Type 1 or Type 2, while others are not. There is some uncertainty about the effects of long-term storage (30+ years), particularly whether the storage containers, seals, valves and fittings could degrade and contaminate the halon. If there were substantial contamination in stocks of halon held either by the NHB or other halon special permit holders, e.g., due to the extraordinary length of time it is stored for, or any significant losses of agent due to processing used to meet the required standards, these could materially reduce the net amount of ISO 7201 or ASTM D5632 Type 2 halon that could be produced from halon stocks. To maximise future available halon, any methods or equipment implemented to reclaim halon to meet international standards should be designed to be efficient and minimise any potential losses of halon during the process and any potential contamination.

The price of halon 1301 has increased since 2012 and is predicted to continue increasing in response to limited supply and increasing demand from aviation, as expected by modelling of future global demand that is predicted by others to exceed supply leading to potential future shortages.

Based on these findings, a number of recommendations have been made in relation to: monitoring halon consumption and relevant developments in civil aviation; ensuring halon quality for civil aviation; and validating and/or improving data on halon usage activities to allow for better quantitative analysis while preserving comparability and continuity with the historic dataset.

1 Background to the Review of Australia's Non-Defence Halon Requirements

1.1 Overview

The Australian Government Department of Agriculture, Water and the Environment (the Department) sought consultancy services to advise it on non-defence halon uses, including current and future trends in halon use, and likely future domestic halon demand. Planet Futures was engaged to prepare this advice.

1.2 Halons and their control

Halons are highly effective fire-fighting agents that were introduced into Australia in the early 1970s. Halon 1211 was commonly used in portable fire extinguishers, and halon 1301 was used for fixed fire protection systems. Halons are brominated halocarbons that are highly potent ozone-depleting chemicals.

The Montreal Protocol on Substances that Deplete the Ozone Layer is a global agreement to protect the Earth's ozone layer by phasing out the chemicals that destroy stratospheric ozone. This phase-out agreement requires zero production and consumption of ozone-depleting substances by specified dates. Due to their ozone-depleting potential, halons are listed as controlled substances under the Montreal Protocol. The Kigali Amendment to the Montreal Protocol includes a range of hydrofluorocarbon (HFC) chemicals, which are not ozone-depleting but have potent global warming potentials, that are required to be phased down over specified periods.

The Montreal Protocol phased out the production and consumption¹, including import and export, of ozone-depleting halons in non-Article 5 parties (developed countries) in 1994 and in Article 5 parties (developing countries) in 2000. This control measure applies unless the Montreal Protocol has otherwise authorised halon production or consumption that is necessary to satisfy uses agreed by them to be essential, under an essential use exemption². The Montreal Protocol control measures relate to newly manufactured halon not to recycled or reused halon, which has been the source of all halon for remaining critical fire protection applications when alternative to using halon have been unavailable since the phase-out. In 1993

¹ Under the Montreal Protocol, consumption is defined as production plus imports minus exports of controlled substances.

² Article 2G sets out halon phase-out requirements and exceptions for essential uses for non-Article 5 parties, and Article 5 sets out halon phase-out requirements and exceptions for essential uses for Article 5 parties. Decision IV/25 sets out the criteria for assessment of an essential use for the purposes of these control measures for the phase out of halons and other ozone-depleting substances.

(Continued next page)

and 1994, Montreal Protocol parties considered nominations for essential use exemptions for halon production or consumption, including import, to occur beyond the mandated phase-out date for developed countries. Essential use exemptions for halon were not authorised by Montreal Protocol parties because “*there are technically and economically feasible alternatives and substitutes for most applications*”, and “*halon is available in sufficient quantity and quality from existing stocks of banked and recycled halon*”³. Nominations for essential use exemptions for halon production or consumption have not been considered by the Montreal Protocol since these decisions were taken in the early 1990s. Since 1993, the import of newly manufactured halons into Australia has been prohibited unless an “essential use exemption” for production or consumption (including import) is authorised by the Montreal Protocol.

The Australian Halon Management Strategy was first published in 2000 in response to the Montreal Protocol’s decision X/7 on halon management strategies. This decision requested each party to develop a national strategy for the management of halons, including emissions reduction and ultimate elimination of their use. The Australian Halon Management Strategy describes Australia’s approach to halon management and outlines principles and measures established to manage halon uses until halon is no longer required. It was reviewed in 2014-2016, and the updated 2019 version is available from the Department’s website⁴.

Australia controls the manufacture and import of equipment that contains halon through licensing under the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* (the Act) and associated *Ozone Protection and Synthetic Greenhouse Gas Management Regulations 1995*. Through these legislative and regulatory requirements, Australia limits the use of halons in new installations and equipment and has enacted measures for the environmentally safe recovery, storage, management and disposal of halons. These requirements also apply to some halon alternatives that are ozone-depleting substances but not halons (e.g., hydrochlorofluorocarbons) and/or are synthetic greenhouse gases (e.g., hydrofluorocarbons).

Under the Act, a halon special permit is required by an individual or company possessing halon for use in fire protection equipment or systems. The Fire Protection Industry (ODS & SGG) Board (the Board) is authorised under the requirements to administer licensing and permits on behalf of the Australian Government. Among other things, halon special permit holders are required to report to the Board on a quarterly basis about quantities of

³ Decisions V/14 and VI/8, e.g., decision V/14 at https://ozone.unep.org/treaties/montreal-protocol/meetings/fifth-meeting-parties-montreal-protocol/decisions/decision-v14?q=treaties/montreal-protocol/meetings/eighth-meeting-parties/decisions/decision-viii9-essential-use&source=decisions_by_issue&args%5B0%5D=454&parent=3012&nextParent=3011 .

⁴ *Australian Halon Management Strategy*, Environment Australia, February 2019 <https://www.environment.gov.au/protection/ozone/publications/australian-halon-management-strategy>.

halon acquired, recovered, supplied, refilled, destroyed and on hand. The Department provided this review with a summary of quarterly reports from halon special permit holders that had been submitted to the Board.

Under its strategy, Australia aims to phase out halons completely when alternatives are available. However, the long-term need for halon is uncertain, with halon systems potentially still required for specific uses that are still essential, such as civil aviation, well into the foreseeable future.

1.3 Australia's strategic halon stockpile: National Halon Bank

The Department manages a strategic halon stockpile originating from surplus halons recovered from decommissioned halon equipment and systems in Australia. The National Halon Bank (NHB) was established in 1993 to maintain a bank of halons (halon 1211 and halon 1301) for Australia's future strategic non-defence requirements until the transition to halon alternatives is completed. Initially, the NHB operated as a decanting, purification, and storage facility for halons 1211 and 1301. Currently, the NHB operates as a storage and supply facility for halon 1211 and 1301 and provides halon testing services. Under contractual arrangements, the halon stockpile is managed under controlled conditions to prevent accidental releases and to preserve the integrity of Australia's strategic halon reserves. The NHB stockpile includes recovered halon that meets ASTM and ISO standards and is ready for service, as well as relinquished material that is held as received but has not yet been analysed to determine its quality.

The halon stockpile is available for permitted uses, such as for medical, veterinary, defence, industrial safety or public safety purposes, where no practical alternative exists. Permissions for supply of halons from the stockpile are administered in accordance with the criteria established in the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* and *Ozone Protection and Synthetic Greenhouse Gas Management Regulations 1995*.

1.4 Halon alternatives

Globally, alternatives to halons are now available for most, but not all, halon applications. Since the mid-1990s, most halon equipment and systems in Australia have been replaced or decommissioned.

Most maritime applications have been, or are in the process of being, replaced by alternatives to halons. Since the mid-1990s, new vessels complying with international maritime treaties have been prohibited from installing halon fire protection systems. Legacy vessels were not required to retrofit alternative non-halon systems, but policies and economics have led to replacement of many of these systems anyway. The vast majority of Australian-flagged vessels are no longer fitted with halon systems. Globally, there has been a similar very significant reduction in vessels fitted with halon, primarily due

to the natural attrition of vessels at their end-of-life. The NHB supplies halon to foreign vessels to replenish halon lost in transit to Australia, if the vessel would otherwise be unable to meet safety standards. However, there have been no apparent NHB halon sales into maritime uses since 2012. Future NHB halon demand for this application is expected to be rare (see also sections 2.4 and 3.2).

Aviation is the largest on-going non-defence application for halon. Progress has been made on halon replacements for handheld extinguishers and lavatory extinguisher (lavex) receptacles on aircraft. However, little progress has been made on engine nacelles/auxiliary power units (APUs) or cargo compartment halon fire protection systems, where still no practical alternatives have been found to be acceptable. In the last five years, transnational consortia of aircraft manufacturers and stakeholders have been established to accelerate the development of halon alternatives for the remaining aviation applications (see section 2.3).

1.5 Australia's future halon requirements

A key issue for the Department, and stakeholders still reliant on halons, is whether there will be adequate halon to supply Australia's future requirements until halon alternatives have replaced remaining halon uses.

An Australian inventory conducted in 1998⁵ estimated that, at that time, 70 tonnes of halon 1211 and 250 tonnes of halon 1301 would be required to meet essential uses until 2030.

A Review of Australia's Halon Essential Use Requirements⁶ was conducted for the Australian Government in 2012 (henceforth referred to as the 2012 Halon Review), which noted that halon stock reserved for non-defence essential uses, as of February 2012, was 73.4 tonnes of halon 1211 (plus another 27 tonnes in bulk storage awaiting reclamation) and 195.2 tonnes of halon 1301.

The 2012 Halon Review was undertaken to investigate Australia's non-defence halon essential uses requirements, including:

- The prospects and possible timeframe for transition of remaining non-defence halon uses;

⁵ *National Halon Inventory and Essential Use Requirements*, Final Report, Sustainable Solutions Pty. Ltd., August 1998.

⁶ *Review of Australia's Halon Essential Use Requirements 2012*, by Energy International Australia for the Department of Environment and Energy, May 2012, <https://www.environment.gov.au/protection/ozone/publications/review-australias-halon-essential-uses-requirements>.

- Whether a strategic stockpile of halon would be required beyond 2030; and
- The quantity of halon likely to be required for remaining non-defence essential uses.

The 2012 Halon Review confirmed that halon is no longer used or needed in the majority of applications where it was previously considered important for fire protection. It concluded that going forward the major non-defence essential use requirements for halons 1211 and 1301 would be for the aviation sector, and that a strategic stockpile would be required beyond 2030, but with all other sectors either having already transitioned or progressing towards a full transition to alternatives.

Noting the limitations of the available data, as outlined in the report⁷, future halon requirements were estimated based on NHB halon sales data using scenarios and a sensitivity analysis approach and compared against halon stocks earmarked for non-defence uses. Future non-defence halon requirements alone were difficult to determine accurately due to the limitations of the available halon sales data⁸, and unquantified sales of non-defence NHB reserves to fire protection service providers going to defence uses.

The table below presents the estimated future halon requirements from the 2012 Halon Review, and the available NHB non-defence halon stocks at that time.

Table 1.1 2012 Halon Review: Estimated future halon requirements

Total Halon (tonnes)	Halon 1211	Halon 1301
Range of Scenarios	35-55	139-229
NHB stocks	73-95	195

⁷ *Review of Australia's Halon Essential Use Requirements 2012*, by Energy International Australia for the Department of Environment and Energy, May 2012, <https://www.environment.gov.au/protection/ozone/publications/review-australias-halon-essential-uses-requirements>

⁸ Halon requirements were based on NHB halon sales. End use data were based on assumptions about the business of fire protection service providers purchasing the halon. At that time, the NHB halon reserve was being used for authorised uses other than non-defence uses. This was occurring through fire protection companies purchasing halon from the NHB halon reserves to service a range of fire protection equipment, including for uses other than non-defence. The relative extent of this activity could not be quantified at that time. Hence, the estimated non-defence (civilian) halon requirements based on NHB halon sales were likely to be over-estimations.

This 2020 Halon Review provides updated and new advice on non-defence halon uses, addresses current halon uses and future trends, and estimates future Australian non-defence halon demand based on available updated and new information from suppliers, stakeholders and experts. Updated historical sales and handling data, improved categorisation of NHB sales into non-defence and defence uses, progress towards alternatives, current expectations of aviation fleet trends, and updated data and new modelling on the amount of halon installed in civil aviation have been used to inform new estimations of Australia's future halon requirements for non-defence uses.

1.6 Project Deliverables

Reporting of progress and/or findings through:

- a brief outline report with preliminary findings
- a draft report
- a draft final report
- a briefing presentation and consultation meeting with stakeholders
- a final report, incorporating relevant feedback from the stakeholder briefing and consultation meeting.

1.7 Project Methodology

Planet Futures has undertaken the following methodology and activities in provision of its services to the Department:

Desktop review of relevant Australian and international resources to summarise current information on the status of halon policy, management and uses in Australia and internationally, future trends in halon use and demand, international halon price and possible trends. Resources include information sources such as web-based resources and reports relating to the national and international industry sectors and halon use, including although not limited to reports of the Technology and Economic Assessment Panel and its Halon Technical Options Committee, and the International Civil Aviation Organization and associated working groups and committees.

Interviews with a selection of relevant major Australian industry sector stakeholders and halon user groups, and international industry sector experts, regarding current and future halon use trends, feasibility, commercialisation, and research of halon alternatives, potential risks and uncertainties that may influence future halon demand, and, in the case of halon special permit holders, clarification of their record keeping practices to explore uncertainties in data reporting.

Data analysis of historic halon stocks and sales associated with the NHB, and halon special permit holder records. Depending on an assessment of available

data and its reliability, which were also determined through limited interviews, a range of methodologies were considered to describe, estimate, and/or corroborate estimations of, future non-defence halon requirements and possible trends, including halon stocks inventory and annual sales analysis, scenario modelling and sensitivity analysis to test the impact of different assumptions relating to future demand patterns and qualitative and quantitative industry analysis. The final methodology was discussed and agreed upon with the Department. Where possible, uncertainties were explored and these have been noted in this report.

1.8 Final Report

This final report incorporates currently available data and its analysis and advice is based on this data, the results of the desktop review, and expert and stakeholder consultations.

2 Remaining Non-Defence Halon Uses and the Status of Alternatives

Halon is no longer used in the majority of non-defence applications where previously it was considered important for fire protection. Most land-based fixed systems and major commercial maritime applications previously using halon for fire protection have been replaced with alternatives.

Halon special permit holders⁹ have reported that almost all maritime commercial fleets have implemented halon alternatives. There may be remaining minor non-defence maritime use, particularly in older, marine craft with legacy halon strangler¹⁰ systems for inboard motors, some of which may not have been serviced in many years.

NSW Police Force (Public Order and Riot) hold a halon special permit and there is preliminary information that halon 1211 is used as an extinguishant in their public order response vehicles. Due to personnel changes, confirmation of the application and quantities involved is pending from the new official halon special permit holder administrator. At the time of publication, no further information could be made available. Follow-up with the new halon special permit holder administrator is continuing.

In the past, there have also been small quantities used for research (University of Newcastle for research into halocarbon destruction) and specialist refrigeration purposes (now CSL Ltd., which had specialist refrigeration equipment using halon as a refrigerant).

Internationally, halon uses also include oil and gas installations, nuclear facilities and feedstock uses in chemical manufacturing.

The remaining major halon uses in Australia are in civil aviation and defence applications. The following sections describe the remaining major non-defence use of halon in Australia, civil aviation, and briefly explains the challenges in replacing halon and the status of the development and introduction of alternatives.

2.1 Effectiveness of Halons in Fire Suppression

Fire suppression agents can operate by a number of mechanisms. These include cooling, reducing oxygen availability, and dilution of fuel availability. In addition to these mechanisms, when exposed to flames, halon 1211 and halon 1301 release bromine that can participate in fast catalytic chain reactions

⁹ See section 1.2.

¹⁰ An engine strangler system works by strangling the air supply to an engine, by injecting an extinguishant into the air intake in circumstances when a fuel combustion engine needs to be shut down quickly. Halons were previously used for this purpose on trucks and boats.

that rapidly and efficiently quench the free radicals that otherwise propagate flame fronts.

These properties make these bromine-containing halons extremely efficient in suppressing fires and allows them to be effective at much lower concentrations than would be required for non-halon agents. Consequently, the search for effective and efficient alternatives poses significant challenges.

2.2 Civil Aviation Halon Uses

For civil aviation, halons have been in use in Australia in four areas:

LOCATION	TYPE/AGENT
Cabin spaces/ Cockpit/ Galleys	Handheld extinguishers/1211
Lavatory trash receptacles/ Lavex	Inbuilt/ mainly 1301, some 1211
Engine nacelles/ Auxilliary Power Units (APUs)	Inbuilt systems/1301
Cargo Compartments	Inbuilt systems/1301

The search for halon alternatives began over 25 years ago, but the prospects for replacements of the streaming agent, halon 1211, and the flooding agent, halon 1301, have diverged sharply in recent years.

Replacements for halon 1211 as a streaming agent are now available and mandated in Australia for new aircraft manufactured after December 2018. Replacements are also available for halon 1301 in lavatory trash receptacles/lavex and mandated in Australia for new aircraft manufactured after December 2018. The *Civil Aviation Safety Regulations 1998*, and associated Manual of Standards, establish these requirements¹¹ (see section 2.3.9).

Progress towards suitable alternatives for halon 1301 in engine nacelle/auxiliary power units and cargo compartments has been slow, and potential solutions are now in an early pre-qualification phase.

Halon alternatives are available for lavatory extinguisher bottles and handheld fire extinguishers. The International Civil Aviation Organization has mandated installation of alternatives for airframes built and certified after

¹¹ See also Civil Aviation Safety Authority, Airworthiness Bulletin, AWB 26-002, Issue 3, 11 January 2018, *Selection and Installation of Handheld Portable Fire Extinguishers*. <https://www.casa.gov.au/files/awb-26-002-issue-3-selection-and-installation-handheld-portable-fire-extinguishers>, accessed February 2020.

2018 (see section 2.3.6). There are no International Civil Aviation Organization or Australian requirements for retrofit of existing aircraft; aircraft built prior to 2019 may continue to use halon for both applications, even though alternative drop-in replacements are available. Installation of halon alternatives for these older aircraft is not mandatory in Australia and the uptake of alternatives is likely to depend on economic issues. The European Union is currently the only jurisdiction that has mandated retrofit dates for halon replacements for existing older aircraft (see section 2.3.7).

The main application in *small aircraft* will continue to be legacy handheld extinguishers containing halon 1211. BTP (2-bromotrifluoropropene) is an available and economic alternative that meets the United States' Federal Aviation Administration (FAA) Minimum Performance Standards (MPS) and is also on the Civil Aviation Safety Authority list of approved halocarbon agents to replace halon 1211 in portable fire extinguishers in Australia (see section 2.3.3).

For the remaining two applications, research into suitable halon alternatives for engines and auxiliary power units and cargo compartments commenced at least 25 years ago, but candidate systems have struggled to meet all civil aviation industry requirements. In more recent years, the International Civil Aviation Organization has inaugurated consortia dedicated to accelerating the search for alternatives to halons (see sections 2.3.4 and 2.3.5).

2.3 Status of Halon Alternatives in Civil Aviation Uses

This section provides the current status of progress towards halon alternatives that have been identified, tested, proposed, or introduced for civil aviation uses.

Technically acceptable halon alternatives have been identified for two of the four civil aviation application areas, notably lavex and handheld extinguishers. However, commercial development of alternative fire suppression systems for cargo compartments and engine nacelle and auxiliary power units is still progressing slowly.

The International Civil Aviation Organization has declared timeframes for the implementation of alternative agent systems in newly manufactured aircraft and new airframe designs. Regional and national aviation authorities are considering implementation of these timeframes within their jurisdictions or have already established timeframes (see sections 2.3.6, 2.3.7, 2.3.8).

In the case of handheld extinguishers and lavex, implementation of halon alternatives has begun. However, for the replacement of halon in cargo and engine nacelle/auxiliary power units, there is still uncertainty about the ability to overcome the technical challenges of implementing effective, efficient and safe alternatives to halon in these two areas of aviation fire

suppression. Potential challenges for any new technology to gain acceptance include the ability to meet fire standards and pass prescribed extinguishant tests, increased weight and size considerations, toxicity (low toxicity at effective fire suppression concentration) and safety requirements (e.g. acceptable airframe pressure increase, no decreased visibility, minimal residue that could lead to electrical malfunction or corrosion). Some potential candidates, such as HFCs, may also be subject to phase down.

When considering how implementation of halon replacements for these two applications might affect future halon use, it is important to note the relative size of the applications with regard to installed halon.

Handheld extinguishers may encompass the majority of installed halon in small aircraft. However, in narrow body mainline aircraft, cargo and engine/auxiliary power units combined can require between 40 and 90 kg of halon 1301 onboard, as compared to less than 0.5 kg of halon 1301 in lavex and perhaps 7.5 kg of halon 1211 in handheld fire extinguishers. For mainline wide-bodied and long-range aircraft, cargo and engine/auxiliary power units combined can require more than 250 kg of halon 1301, while requiring less than 2 kg of halon 1301 in lavex and perhaps 15 kg to 30 kg of halon 1211 in handheld fire extinguishers. So, while the main application for halon 1211 has been resolved, in the case of halon 1301, the lavex solution may account for less than 1% of a mainline aircraft's installed halon 1301 quantity.

2.3.1 Benefits of Halons for Civil Aviation Applications

Halon 1211 is used as a streaming agent for direct application to fires usually by handheld extinguisher, while halon 1301 is often used as a total flooding agent due to its low toxicity. The relatively low toxicity of halon makes them acceptable for use in occupied spaces.

There are a number of positive benefits for civil aviation applications:

- Excellent flame-retardant capability at relatively low concentration compared to alternatives
- Minimal pressure increases in airframes after release of fire suppression agent at effective concentration (as a total flooding agent halon 1301 is an effective extinguishant at a concentration less than 6.5%)
- Low weight/volume
- “Clean” - halon agents leave no residue (no possibility of corrosion due to hidden residues in inaccessible areas after application)
- Non-conductive

- Do not pose a visibility hazard
- Economic
- Low toxicity at effective suppression concentrations

2.3.2 Alternatives to Halons in Lavatory Trash Receptacles/Lavex

Historically, mainly halon 1301, but also some 1211, have been used in lavatory trash receptacle/lavex extinguishers.

Implementation of halon-free lavatory fire protection systems has now been achieved in new type designs in accordance with the Convention on International Civil Aviation, Annex 8 – *Airworthiness of Aircraft*. In Australia, regulations under the *Civil Aviation Act 1988* prohibit lavex extinguishers containing halon in aircraft manufactured after December 31, 2018.

Both HFC-227ea (C₃HF₇) heptafluoropropane (Airbus A320/ A321) and HFC-236fa (C₃H₂F₆) hexafluoropropane (Boeing 787-800) are known to have been used in current aircraft to replace halon 1301 in lavex. Both are high global warming potential HFCs that are listed as controlled substances and subject to HFC phase-down under the Montreal Protocol. Virtually all current production civil aircraft are compliant and are now being fitted with these halon alternatives for lavex applications. This does not necessarily extend to retrofit of legacy aircraft with these HFCs because some may require Type Certification/ Aircraft Manuals to be updated. Private communications with halon special permit holders indicate that retrofits are not being widely installed in the Australian civil aviation fleet. Overall, while creditable, the implementation of halon alternatives in lavex will have only a very small effect on overall aviation demand for halon 1301.

2.3.3 Alternatives to Halon 1211 in Handheld Extinguishers

A number of halocarbons are now available as alternatives to halon 1211 in handheld extinguishers in civil aviation. The replacements require a somewhat larger volume/weight of agent than an equivalent halon 1211 extinguisher. The Australian Civil Aviation Safety Authority advises that halocarbon agents may require 50 to 150% more agent by weight to achieve the same level of fire suppression as halon 1211 and notes requirements for mounting to meet added structural requirements.

Globally, the International Air Transport Association standards and the United States' Federal Aviation Administration regulations require that new aircraft manufactured after December 2014 be fitted with handheld extinguishers containing non-halon agent.

In Australia, regulations under the *Civil Aviation Act 1988* prohibit handheld

extinguishers containing halon 1211 in aircraft manufactured after December 31, 2018.

The Civil Aviation Safety Authority has approved the following halocarbon agents as equivalents to halon in portable fire extinguishers¹²:

Name	Trade Name	Chemical Name	Chemical Formula
HCFC Blend B	Halotron 1	2-bromotrifluoropropane	C ₃ H ₂ BrF ₃
HFC-227ea	FM-200, or FE-227	1,1,1,2,3,3,3-heptafluoropropane	C ₃ HF ₇
HFC-236fa	FE-36	1,1,1,3,3,3-hexafluoropropane	C ₃ H ₂ F ₆
2-BTP	Halotron BrX	2-bromo-3,3,3-trifluoropropene	C ₃ H ₂ BrF ₃

2-BTP appears to have become the industry preferred choice as the closest to a drop-in replacement for halon 1211 handheld extinguishers with the least weight penalty. While 2-BTP contains bromine, like halons, this chemical has a very short atmospheric lifetime (about 7 days), an ozone-depleting potential of 0.0028 and a global warming potential of 0.26. This chemical is not deemed as a potentially significant contributor to ozone depletion or global warming.

It can be expected that there will be reduced civil aviation demand for halon 1211 due to mandated alternatives in new production and the availability of economically feasible HFCs for retrofit as halon replacements.

2.3.4 Engine and Auxiliary Power Unit Fire Suppression Systems

Prepared for the 39th International Civil Aviation Organization Triennial Assembly in 2016, an update on the Development of Halon Alternatives identified four potential halon alternatives for use in engine nacelle/auxiliary power units (HFC-125, Novec 1230, FIC-1311 and Powder Aerosol F) that had been tested to the draft Minimum Performance Standards, and whose halon 1301 minimum equivalent extinguishing concentrations had been determined. It was noted that further research and development was needed for both Novec 1230 and FIC-1311.

Novec 1230 implemented in an engine/nacelle/auxiliary power unit system

¹² Civil Aviation Safety Authority, Airworthiness Bulletin, AWB 26-002, Issue 3, 11 January 2018, *Selection and Installation of Handheld Portable Fire Extinguishers*.

had failed a United States' Federal Aviation Administration live fire test under low temperature conditions. Powdered Aerosol F had failed a Federal Aviation Administration full-scale engine fire test. More research and development would be required to develop satisfactory performance systems using these agents.

It has been reported that HFC-125 has been successfully installed and used by the United States' military in aircraft. HFC-125 is the only halon 1301 alternative agent available today which has passed the Federal Aviation Administration Minimum Performance Standards testing and the United States EPA's Significant New Alternatives (SNAP) assessment. HFC-125 has a high global warming potential (GWP) and would have increased weight and space requirements making retrofit solutions unlikely and presents challenges to installation and operational considerations in new airframe designs. Research and development continue.

In 2013, due to the slow progress in halon alternatives development, the Engine/Auxiliary Power Unit Halon Alternatives Research Industry Consortium (IC) was established to accelerate the search for acceptable halon 1301 alternatives. In 2015, this was renamed the Halon Alternatives for Aircraft Propulsion Systems (HAAPS) consortium.

The HAAPS consortium includes aircraft original equipment manufacturers (OEMs) Airbus, Boeing, Bombardier, Embraer, Textron, with the Ohio Aerospace Institute acting as administrator. The consortium's stated aims are to engage with the United States' Federal Aviation Administration and potential agent and equipment suppliers and collaborate on the design of selection criteria for evaluation of potential solutions with final selection of qualified agents and equipment by the end of 2022.

Table 2.1 *Timeline of the Halon Alternatives for Aircraft Propulsion Systems (HAAPS) consortium*

Phase	Activities	Implementation/Notional Completion Date
Phase 1	Administrative start-up Signed Joint Collaboration Agreement	2015/October 2018
Phase 2	United States' Federal Aviation Administration engagement Issue design requirements Engage stakeholders Engage potential solution suppliers High level selection criteria Design of certification paths Agreement on Minimum Performance Standards	October 2018/October 2019 (notional completion) Work remains ongoing
Phase 3	Establish supplier agreements In-depth agent evaluation and testing Final agent(s) selection	October 2019 (notional commencement) 31 December 2022 (completion date)

2.3.5 Cargo Compartment Fire Suppression

The search for environmentally safe replacements for halon in the civil aviation sector commenced in 1993. The Cargo Compartment Halon Replacement Advisory Group (CCHRAG) was formed in 2013 to advance development of halon replacements for aircraft cargo compartment fire protection. In 2016, after engaging with industry, government and regulator stakeholders and potential suppliers, and developing a list of technical requirements, the Cargo Compartment Halon Replacement Advisory Group recommended to the 39th International Civil Aviation Organization General Assembly a deadline of November 30, 2024, after which halon alternatives would be required for new type certificate aircraft. This timeline was accepted by the General Assembly and the Cargo Compartment Halon Replacement Advisory Group were requested to continue work to ensure technical readiness of solutions by the deadline.

In October 2018, the United States' Federal Aviation Administration announced that a new Cargo Fire Suppression Minimum Performance Standards Task Group had been formed. This group reports quarterly and is working on improvements to Minimum Performance Standards testing procedures and capabilities. As of October 2019, a full range of Minimum Performance Standards testing procedures for halon alternatives was not yet finalised.

In 2019, at the 40th International Civil Aviation Organization General Assembly, the Cargo Compartment Halon Replacement Advisory Group reported that, in the previous year, eight potential solution providers had agreed to submit detailed, non-proprietary, information on nine technologies. The submitted candidate technologies included three chemical agents, several inerting gas agents, and two combined technologies. The inerting gas agents included proposals for solid propellant, onboard gas generators and tanked gas. The combined technologies included water/gas and foam/gas.

The Cargo Compartment Halon Replacement Advisory Group reported that, so far, only one candidate had passed an independent laboratory supervised ISO 14520 heptane cup burner test, while one other candidate had passed an in-house heptane cup burner test. Progress towards maturity of a solution is being reported in terms of NASA Technical Readiness Levels¹³ (TRL). One technology was said to meet TRL 4, indicating a technology had been demonstrated in laboratory. The Cargo Compartment Halon Replacement Advisory Group goal is to have at least one candidate developed to TRL 7, essentially a successful prototype demonstration in an operational environment, by 2021.

Despite the slow progress so far, as noted by the Halon Technical Options Committee special report¹⁴, the Cargo Compartment Halon Replacement Advisory Group reported confidence that a solution would be available to meet the 2024 deadline. However, it noted that if a candidate system had not been demonstrated to be TRL 7 "application ready" by 41st International Civil Aviation Organization General Assembly, scheduled to be held before the end of 2022, then reasons for failure to meet the timelines and consequences for the 2024 deadline would be submitted.

None of the solutions being explored by the Cargo Compartment Halon Replacement Advisory Group would appear to meet the requirements of a drop-in replacement for halon 1301. Inerting and combination systems would need significant equipment modifications and new installations, while all chemical agents would incur weight and volume penalties which would offer

¹³https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html

¹⁴UNEP, *Report of the UNEP Technology and Economic Assessment Panel, Volume 2, Decision XXIX/8 on the Future Availability of Halons and their Alternatives*, September 2018.

technical, economic and environmental challenges to retrofit.

Based on past progress, the proposed Cargo Compartment Halon Replacement Advisory Group 2024 deadline might be considered as optimistic. Even if the proposed dates for application-ready alternatives are met, while new type certificate aircraft after this date would be designed and manufactured with halon alternative systems, it seems quite unlikely that there would be a simple retrofit available for existing aircraft or airframe designs submitted prior to the deadline. This suggests that technical and economic challenges are likely to prevent halon replacement in the existing fleet before retirement or sale/transfer of the current fleet’s aircraft.

2.3.6 Summary of International Civil Aviation Organization Requirements for Halon Replacements

The International Civil Aviation Organization has mandated requirements for the use of halon replacements in fire extinguishers used on civil transport aircraft in International Civil Aviation Organization safety management Standards and Recommended Practices (SARPs) through amendments to Annexes 6 and 8 of the Convention on International Civil Aviation. Safety management Standards and Recommended Practices are intended to assist Member States to the Convention in managing their aviation safety risks.

Table 2.2: International Civil Aviation Organization Standards and Recommended Practices Halon Replacement Requirements

	Lavatory Halon 1301	Handheld Halon 1211	Engine/APU Halon 1301	Cargo Halon 1301
New Design Aircraft (Deadline for Applications for New Aircraft Type Certification)	2011	2018	2014	2024
Current Production Aircraft	2011	2018	-	-

Note: the date is 31 December of the specified year.

However, Member States are not required to follow these requirements and can file “differences” that signal an intention not to meet these requirements and to continue to use halons beyond the stipulated dates. Some Member States have filed differences indicating that they will continue to use halon beyond these dates¹⁵. Australia has filed differences for the Annex 8, section 1.2.6 design standard with respect to engine and auxiliary power units, and the Annex 8, section 1.2.7 design standard for cargo compartments.

In July 2019, the International Coordinating Council of Aerospace Industries

¹⁵ UNEP, *Report of the Halons Technical Options Committee, Assessment Report 2018, Volume 1*, December 2018.

Associations (ICCAIA), an industry body established to provide representation by the civil aircraft industry and observer status in the deliberations of the International Civil Aviation Organization, indicated (in a working paper prepared for the 40th Session of the International Civil Aviation Organization Assembly for the Technical Commission¹⁶) that:

- *Engine/Auxiliary Power Units* – an industry consortium (the Engine/ Auxiliary Power Unit Halon Alternatives Research Industry Consortium) has been formed and is implementing a phased plan to progress the development of halon alternatives, scheduled for completion by the end of 2022.
- *Cargo compartment systems* – the industry is committed to supporting the 2024 deadline for halon replacement in cargo compartments of new type certificated aircraft with applications submitted after November 2024.
- If a halon replacement candidate for *cargo compartment systems* has not been demonstrated to be application ready by the 41st Session of the International Civil Aviation Organization Assembly which must be held before the end of 2022, the International Coordinating Council of Aerospace Industries Associations will identify the reasons for not adhering to the timeline and indicate the implications for meeting the 2024 deadline.

The International Coordinating Council of Aerospace Industries Associations outlined the risks of delays in meeting the International Civil Aviation Organization Standards and Recommended Practices that are associated with the uncertainties in halon alternatives development, testing and certifications by regulatory authorities.

2.3.7 European Union Requirements for Halon Replacements

The European Union (EU) banned all non-critical uses of halons in aircraft in 2003. Critical uses of halon in aircraft are listed in Annex VI to Regulation (EC) No. 1005/2009, which includes the permitted on-board uses of halons in aviation. Regulation (EU) No. 744/2010 amended Regulation (EC) No. 1005/2009 and Annex VI to include “cut-off dates”, after which halons cannot be used for fire extinguishers or fire protection systems for new equipment (e.g., new design aircraft), and “end dates”, after which halon cannot be used for the application and when halon extinguishers and fire protection systems

¹⁶ A40-WP/93 TE/25, *Halon Replacement – Challenges and Solutions*, presented by the International Coordinating Council of Aerospace Industries Associations, 26/7/19. https://www.icao.int/Meetings/a40/Documents/WP/wp_093_en.pdf, accessed December 2019.

(Continued next page)

must be decommissioned.

Commission Regulation (EU) 2015/64011, as amended by (EU) 2019/133, provides for the replacement of halon in lavatories (from 18 May 2019) and handheld fire extinguishers (from 18 February 2020) on newly produced aircraft (i.e. 'forward fit') based on existing aircraft type certificates.¹⁷ These European Union requirements differ from those of the International Civil Aviation Organization.

Table 2.3: European Union Halon Replacement Requirements

	Lavatory	Handheld	Engine/APU	Cargo
New Design Aircraft (Cut-off Dates for Applications for New Aircraft Type Certification)	2011	2014	2014	2018
Current Production Aircraft	Feb. 18, 2020	May 18, 2019	-	-
Retrofit (End-Use Dates)	2020	2025	2040	2040

Note: If not otherwise specified, the date is 31 December of the specified year.

The European Union rules cover non-European Union aircraft types registered in a European Union Member State.

Derogations from cut-off and end dates can be granted by the European Commission in specific cases where it is demonstrated that no technically and economically feasible alternative is available.

2.3.8 The United States

For the United States, *Clean Air Act Amendments* (1990) provided the United States' Environmental Protection Agency with the authority to regulate the production and consumption of halons consistent with the Montreal Protocol, but not with the authority to regulate halon uses. The United States' Federal Aviation Administration has included provisions for the use of alternative fire-extinguishing and suppression agents as part of the airworthiness standards for the issue of type certificates (i.e., 14 Code of Federal Regulation (CFR) Part 25 - Airworthiness Standards). However, no schedule currently exists for the replacement of halon by the Federal Aviation Administration.

¹⁷ European Union Aviation Safety Agency, *Halon Replacement in the Aviation Industry*, November 2019. <https://www.easa.europa.eu/document-library/general-publications/halon-replacement-aviation-industry>. Accessed December 2019.

2.3.9 Australian Requirements for Fire Extinguishing Agents under the Civil Aviation Act 1988

Requirements for civil aviation fire extinguishing agents are established in Australia through the *Civil Aviation Act 1988* and its *Civil Aviation Safety Regulations 1998* (CASR 1998), and the Part 90 Manual of Standards made under regulation 90.020 of CASR 1998.

Airworthiness Directive AD/GENERAL/65, Amendment 5 (2008), made under CASR 1998, establishes the number of hand-held fire extinguishers required in the passenger compartment according to passenger seating capacities¹⁸, and required that for aircraft needing 2 or more fire extinguishers in the passenger compartment that at least 2 shall contain halon 1211 or an equivalent approved by the Civil Aviation Safety Authority.

As a result of resolutions, the International Civil Aviation Organization supports the adoption of halon alternatives in engines and auxiliary power units, handheld extinguishers and lavatories, and has established the associated International Civil Aviation Organization Standards and Recommended Practices, as noted above. In response, the Civil Aviation Safety Authority has adopted some complimentary regulations. CASR 1998, regulation 90.150, and the Part 90 Manual of Standards, now requires that, for all aircraft manufactured on or after the 31st December 2018, halon is a prohibited fire extinguishing agent in any hand-held fire extinguishers and any fire extinguisher fitted for a lavatory disposal receptacle for towels, paper or waste.

Therefore, for new aircraft manufactured after 2018 requiring more than one fire extinguisher in the cabin, an approved halon-replacement fire extinguisher is the only option. For an aircraft manufactured after 2018 requiring only one fire extinguisher, that extinguisher must also not contain halon but can be any other agent appropriate for the location in which it will be used. For lavex, halon is also prohibited for aircraft manufactured after 2018.

The Civil Aviation Safety Authority has approved a range of halon-free fire extinguishing agents as equivalents for halon 1211 in hand-held fire extinguishers. Major Australian airlines are already using halon alternatives (HFC-227ea and HFC-236a) for lavex fire extinguishing applications in some aircraft.

2.4 Non-Defence Maritime Uses

The installed base of halon used in Australian-flagged vessels and

¹⁸ 6 – 30 Passengers, 1 extinguisher (no requirement for halon); 31 – 60, 2; 61 – 200, 3; 201 – 300, 4; 301 – 400, 5; 401 – 500, 6; 501 – 600, 7; 601 or more, 8.

international vessels is expected to be insignificant in its effect on NHB stocks. The International Maritime Organisation (IMO) prohibited new installations of halon containing fire-extinguishing systems from October 1, 1994. Extant halon systems prior to 1994 were not required to be replaced by alternatives. Nonetheless, natural attrition with age has meant the number of vessels using halon is expected to be small and diminishing.

2.4.1 Australian Flagged Vessels

The 2012 Halon Review reported that there was no longer any significant call on NHB stocks by Australian flagged vessels.

One maritime fire services provider has provided us with current information that there is one registered commercial vessel in South Australia that still has a halon fire suppression system, containing a nominal 600 kg of halon 1301.

Additionally, it was reported that a former New Zealand Defence vessel (believed to be ex-HMNZS Manawanui) had been imported during 2018-2019 into Australia with a halon 1301 fire suppression system and renamed as the MV Ocean Recovery out of Newcastle.

For both vessels, it has been suggested that if the fire suppression systems were ever used that they would be refilled economically with a halon alternative drop-in replacement. This suggests that these vessels are unlikely to make any future call on NHB stocks.

2.4.2 Foreign Flagged Vessels

Australia is one of the largest global shipping nations in terms of tonnes of cargo shipped and kilometres travelled. A large number of foreign flagged bulk and containerised commercial shipping, and an increasing number of cruise ships, visit each year.

Most cruise vessels are expected to have been built post-1994 and to have complied with IMO resolutions banning halon on new vessels.

Visiting foreign flagged vessels requiring halon while in Australian ports can access halon through Australian fire protection companies with the necessary halon special permits required under the Act. Requests for supply of halons from the NHB are administered in accordance with the criteria established under the Act. Halons are permitted to be provided for fire protection systems in maritime applications where halon is still required, and no practical alternatives exist.

The major uncertainty in estimating future halon requirements for the non-defence maritime sector is expected to be foreign flagged vessels that have a discharge incident on route to Australia or while serving Australian coastal

routes. It is not considered likely that foreign flagged vessels would pose significant risks to Australia's halon stocks.

2.4.3 *Halon Alternatives*

Numerous alternatives are available to replace halon fire protection systems in maritime use. These include, but are not limited to, CO₂, water mist, foam, FM-200 and dry powder extinguishers. These, and other technologies, have replaced halon use in new vessels since 1994. For existing vessels with legacy halon systems, it has been reported that after an on-board halon release event it would be more cost-effective to retrofit a halon-alternative chemical agent than to refill with halon.

2.5 Defence Uses

The 2020 Halon Review investigates non-defence halon uses and considers requirements for the strategic non-defence stockpile of halon at the NHB to meet those needs. Defence halon usage and future halon requirements have been addressed separately.

3 Future Trends in Halon Consumption

The status of alternatives to halon use in civil aviation and maritime uses has been described in the previous section. This section describes possible future trends in the consumption of halon for remaining uses, taking into account the status of alternatives, current directions and possible outcomes in the international and national civil aviation sector and the non-defence maritime sector.

3.1 Civil Aviation Uses

Technically acceptable alternatives to halons have been identified for two of the four civil aviation application areas, notably lavex and handheld extinguishers. The *Civil Aviation Act 1988* has established prohibitions on halon 1211 in handheld extinguishers and halon 1301 in lavex systems in aircraft manufactured after 2018. However, commercial development of an alternative fire suppression system for cargo compartments and engine/auxiliary power units is still progressing slowly.

Australian civil aviation is dependent on international aircraft manufacturers to identify, develop, certify, and implement the alternatives to halon 1301 in engine/auxiliary power units and cargo compartments. For large, integrated systems like engine/auxiliary power units and cargo compartments, this might more likely occur through type certifications for new design aircraft than through retrofit. Nevertheless, the European “end-use” date requirements for retrofit for all halon aviation applications, including engine/auxiliary power units and cargo compartments, may facilitate the search for retrofit options for existing halon equipment and systems.

Once a type certification is approved for new design aircraft, there is a delay until production of the new design aircraft. Based on international expert opinion¹⁹, the average delay between type certification of new design aircraft and that aircraft going into production is about 10 years. This delay means that halon consumption would continue after an approved type certification that includes halon alternatives until that new design aircraft goes into production. Even then, the newly produced aircraft would only gradually add to the aircraft fleet or replace retired existing aircraft with halon fire protection and thereby reduce halon consumption.

Unless there is a drop-in alternative that meets Minimum Performance Standards (e.g. as for lavex systems), there is generally no simple way to retrofit halon alternatives into existing aircraft. Some retrofit of existing halon 1301 lavex systems has occurred with an alternative that is an HFC during scheduled maintenance (e.g. Lufthansa) but most halon alternatives in

¹⁹ David Catchpole and Dan Verdonik, HTOC co-chairs (2011), personal communications 2011.

aviation will most likely be introduced in new production aircraft. Based on Australian experience, even when a near drop-in replacement is available (e.g. FM-200 handheld extinguishers) there is unlikely to be voluntary replacement because of added weight, cost, and risk of future restrictions due to the replacement's high GWP. Due to the requirements for type certificates and maintaining individual aircraft certificates for airworthiness, and probably also due to cost, weight and size implications, little retrofit is anticipated unless regulatory measures are introduced.

With no current halon alternatives, and slow progress on future alternatives, for cargo compartments and engine/auxiliary power units, and these built-in transition delays, halon 1301 is still likely to be installed in new production aircraft for the next 20-30 years or more (the Montreal Protocol's Halons Technical Options Committee, HTOC, has indicated 20-40 years²⁰). For example, the International Civil Aviation Organization cargo compartment requirement for new design aircraft is currently 2024. Even if this date is achieved, it would be around 2035 onwards that newly produced aircraft installed with alternatives become available in the international aircraft fleet. Therefore, halon 1301 use is likely to increase over at least the next decade with aircraft numbers; it may plateau if alternatives become available, but it will not reduce for some time. International expert opinion^{21,22} has not changed substantially since the 2012 Halon Review, suggesting that it may be at least 2050 before halon 1301 use decreases globally, and, even then, cargo bay use may still remain.

Given the prohibition in the *Civil Aviation Act 1988* for halon 1301 lavex applications in aircraft manufactured after 2018, demand for halon 1301 in lavex applications is expected to slowly decline in line with attrition of aircraft at end-of-life and installation of alternatives in newly manufactured aircraft. While retrofits are not required in Australia, drop-in alternatives are available. Despite the availability of drop-in alternatives for lavex applications, with cost implications for those retrofits, and with 20 to 30-year aircraft lifetimes, demand for halon 1301 is expected to continue to service existing systems in aircraft manufactured before 2019, and gradually decline. Virtually all current production aircraft lavex systems are now being fitted with HFC-227ea and HFC-236fa (see section 2.3.2). This does not necessarily extend to retrofit of these HFCs to legacy aircraft as some may require Type Certification/Aircraft Manuals to be updated. Australian industry sources suggest that retrofits are not being widely installed in the Australian civil aviation fleet.

²⁰ UNEP, *Report of the Technology and Economic Assessment Panel, Volume 2, Decision XXIX/8 Report on the future availability of halons and their alternatives*, September 2018.

²¹ David Catchpole and Dan Verdonik, HTOC Co-Chairs (2011), personal communications 2011.

²² Adam Chattaway and Dan Verdonik, HTOC Co-Chairs (2019), personal communications 2019.

Given the prohibition in the *Civil Aviation Act 1988* for halon 1211 handheld extinguishers in aircraft manufactured after 2018, demand for halon 1211 is expected to slowly decline in line with attrition of aircraft at end-of-life and installation of alternatives in newly manufactured aircraft. While retrofits are not required in Australia, drop-in alternatives are available; these may necessitate structural and weight adjustments. Nevertheless, demand for halon 1211 is expected to continue to service existing systems in aircraft manufactured before 2019, and slowly decline.

3.1.1 Australian Aircraft Fleet Growth

Global and Australian market dynamics, relating to industry trends and forecasts in the aircraft fleet, have been considered to establish plausible assumptions for estimating halon requirements and the future phase-out of halon in Australian aviation.

Based on superseded requirements in the *Civil Aviation Act 1988*, halon 1211 extinguishers are installed in the categories of pre-2019 aircraft with seating capacities over 30 passengers. These include the regional and mainline categories of aircraft, where regional aircraft are those with seating capacities between 70-100 passengers (e.g., Bombardier Dash 8, Q200, Q300, British Aerospace 146, and Embraer 170/190) and mainline aircraft are those with seating capacities over about 100 passengers (e.g., Airbus A320, A321, A330, A380, Boeing 717, 737, 747, 767, 777, 787), or smaller aircraft (e.g., Embraer ERJ series with seating capacities of 37-50).

Halon 1301 in lavex systems, engine/auxiliary power units and cargo compartments are installed across a range of categories of smaller seating capacity, regional, and mainline aircraft. Engine/auxiliary power unit halon systems are not installed in piston engine aircraft, e.g., Cessna 404, Piper Navajo, Rockwell Aero Commander. Instead, they are installed in multi-engine turboprop and turbofan aircraft, ranging from the smaller multi-engine turbofan aircraft, e.g., Cessna Citation (7-10 passenger), Bombardier Challenger (19 passengers), to the larger multi-engine turbofan aircraft, e.g., Airbus A330 and Boeing 747.

Recent analysis developed by ICF²³ for the global aircraft fleet concludes assumptions that very large aircraft have the largest total installed halon 1301 quantity, with the largest components for cargo applications (average 157 kg per aircraft) and engine applications (average 80 kg per aircraft). Intermediate

²³ *Drawing Down Halon 1301 Inventories: Updated Analysis*, ICF International Inc. for United States' Environmental Protection Agency, September 2018, and through personal communications, ICF, December 2019. The 2018 analysis includes company-specific assumptions, a refined methodology and assumptions, and updated activity data. It uses aircraft activity data from publicly available Boeing and Airbus sources and applied assumptions of halon used in different applications (e.g., engine, cargo) to the different plane types (e.g., very large, intermediate twin, business jets, turboprops). The mainline and regional assumptions take into account both passenger and freighter aircraft.

twin engine aircraft have slightly less for cargo (average 122 kg per aircraft), and relatively considerably less for engine applications (average 28 kg per aircraft).

Taking all of the above into consideration, this study has focused its global and Australian market analysis towards the trends in aircraft with larger seating capacities as surrogates for the entire fleet in estimating projections for future halon requirements. The trends analysis is based on recently available aviation industry market data and projections and do not take into account potential unexpected market anomalies, such as the COVID-19 global pandemic in 2020.

Globally, low airfares, growth in tourism and travel, higher living standards and a growing middle class in emerging markets, and new economies within the airline business, are driving air travel growth at 6.7% year-on-year during the last five years, which is higher than the long-term average of 5%²⁴. In turn, this is driving fleet growth for aircraft with passenger seating capacities over 100. Boeing estimates the global mainline fleet to increase from 25,830 aircraft in 2018 to 50,660 aircraft in 2038, corresponding to average annual growth of 4.8%. Airbus²⁵ estimates the global mainline fleet to increase from 20,870 aircraft in 2019 to 44,860 aircraft in 2038, corresponding to average annual growth of 6%. While the proportion of new aircraft deliveries for replacement versus new aircraft deliveries for growth varies widely from year to year, generally, new aircraft deliveries for growth outpace new aircraft deliveries for replacement, with this trend expected for the period 2018-2038 at the ratio of 56:44²⁶. Long-term global retirement rates are expected to remain steady, at 3% of the fleet per annum, for the period 2018-2038.

Regionally, the Asia-Pacific region is expected to dominate global growth in travel and aircraft demand, due primarily to the China market. Airbus estimates that the Asia-Pacific mainline fleet will increase from 7,105 aircraft in 2019 to 19,225 aircraft in 2038, corresponding to average annual growth of 9%.

In Australia, the Bureau of Infrastructure, Transport and Regional Economics (BITRE) provides data analysis of transport issues, including aviation. An

²⁴ *Commercial Market Outlook, 2019-2038*, Boeing, 2019.

²⁵ *Global Market Forecast, Cities, Airports and Aircraft, 2019-2038*, Airbus, 2019.

²⁶ For every 100 new aircraft deliveries, 56 are for growth or increased demand, and 44 are for replacement of retired aircraft.

(Continued next page)

analysis of aircraft data for 2014²⁷, 2016²⁸ and 2018²⁹ indicates average annual growth in the number of large multi-engine turbofan aircraft of between 3% (for 2014-2018) to 4% (for 2016-2018). Smaller fixed-wing multi-engine aircraft (e.g., Bombardier, Beechcraft, Fairchild, Fokker) show lower average annual growth. A report by the International Air Transport Association for Air Services Australia³⁰ forecast aircraft numbers for major Australian airlines between 2014 and 2021, corresponding to average overall annual growth in aircraft among those major airlines of 3%.

Based on these considerations, for the purposes of assumptions used in this report, the Australian aircraft fleet is forecast to grow annually between 4-6% on average, which lies between the short-term local and the long-term global estimates of average annual growth, respectively. The 6% global growth rate is included as an upper bound assumption for annual Australian aircraft fleet growth and as a conservative concession to the expected relatively higher growth in Asia-Pacific region (9%), which, however, may not be realistic for Australia.

3.1.2 Aircraft Lifetime and Australian Aircraft Fleet Age

Aircraft lifetimes, and the aging profile of the Australian aircraft fleet, are relevant to the analysis of future halon requirements in aviation due to the process of attrition of older aircraft through retirement and the introduction of newly manufactured aircraft with installed halon alternatives. Global aircraft manufacturers design aircraft for a minimum lifetime of 20 years, with a specified number of flight hours and flight cycles³¹. Generally speaking, in practice, aircraft are durable assets that typically remain in service for 20-30 years, and often longer³². Aircraft age is determined not only by age in years but also by the number of pressurization cycles causing stress on the aircraft. Aircraft are generally retired when the cost to maintain and operate them exceeds their generated revenue.

Based on the Bureau of Infrastructure, Transport and Regional Economics data for 2018, the Australian fleet Airbus and Boeing categories of fixed wing,

²⁷ Bureau of Infrastructure, Transport and Regional Economics Statistical Report, *Australian Aircraft Activity 2014*, 2017.

²⁸ Bureau of Infrastructure, Transport and Regional Economics Statistical Report, *Australian Aircraft Activity 2016*, 2018.

²⁹ Bureau of Infrastructure, Transport and Regional Economics Statistical Report, *Australian Aircraft Activity 2018*, 2019.

³⁰ *Activity Forecasts for the Period 2014-2015 to 2020-2021*, International Air Transport Association for Air Services Australia, Draft Final Report, 25 February 2015.

³¹ *How old is too old? The impact of ageing aircraft on aviation safety*, Australian Transport Safety Bureau, February 2007.

³² *Commercial Market Outlook, 2019-2038*, Boeing, 2019.

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multi-engine aircraft have an average age of 10 years. The average age of other multi-engine aircraft tends to be higher, e.g., the Fokker category is 26 years on average. Based on a report by the Australian Transport Safety Bureau using data for the Australian aircraft fleet in 2005³³, generally, smaller multi-engine turboprop aircraft have higher average age, and a wider spread of aircraft age. In 2005, 34% of this small-sized aircraft category was aged over 20 years. For medium-sized multi-engine turboprop aircraft, 5% were aged over 20 years. For large multi-engine turboprop aircraft, 3% were aged over 20 years in 2005.

Based on these considerations, for the purposes of assumptions used in this report, Australian aircraft are assumed to reach their end-of-life in service in Australia at 30 years. A lower bound aircraft lifetime of 20 years has also been included as a variable assumption.

3.1.3 Acquisition of New Aircraft and Disposal of Old Aircraft by Major Airlines

Information was solicited from the major airline carriers regarding the current source of halon in new aircraft and the current fate of halon from retired aircraft. The commencement of operations by Asia Pacific Aircraft Storage (APAS) in June 2014 has provided the possibility for storage of aircraft and retired aircraft being broken down in Australia and the installed halon recovered to Australian stock. Asia Pacific Aircraft Storage offer services to Australian and international carriers.

3.1.3.1 Large Passenger Aircraft Entering the Australian Major Airline Fleet

New aircraft must fly with fire suppression systems fully installed to meet airworthiness requirements. Industry sources indicate that large passenger aircraft entering the Australian fleet, either due to international purchase or lease, come supplied with halon 1301 and so are a net increase in Australian installed base of halon. Handheld extinguishers may be specified as “buyer furnished equipment” in which case the buyer must furnish the equipment and deliver to the manufacturer for fitting to the aircraft prior to delivery. This would mean that new aircraft purchased have required halon 1211 handheld extinguishers drawn from Australia’s stock of halon 1211. So, while new aircraft purchases will have drawn on Australia’s halon 1211, aircraft retired or on-sold overseas will have been lost from Australia’s halon 1211 stocks. Now that replacements for halon 1211 have been mandated for handheld extinguishers in new aircraft the “buyer furnished equipment” clause leading to temporary export, fitting to aircraft and reimport in aircraft of halon 1211 would no longer be occurring.

A high rate of turnover is expected to be on-going in Australia’s aviation mainline fleet over the next decade due to continued population growth,

³³ *Ibid.*, Australian Transport Safety Bureau.

significant growth in passenger enplanements (passenger seats occupied) well above GDP growth, and the continued introduction by manufacturers of new aircraft with lower running costs, significant fuel efficiency and associated environmental benefits.

Predictions for growth in the fleet have been estimated to provide the basis for modelling of the net effect on Australia's halon stock and installed base of halon (see section 3.1.1).

3.1.3.2 Large Passenger Aircraft Leaving the Australian Major Airline Fleet

Large passenger aircraft exiting an Australian-based airline's fleet may be on-sold or leased locally or overseas, converted for cargo transport and used locally, or retired and broken down for parts and scrap if it has reached the end of its airframe life.

Industry sources indicate that installed halon from large passenger aircraft removed from an airline's passenger fleet and retired overseas (with halon still aboard) effectively removes that halon from Australia's installed base.

The commencement of operations by Asia Pacific Aircraft Storage Pty. Ltd. at Alice Springs in June 2014 has provided the possibility of retired aircraft from Australia and overseas being broken down in Australia and the installed halon recovered to Australian stock. It was reported that Asia Pacific Aircraft Storage Pty Ltd commenced with a hard stand area capable of accommodating up to 25 aircraft, including very large aircraft of the size of the Airbus A380. Asia Pacific Aircraft Storage Pty Ltd lists Australian and international airlines as customers, so there is a possibility that aircraft retired from overseas could be broken down in Australia and provide a future source of halon for recycling in Australia. Aircraft in storage and being recommissioned potentially could require halon from Australian stocks. While Asia Pacific Aircraft Storage Pty Ltd provides aircraft recycling, reports indicate that the current business model leans more to the provision of short-term storage than to end-of-life solutions however the business has potential to evolve in the future. At the time of publication, we do not have further information on the scale of current operations, future growth, or potential plans for future expansion of services with regard to the fate of halon.

3.1.4 International Aircraft Visiting Australia and Australian Aircraft Visiting Abroad with Halon Requirements

Visiting international aircraft may make calls on Australia's halon stocks after an in-flight incident involving the release of halon on route or while on the ground. Similarly, Australian aircraft travelling abroad that incur a release of halon may require restocking from their international port of call. It is expected that, at worst, such incidents will roughly balance the loss and gain to the Australian installed base of halon and have negligible overall effect on

NHB stocks.

3.1.5 Estimating Future Civil Aviation Halon Requirements

The 2012 Halon Review³⁴ presented a quantitative analysis of future civil aviation halon requirements based on an estimation of the quantities of halon installed in and emitted from civil aircraft in Australia (including commercial passenger and freight but excluding general aviation such as unscheduled private and recreational aviation) from 2012 to 2060. The methodology was based on that described by ICF³⁵, using mainline and regional aircraft forecasts, modified for the purposes of the 2012 Halon Review. The number and age of existing commercial passenger and freighter aircraft in service in mainline and regional categories at the end of 2011 were determined from available online sources of aircraft data.

Since 2013, the Civil Aviation Safety Authority provides its civil aircraft register, which is available online. For this report, analysis has been undertaken, using the Civil Aviation Safety Authority data, company annual reports and data handbooks, and other online sources to compile a comprehensive list of specific larger aircraft models.

Specific data on halon quantities for a substantial number of aircraft models was made available for Qantas group carriers. This data was applied to similar aircraft in other major airline fleets to provide a reasonably comprehensive set of data for major airlines (Jetstar, Qantas, QantasLink, Network Aviation, Qantas Freight, Virgin, Alliance Airlines, Tiger Air). Statistics from the Bureau of Infrastructure, Transport and Regional Economics were used to estimate the remainder of the Australian air fleet, for smaller aircraft types. These data were combined to produce a bottom-up model for installed halon and warehoused halon (on-hand spares). A range of annual emission and consumption factors were investigated along with expectations for fleet growth. This approach provides complementary analysis to NHB halon sales data modelling, which remains the primary source for quantitative analysis in estimating future halon requirements.

For the 2012 Halon Review, the average quantities of halon installed in Australian commercial passenger and freighter aircraft in mainline and regional categories were estimated based on the global average quantities of

³⁴ *Review of Australia's Halon Essential Use Requirements 2012*, by Energy International Australia for the Department of Environment and Energy, May 2012, <https://www.environment.gov.au/protection/ozone/publications/review-australias-halon-essential-uses-requirements>

³⁵ ICF International, *Revised Draft Report: Estimated Usage and Emissions of Halon 1301, 1211, and 2402 in Civil Aircraft Worldwide*, June 2006, made available through personal communication with Ms. Bella Maranion, United States EPA.

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halon installed for each fire protection application and aircraft type as reported by ICF³⁶. ICF based its analysis on an earlier study undertaken by O’Sullivan³⁷. The results of the 2012 Halon Review analysis, and comparison with estimated halon consumption based on NHB sales data, appeared to indicate that the aviation model was under-estimating halon usage in commercial passenger and freighter aircraft³⁸.

For the 2012 Halon Review, the total quantities of halon 1301 and halon 1211 emitted each year were calculated based on estimated leakage and inadvertent discharge rates for each of the halon fire protection systems, as used by ICF. A leakage rate of 2% per year was used for each of the halon 1301 systems³⁹. A leakage rate of 6% per year was assumed for halon 1211 handheld fire extinguishers⁴⁰. Both of these assumed leakage rates are within the ranges estimated in the 2005 Intergovernmental Panel on Climate Change/TEAP Special Report (IPCC/TEAP)⁴¹. The IPCC/TEAP estimated the average in-service-life annual emissions rates (i.e., not including end-of-life emissions or decommissioned quantities) for halon 1301 fixed systems and halon 1211 portable systems as $2 \pm 1\%$ per year and $4 \pm 2\%$ per year, respectively. For this 2020 Halon Review, an emission factor of 6% per year was used to estimate possible current halon 1211 demands in aviation uses as a basis for projecting future demand.

In 2016, Vollmer *et al.*⁴² reported an average annual halon 1301 emission rate

³⁶ ICF International, *Revised Draft Report: Estimated Usage and Emissions of Halon 1301, 1211, and 2402 in Civil Aircraft Worldwide*, June 2006.

³⁷ O’Sullivan, J., *National airlines and halon data*, (data compiled by British Airways technical expert), 2005.

³⁸ For the 2012 Halon Review, estimated emissions from the civil aviation model corresponded to 27% and 43% of the estimated annual consumption for halons 1211 and 1301 respectively, where annual NHB halon sales was assumed equivalent to total annual consumption. Even after considering unaccounted general aviation (the aviation model estimated halon installed in commercial passenger and freighter aircraft and not in general aviation, such as unscheduled private or recreational aviation), defence and maritime halon uses that would have made up the remainder of total annual halon consumption, the 2012 Halon Review aviation model seemed to under-estimate halon usage in commercial passenger and freighter aircraft. Further work was considered necessary to better quantify defence halon usage and its contribution to annual NHB halon sales to test implications. There was also underlying uncertainty in the aviation model in using global average quantities of installed halon per aircraft type and application as a surrogate to estimate installed halon for the Australian passenger aircraft fleet.

³⁹ This is the leakage rate assumed for both halon total flooding and streaming systems in the United States EPA Vintaging Model, as reported by ICF, 2006.

⁴⁰ As reported by O’Sullivan, 2005, and used by ICF, 2006.

⁴¹ IPCC/TEAP Special Report, *Safeguarding the Ozone Layer and the Global Climate System: Issues Related to Hydrofluorocarbons and Perfluorocarbons*, 2005.

⁴² Vollmer, M. K., et al. (2016), Atmospheric histories and global emissions of halons H-1211 (CBrClF₂), H-1301 (CBrF₃), and H-2402 (CBrF₂CBrF₂), *J. Geo-phys. Res. Atmos.*, **121**, 3663–3686, doi:10.1002/2015JD024488.

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of 4% based on atmospheric-derived emissions, which relates to emissions from all halon 1301 applications and is higher than the emissions rates previously assumed in halon analyses.

In 2014, the United States' Federal Aviation Administration Halon Aviation Rulemaking Committee⁴³ estimated an emission rate for halon 1301 aviation systems in the range of 7-8% per year, noted as being much higher than for most other halon applications. Only a small percentage of these total releases result from the extinguishment of fires, with the vast majority of emissions resulting from accidental releases or occurring during testing or handling. The United States' Federal Aviation Administration Halon Aviation Rulemaking Committee estimated emission rate is also higher than the global average halon 1301 emissions rate derived by Vollmer *et al.* from atmospheric emissions of all halon 1301 applications.

More recently, the Montreal Protocol's Halon Technical Options Committee Assessment Report 2018⁴⁴ and the Technology and Economic Assessment Panel response to Decision XXIX/8 on the Future Availability of Halons and their Alternatives⁴⁵ reported a survey conducted by the International Civil Aviation Organization. Information was gathered on the difference between the amount of halon that enters civil aviation halon 1301 service provider facilities in cylinders for servicing (recovered) and the amount that leaves the facility in serviced cylinders (filled), as a way of estimating the size and rate of halon emissions. From a limited survey response, the difference between the amount of recovered halon and the amount filled ranged from 4% to 50%, with an average of about 14%. While it was not possible from these limited data to determine whether the 14% data point relates accurately to an actual emission rate, it provides further anecdotal evidence supporting the 2014 United States' Federal Aviation Administration Halon Aviation Rulemaking Committee conclusions that the aviation emissions rate for halon 1301 may be significantly higher than the global average of 3-4% (derived from atmospheric measurements) and previously applied emission factors.

In the Halons Technical Options Committee's 2018 analysis, a range of emissions scenarios were used to determine the potential availability of halon 1301 to support global civil aviation through to 2060, with annual emissions

⁴³ FAA Halon Aviation Rulemaking Committee Final Report, 2014, https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/HRARC-7022013.pdf.

⁴⁴ UNEP, *Report of the Halons Technical Options Committee, Volume 1, 2018 Assessment Report*, December 2018, https://ozone.unep.org/sites/default/files/Assessment_Panel/Assessment_Panels/TEAP/Reports/HTOC/HTOC_assessment_2018.pdf.

⁴⁵ UNEP, *Report of the UNEP Technology and Economic Assessment Panel, Volume 2, Decision XXIX/8 on the Future Availability of Halons and their Alternatives*, September 2018.

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rates from halon 1301 aviation applications from 2.3% through to 15%. For this 2020 Halon Review, a selection of these emissions factors (low 2.3%, medium 7.6%, high 15% per year) were used to estimate possible current halon 1301 demands in aviation uses as a basis for projecting future demand.

The Halons Technical Options Committee Assessment Report 2018⁴⁶ describes new aviation analyses by ICF International in 2015 and 2018 that were kindly provided for this study. These provide updated estimates of global average quantities of halon installed for each fire protection application by aircraft type⁴⁷. Some of this information has been referenced to help predict future aviation trends in this report.

The methodologies used to estimate future civil aviation halon requirements are elaborated further in section 4.4.

3.2 Non-Defence Maritime Uses

The maritime use of halon has declined dramatically since the mid-2000s. For the 2012 Halon Review, Australian maritime service companies that were surveyed and responded provided no quantitative annual historical data. According to respondents for that review, it appeared that no servicing of halon equipped vessels had occurred in the prior two years in Australia. This was supported by conversations with representatives of the maritime safety organisations at the time.

Companies previously servicing oil tankers in coastal and international transfers reported that these vessels were no longer operating in Australian waters, and over the prior two years no vessels had been seen with halon installed. While vessels were operating internationally still with halon systems, there was no certainty when or if these vessels would visit Australian waters.

Since the 2012 Halon Review, the Department has indicated anecdotal evidence of continued halon usage in non-defence maritime uses. Consequently, we held discussions with a number of halon special permit holders who confirmed that they had not serviced a non-defence commercial vessel fitted with halon in many years. However, one maritime fire protection services provider, not a current halon special permit holder, provided us with information that there is one SOLAS (Safety of Life at Sea) registered commercial vessel sailing out of South Australia that still has a halon fire

⁴⁶ UNEP, *Report of the Halons Technical Options Committee, Volume 1, 2018 Assessment Report*, December 2018, https://ozone.unep.org/sites/default/files/Assessment_Panel/Assessment_Panels/TEAP/Reports/HTOC/HTOC_assessment_2018.pdf.

⁴⁷ ICF International, *Projections of Halon 1301 Supply and Demand for Aviation Applications*, May 2015. ICF International, *Drawing Down Halon 1301 Inventories: Updated Analysis*, September 2018.

suppression system that may contain a nominal 600 kg of halon 1301.

Additionally, during 2018/19 a vessel acquired into Newcastle, formerly a New Zealand Defence vessel commissioned in 1988 and originally designed for North Sea oil rig operations, has been imported into the Australia fleet and is currently being refitted and is believed to be equipped with a halon 1301 fire suppression system. At this point in time enquiries have been made but these reports are awaiting confirmation.

For both vessels it has been suggested that, if the fire suppression systems were ever used, that they would be refilled more economically with a halon alternative drop-in replacement. This suggests that these vessels are unlikely to make any call on future NHB stocks.

Furthermore, fire protection service providers suggest that end-of-life ships are almost always broken down overseas and so it is likely that these vessels will have negligible implications for maritime as a source of halon supply or demand for the NHB.

In the Halons Technical Options Committee's 2018 Assessment Report⁴⁸, an analysis of remaining global halon 1301 installed on ships was undertaken. In the mid-1970s, ships switched from carbon dioxide to halon 1301, and the International Maritime Organization (IMO) then banned the use of halons in new constructions in 1992, carbon dioxide once again became the preferred choice for ships. From 1975 – 1993, a significant amount of halon 1301 was installed in maritime applications. Assuming a 30 to 40-year lifetime of ships with installed halon, the Halons Technical Options Committee estimated a global average of between 200-300 tonnes/year of halon 1301 could still be potentially available annually for recovery until between 2023 to 2033, the period within which the decommissioning of ships with installed halon systems is expected to be completed.

The Halons Technical Options Committee analysis provides sources of information that could allow an analysis of Australian flagged ships and an indicative estimate of remaining installed halon. However, multiple sources have suggested that decommissioning of Australian flagged ships most likely is occurring at international ship-breaking yards in Bangladesh and Pakistan⁴⁹, where halon 1301 may be collected by shipbreakers for international sale. Together with reports that only two vessels in Australia currently have installed halon systems, it is likely that an analysis of Australian flagged ships and their installed halon, as a potential source of

⁴⁸ UNEP, *Report of the Halons Technical Options Committee, Volume 1, 2018 Assessment Report*, December 2018, https://ozone.unep.org/sites/default/files/Assessment_Panel/Assessment_Panels/TEAP/Reports/HTOC/HTOC_assessment_2018.pdf.

⁴⁹ Adam Chatterway and Daniel Verdonik, HTOC co-chairs (2019), personal communications, 2019.

halon for the NHB, would not be worthwhile.

Under the Australian Halon Management Strategy 2019, foreign ships, which source halon from the NHB to replenish halon that has been depleted while sailing to Australia, must inform the Australian Maritime Safety Authority (AMSA) of these occurrences. Enquiries have been made with the Australian Maritime Safety Authority requesting information on any recent occurrences but received no response.

With maritime use of halon decreasing, and with existing vessels broken down at end-of-life, there are implications for the continued collection of recovered halon because quantities from decommissioned equipment are decreasing and will cease altogether in the next decade or so. Initial indications from consultations are that no halon has been recovered by the NHB from maritime uses since 2012. Further consultations with service providers suggest that halon supply and demand for this sector in Australia will not be significant.

3.3 Defence Uses

Defence future halon requirements have been addressed separately.

4 Estimated Non-Defence Halon Availability and Future Requirements

4.1 Interviews with Selected Halon Special Permit Holders

Each of the 42 halon special permit holders was contacted via email requesting basic information about their halon applications with a response rate of around 40%. Key stakeholders and major users were followed up individually. A number of stakeholders provided excellent quantitative and qualitative information that has helped inform this review. Insights gained from the information gathered have been incorporated throughout this report.

4.2 Halon Special Permit Holders' Statutory Reports and Analysis

Under the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989*, halon special permit holders are required to report quarterly on the information outlined in the next section. The Fire Protection Industry Board administers the collection of this data.

The Department provided a summary of quarterly reports from halon special permit holders made to the Fire Protection Industry Board. Aggregated quarterly data from halon special permit holders for halon 1211 and halon 1301 were provided for March 2013 through June 2019, with September 2019 data being incomplete.

4.2.1 Categories of Reported Data of Statutory Reports

The six categories of reported data by halon special permit holders are:

- Acquired, which is the quantity of halon acquired, and includes quantities acquired from the NHB and fire protection companies, by the user or by other fire protection companies (includes double counting);
- Recovered, which is the quantity of halon recovered from fire protection cylinders (a discreet quantity which excludes double counting);
- Supplied, which is the quantity of halon supplied, used or sold, and includes the quantity refilled (includes double counting);
- Refilling, which is the quantity of halon used for refilling cylinders (if known) (a discreet quantity which excludes double counting);
- Destroyed, which is the quantity of halon sent for destruction (a discreet quantity which excludes double counting); and
- On Hand, which is quantity on hand at end of reporting period.

The information on halon activity gathered through this reporting system is as good or better than any other available in the world. It can be used to indicate trends in halon activity in any of the categories reported.

Nevertheless, due to probable double counting caused by halon trade and on-selling between fire protection companies and halon users, which is an inevitable function of the nature of these businesses, the data in some of the categories cannot be considered reliable for accurately estimating the total quantity of each discrete activity of halon use that is reported. For example, acquired quantities can be acquired through multiple sources (the NHB or through other holders of halon, such as fire protection companies or halon users with surplus halon) and could be counting multiple transactions for the same parcel of halon. Therefore, a simple accounting of data within each category and across categories does not necessarily give the actual total quantity of each activity.

As a valuable resource of information for estimating future halon requirements, there is an opportunity to consider improvements to the halon special permit holder reporting system that could potentially benefit all of the stakeholders involved in the record keeping system.

4.2.2 Preliminary Analysis of Halon Special Permit Holders' Statutory Reports

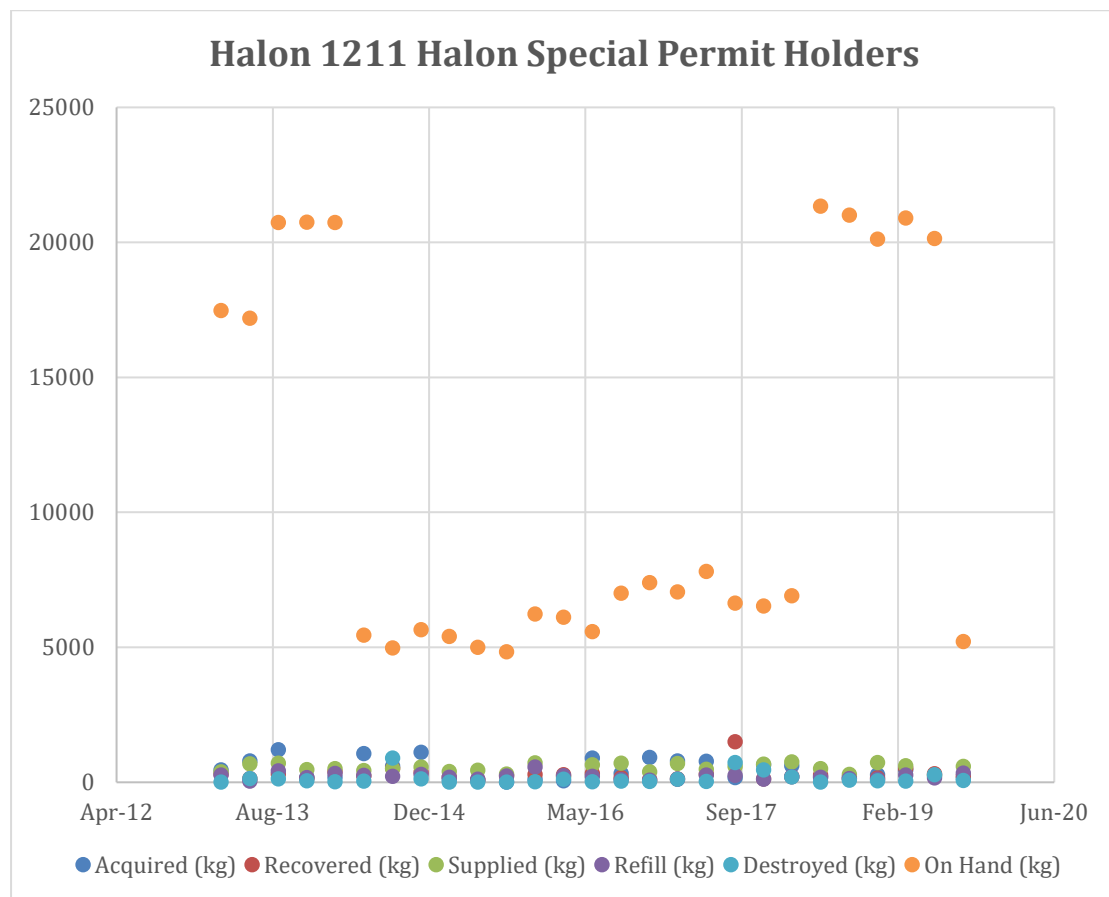
The data for halon "on hand" should in theory provide useful indicative information about the amount of halon stored at the end of each reporting period by fire protection companies and halon users. In practice, there are some anomalies in the data, such as unusual changes in inventory size that appear inconsistent with other data. For example, there appears to be some unusual activity with a significant increase in "on hand" halon 1211 from March to June 2018 that is not explained by the "acquired" data. A similar increase and then decrease is observed in 2013-2014. More detailed information from individual halon special permit holders would be needed to understand further the implications.

Nevertheless, some possible general trends can be proposed. For halon 1211, discounting the anomalous sudden increases and decreases, total inventory held by halon special permit holders appears to remain otherwise relatively stable, between around 5 to 8 tonnes. For halon 1301, compared to the inventory on hand at the NHB, which shows a gradual continuous decline, the inventory held by other halon special permit holders shows no trend, with the total quantity between around 11 tonnes to 28 tonnes, with the average between 2013 and 2018 around 18 tonnes.

Relatively large quantities of halon 1301 appear to be changing hands, as indicated by the other reporting categories, even if double counting is causing inflated quantities. When considered against the sales of halon 1301 from the NHB, this could imply potential significant trade in halon 1301 not involving

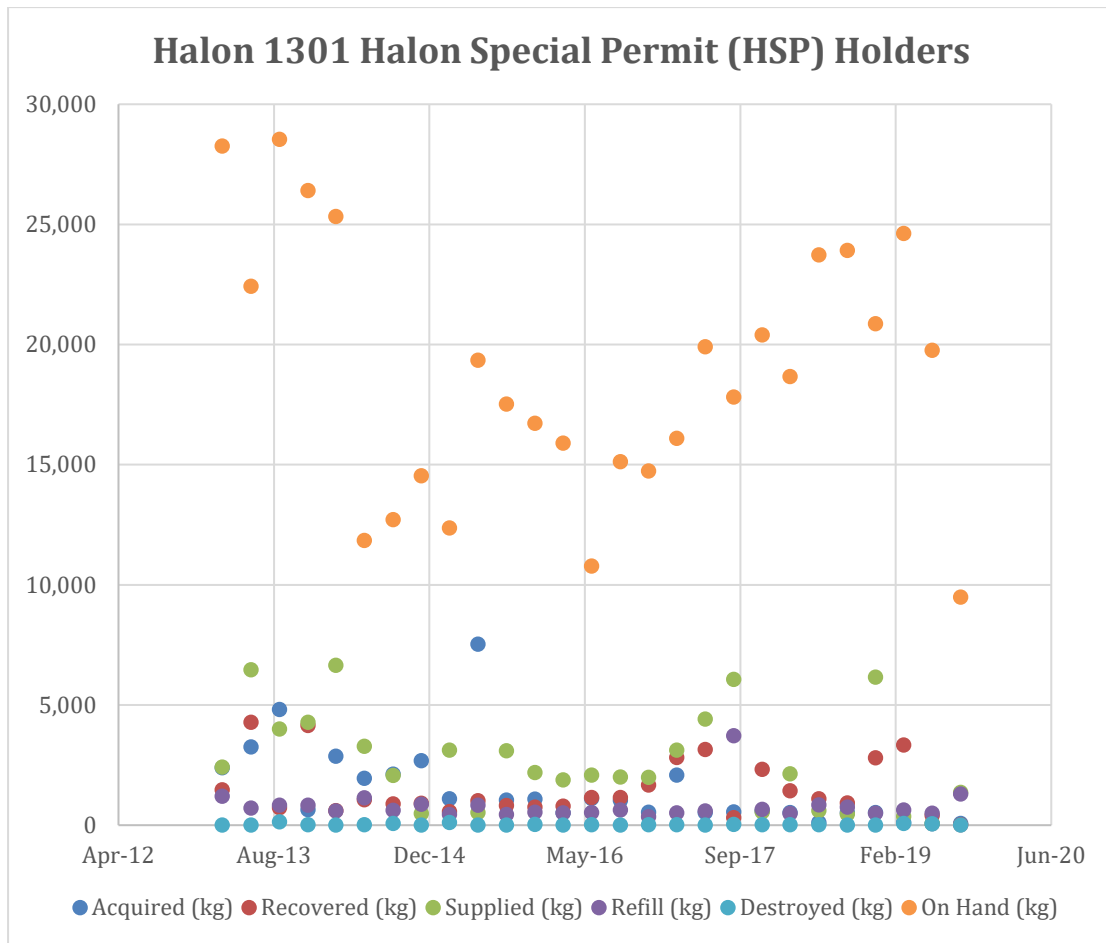
the NHB. It is not clear whether any such activity could include supplying non-defence halon demand. Discussions with a number of halon special permit holders indicate that some are decanting and recycling halon and now have the capacity to reclaim halon to meet international standards required for aviation. This implies that supply from the NHB may not represent a full picture of activities taking place with regard to use/recycle/reclamation of halon. This might have implications for the estimation of future non-defence halon requirements.

Figure 4.1: *Halon Special Permit Holders Quarterly Reported Data for Halon 1211, March 2013 to September 2019⁵⁰ (Kilograms)*



⁵⁰ Quarter September 2019 data may be incomplete.

Figure 4.2: Halon Special Permit Holders Quarterly Reported Data for Halon 1301, March 2013 to September 2019⁵¹ (Kilograms)



While useful in other ways, the uncertainties underlying the data available through the halon special permit system do not appear to lend themselves well to a quantitative estimation of activity in halon use for the purposes of this 2020 Halon Review, due to double counting and omissions (through possible mis-reporting). The exception to this is the data available from the NHB owing to the nature of its dedicated business as a repository for, and seller of, halon.

4.3 NHB Halon Sales and Halon Special Permit Holder Data

NHB halon sales data provided by the Department cover the financial years ending (FYE) 2002 to February 2020 and provides a reliable source of data for analysis of historic halon demand from the NHB. The data relate to the halon purchases by halon special permit holders; halon special permit holders can service multiple industries (defence, aviation, maritime) making it difficult to

⁵¹ Quarter September 2019 data may be incomplete.

interpret accurately end-uses. The Department provided a further breakdown of identified end-use activity (e.g., defence or aviation), which has been self-identified by halon special permit holders in recent years, related to sales for the FYE 2016 to 2020.

Historically, it appears that a portion of halon nominally denoted for one end-use may have inadvertently been employed for another end-use, due to legitimate on-sales or supply of products from one fire protection service provider to another for legitimate use in applications. This could have led to the misassignment of the intended end-use of those original NHB sales. This could result in either over- or under-estimation of halon 1211 and 1301 sales that are designated by halon purchasers for civil aviation end-uses. Nevertheless, based on the NHB sales information, interviews with halon special permit holders, and assumptions about the business of halon special permit holders, end-use activity has been allocated to the extent possible for NHB sales for FYE 2011 to 2020.

For halon 1211, the data indicate that for the last ten years, NHB sales into non-defence uses have been identified as going solely to civil aviation end-uses, with an overall downward trend. For halon 1301, the data indicate that civil aviation sales, as a proportion of total NHB sales, are quite variable from year to year. In absolute terms, in recent years, there seems to be a general trend towards increasing annual quantities sold into civil aviation. These trends are consistent with decreasing demand for halon 1211 with the introduction of halon alternatives in civil aviation and increasing demand for halon 1301 associated with increasing aircraft numbers, demand for halon 1301 and the absence of alternatives in the major use areas (engine/auxiliary power unit and cargo compartments).

NHB halon special permit data was provided via the Department from the Fire Protection Industry Board and includes amounts collected, decanted and destroyed, and on-hand. The NHB clarified questions about definitions for data categories for NHB sales and some anomalous NHB sales data. This data was provided for the “Department/NHB” covering March 2015 through June 2019, with September 2019 data being incomplete.

Regarding the quantities of halon 1211 and 1301 being surrendered to the NHB, in recent years annual averages of 3.5 tonnes halon 1211 and 0.8 tonnes halon 1301 have been surrendered to the NHB. For the period January 2017 to January 2020, there appears to be a trend of increasing quantities of surrendered halon 1211 and a trend of decreasing quantities of surrendered halon 1301.

The “Department/NHB” on-hand data is an aggregate of non-defence inventory at the NHB. The non-defence component consists of a stockpile of recovered halon that meets ASTM and ISO standards and is ready for service,

as well as surrendered material that is held “as received” but is of unknown quality and nominal quantity.

4.3.1 Current Availability of NHB Halon for Non-Defence Uses

The Department provided data for the NHB inventory of reclaimed quantities of halon 1211 and 1301 reserved for non-defence purposes for April 2013 to January 2020. At January 2020, the NHB held:

- 93.03 tonnes of halon 1211, and
- 165.87 tonnes of halon 1301.

For halon 1211, an additional nominal quantity of 24.6 tonnes has been surrendered but not yet reclaimed; for halon 1301 an additional nominal quantity of 3.7 tonnes has been surrendered but not yet reclaimed. The amounts of halons that could be recovered from these materials to meet international standards are not known and are yet to be determined.

Halon 1211 inventory shows a gradual decline in quantities as a result of sales. Halon 1301 inventory shows a more uneven decline over the period, with a number of significant one-off sales for purposes other than non-defence uses.

Figure 4.3 Monthly NHB Non-Defence Inventory of Reclaimed Halon 1211, April 2013-January 2020 (Kilograms)

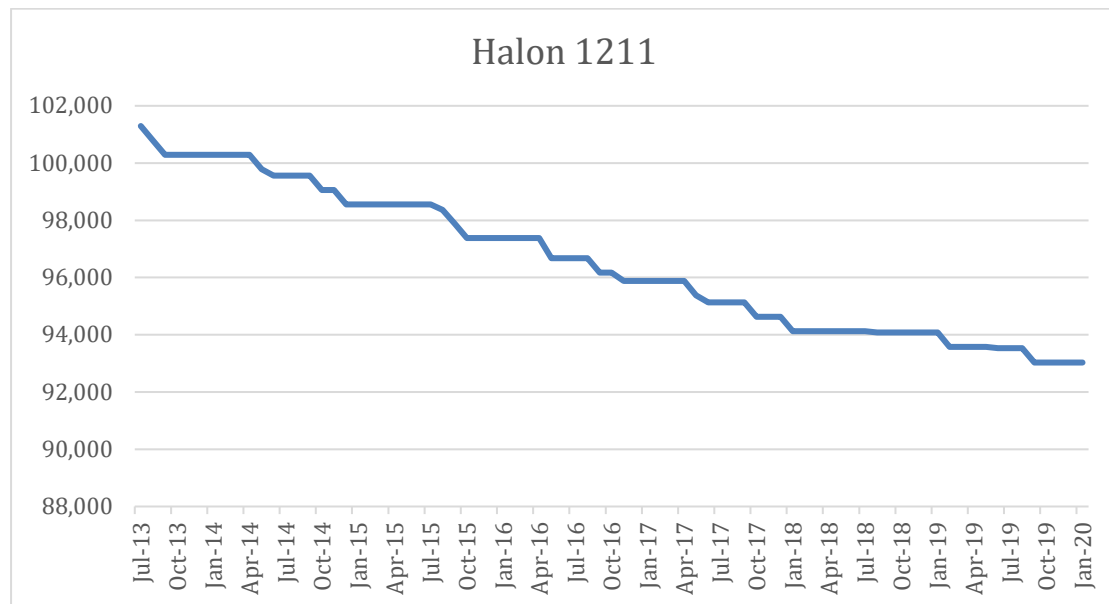
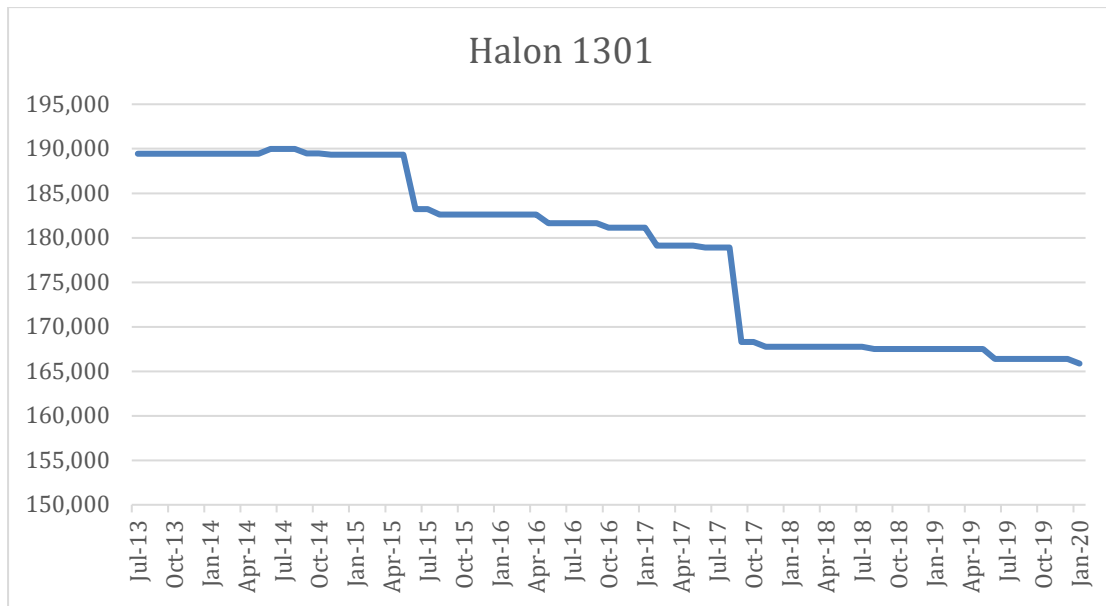


Figure 4.4 Monthly NHB Non-Defence Inventory of Reclaimed Halon 1301, April 2013-January 2020 (Kilograms)



The NHB non-defence reserves of halon are likely to constitute the majority of halon available for non-defence uses in Australia. Fire protection companies and a few non-defence halon users have small privately held reserves (based on halon special permit holder reporting), and some surplus halon will also be contained in equipment that has not yet been decommissioned or collected by the NHB.

4.4 Future Halon Requirements for Non-Defence Uses Based on NHB Sales

4.4.1 Methodology to Forecast Future Halon Requirements Based on NHB Sales

Using a breakdown of end-uses of NHB halon sales data for previous years, based on information provided by halon special permit holders in their reporting and assumptions made about the business activity of some halon special permit holders, average annual sales of halon 1211 and 1301 have been derived and used for the starting year of 2020 as a basis for future projections.

Non-defence halon sales have predominantly been into aviation, with no apparent halon sales from the NHB into maritime uses since 2012. There is some year to year variability of NHB sales of halon 1211 and 1301 into non-defence uses, and this was taken into account in determining assumptions. Using the International Civil Aviation Organization or other mandated halon replacement requirements, assumptions have been applied to approximate the phase-out of halon 1211 and 1301 in aviation and to estimate future halon sales.

For halon 1211, using the average annual sales into non-defence (aviation) uses in the previous 3 years of data, assumptions about the phase-out of halon 1211 in aviation have been applied to estimate future halon 1211 demand from 2020 onwards.

For halon 1301, using the average annual sales into non-defence (aviation) uses in the previous 2 years of data, aviation industry-based assumptions (average annual growth rates in aircraft fleet size, 4% and 6%) have been applied to forecast future halon sales into aviation in periods when no replacements are available, and to estimate future halon 1301 demand from 2020 onwards. Future halon sales were forecast based on a range of scenarios and assumptions as outlined in the sections below.

4.4.2 Methodology to Forecast Future Halon Requirements Based on Aviation Analysis

Using Australian aviation industry data on installed and warehoused halon, aircraft types and numbers, estimates of halon for the remainder of the Australian fleet for smaller aircraft types (see section 3.1.5), and a 10% loading as contingency for potential undercounting, a bottom-up model was developed to estimate the total current inventory of installed and warehoused halon 1211 and halon 1301 in Australian aviation. The estimated halon inventories for Australian aviation are:

- Halon 1211, 6.6 tonnes
- Halon 1301, 32.6 tonnes

Current annual demand (consumption) for Australian aviation was estimated by applying leakage rates (i.e., emission factors) for halon equipment and systems, as reported in published international references, to the total inventory and then used as consumption for the starting year of 2020 as a basis for future projections.

Background from published references reporting the best available information on leakage rates and annual emission factors for halon 1211 and 1301 are described earlier in section 3.1.5. These published references have been used to assign annual emission factors for the purposes of this 2020 Halon Review.

For the 2012 Halon Review, a leakage rate of 6% per year was assumed for halon 1211 handheld fire extinguishers⁵². For this 2020 Halon Review, the same emission factor of 6% per year was used to estimate possible current

⁵² As reported by O’Sullivan, J., *National airlines and halon data, (data compiled by British Airways technical expert)*, 2005, and used by ICF, 2006, *ibid*.

(Continued next page)

halon 1211 demands in aviation uses as a basis for projecting future demand.

In the Halons Technical Options Committee's 2018 analysis⁵³, a range of emissions scenarios were used to determine the potential availability of halon 1301 to support global civil aviation through to 2060, with annual emissions rates from halon 1301 aviation applications from 2.3% through to 15%. For this 2020 Halon Review, a selection of these emissions factors (low 2.3%, medium 7.6%, high 15% per year) were used to estimate possible current halon 1301 demands in aviation uses as a basis for projecting future demand.

The general assumptions and scenarios, as outlined in the sections below, were applied to the estimated current annual demand halon 1211 and 1301 derived from the aviation analysis to predict future halon requirements and to complement the analysis of NHB sales.

4.4.3 General Assumptions

Annual halon sales from the NHB into civil aviation uses are assumed to be equivalent to annual halon consumption in those uses. Halon special permit holders are purchasing halon supplies from the NHB to supply consumption.

Based on information from the NHB sales and discussion with relevant halon special permit holders, halon supply of maritime uses is likely to be insignificant. The future supply of maritime applications is not taken into account.

Halon 1301 is currently being installed overseas in new aircraft systems and then imported into Australia in the aircraft. Halon in aircraft retired from the Australian fleet is either leaving the country within the aircraft, if the aircraft is on-sold, or recovered if the scrapped aircraft remain in Australia. These practices are difficult to account for in the analysis. Therefore, halon coming into Australia in new aircraft is assumed to match halon going out of Australia in retired aircraft. Any halon recovered will make its way back into supplying demand, but these unknown quantities are not taken into account in this analysis.

4.4.4 Scenarios for halon 1211

Under the *Civil Aviation Act 1988*, halon 1211 is prohibited in Australia as a handheld fire extinguishing agent in aircraft manufactured after 2018. Based on these requirements, two scenarios have been applied to forecast halon 1211 requirements that assume:

⁵³ UNEP, Report of the Halons Technical Options Committee, Volume 1, 2018 Assessment Report, December 2018, https://ozone.unep.org/sites/default/files/Assessment_Panel/Assessment_Panels/TEAP/Reports/HTOC/HTOC_assessment_2018.pdf.

- A 20 or a 30-year lifetime for aircraft,
 - 20-year lifetime – no aircraft are installed with 1211 extinguishers by 2040, when halon consumption is zero;
 - 30-year lifetime – no aircraft are installed with 1211 extinguishers by 2050, when halon consumption is zero.
- Annual halon 1211 consumption reduces linearly from 2020, to zero consumption by 2040 or 2050, to approximate the phase-out as new aircraft enter the fleet and old aircraft are retired each year. A linear reduction may not be representative of actual annual phase-out but is used for the purposes of approximation.

4.4.5 Scenarios for halon 1301

Under the *Civil Aviation Act 1988*, halon 1301 is prohibited in Australia as a lavatory fire extinguishing agent in aircraft manufactured after 2018. This will already be having an impact on halon 1301 consumption. However, lavatory is a small portion (less than 1%) of overall halon 1301 consumption in aviation. Therefore, modelling of halon 1301 consumption is assumed to be dependent on the phase-out of halon 1301 in engines/auxiliary power units and cargo compartments.

Based on the International Civil Aviation Organization timelines for new design aircraft for halon replacement for engine/auxiliary power units (which is 2014, although already not achieved) and cargo compartments (which is the end of 2024, with the possibility this date will not be achieved), the latter date of the end of 2024 is assumed to be the starting date after which halon replacements are certified for new design aircraft for both applications. That is, engine/auxiliary power unit halon phase-out is assumed to coincide with cargo compartment halon phase-out for new design aircraft.

One set of scenarios will assume the end of 2024 date is achieved; another set of scenarios will assume the nominated 2025 implementation is delayed by 5 years; another set will assume a 10-year delay; and another set will assume a 15-year delay.

Owing to the delay in new design aircraft production after new design type certifications, a 10-year delay is assumed after replacements in new design aircraft have been implemented until the reduction of halon consumption.

In the years until the date assumed for production of new design aircraft, halon consumption is assumed to grow according to two sets of average annual growth rates, 4% and 6%, which are consistent with aviation industry trends and aircraft growth forecasts (see section 3).

4.4.5.1 *Scenarios for halon 1301: 2025 new design aircraft*

A set of scenarios has been developed to forecast halon 1301 consumption for a 2025 implementation date for new design aircraft, which assumes:

- Annual halon 1301 consumption increases at two sets of annual growth rates, 4% and 6%, until new production aircraft include halon replacements;
- 2025 is the date when halon replacements are required for new design aircraft, with 10-year delay until production of new aircraft without halon entering the fleet, during which halon 1301 continues to be installed in new aircraft,
 - 2035 is when new aircraft entering fleet without halon;
 - Halon consumption increases at annual growth rates until 2035.
- A 20-year or a 30-year lifetime for aircraft:
 - 20-year lifetime – no aircraft are installed with 1301 by 2055, when halon consumption is zero.
 - 30-year lifetime – no aircraft are installed with 1301 by 2065, when halon consumption is zero.
- Annual halon 1301 consumption reduces linearly from 2035, to zero consumption by 2055 or 2065, to approximate the phase-out as new aircraft enter the fleet and old aircraft are retired each year. A linear reduction may not be representative of actual annual phase-out but is used for the purposes of approximation.

4.4.5.2 *Scenarios for halon 1301: 2030 new design aircraft*

A set of scenarios has been developed to forecast halon 1301 consumption for a 2030 implementation date for new design aircraft, which assumes:

- Annual halon 1301 consumption increases at two sets of annual growth rates, 4% and 6%, until new production aircraft include halon replacements;
- 2030 is the date when halon replacements are required for new design aircraft, with 10-year delay until production of new aircraft without halon entering the fleet, during which halon 1301 continues to be installed in new aircraft,
 - 2040 is when new aircraft entering fleet without halon;

- Halon consumption increases at annual growth rates until 2040.
- A 20-year or a 30-year lifetime for aircraft:
 - 20-year lifetime – no aircraft are installed with 1301 by 2060, when halon consumption is zero.
 - 30-year lifetime – no aircraft are installed with 1301 by 2070, when halon consumption is zero.
- Annual halon 1301 consumption reduces linearly from 2040, to zero consumption by 2060 or 2070, to approximate the phase-out as new aircraft enter the fleet and old aircraft are retired each year. A linear reduction may not be representative of actual annual phase-out but is used for the purposes of approximation.

4.4.5.3 *Scenarios for halon 1301: 2035 new design aircraft*

A set of scenarios has been developed to forecast halon 1301 consumption for a 2035 implementation date for new design aircraft, which assumes:

- Annual halon 1301 consumption increases at two sets of annual growth rates, 4% and 6%, until new production aircraft include halon replacements;
- 2035 is the date when halon replacements are required for new design aircraft, with 10-year delay until production of new aircraft without halon entering the fleet, during which halon 1301 continues to be installed in new aircraft,
 - 2045 is when new aircraft begin entering the fleet without halon;
 - Halon consumption increases at annual growth rates until 2045.
- A 20-year or a 30-year lifetime for aircraft:
 - 20-year lifetime – no aircraft are installed with 1301 by 2065, when halon consumption is zero.
 - 30-year lifetime – no aircraft are installed with 1301 by 2075, when halon consumption is zero.
- Annual halon 1301 consumption reduces linearly from 2045, to zero consumption by 2065 or 2075, to approximate the phase-out as new aircraft enter the fleet and old aircraft are retired each year. A linear reduction may not be representative of actual annual phase-out but is used for the purposes of approximation.

4.4.5.4 Scenarios for halon 1301: 2040 new design aircraft

A set of scenarios has been developed to forecast halon 1301 consumption for a 2040 implementation date for new design aircraft, which assumes:

- Annual halon 1301 consumption increases at two sets of annual growth rates, 4% and 6%, until new production aircraft include halon replacements;
- 2040 is the date when halon replacements are required for new design aircraft, with 10-year delay until production of new aircraft without halon entering the fleet, during which halon 1301 continues to be installed in new aircraft,
 - 2050 is when new aircraft begin entering the fleet without halon;
 - Halon consumption increases at annual growth rates until 2050.
- A 20-year or a 30-year lifetime for aircraft:
 - 20-year lifetime – no aircraft are installed with 1301 by 2070, when halon consumption is zero.
 - 30-year lifetime – no aircraft are installed with 1301 by 2080, when halon consumption is zero.
- Annual halon 1301 consumption reduces linearly from 2050, to zero consumption by 2070 or 2080, to approximate the phase-out as new aircraft enter the fleet and old aircraft are retired each year. A linear reduction may not be representative of actual annual phase-out but is used for the purposes of approximation.

4.4.6 Estimated Future Halon Requirements for Non-Defence Uses

Future halon requirements for non-defence uses have been estimated based on the NHB halon sales data analysis and the aviation inventory analysis following the methodology, scenarios and assumptions outlined above. The results of these analysis are presented below.

Table 4.1 Estimated Future Halon 1211 Requirements for Non-Defence Uses Based on NHB Sales (Tonnes)

Forecast of NHB Sales of Halon 1211 into Non-Defence Uses Only 2020 start year: 3-Year An. Av. Sales = 0.668 tonnes Current NHB Halon 1211 Stocks = 93.03 tonnes	
20-Year Aircraft Lifetime End 2040	30-Year Aircraft Lifetime End 2050
7.01	10.35

Table 4.2 Estimated Future Halon 1211 Requirements for Non-Defence Uses Based on Aviation Inventory Analysis (Tonnes)

Forecast of Halon 1211 Demand into Non-Defence Uses Only 2020 start year: Aviation Analysis Consumption = 0.398 tonnes Current NHB Halon 1211 Stocks = 93.03 tonnes	
20-Year Aircraft Lifetime End 2040	30-Year Aircraft Lifetime End 2050
4.12	6.17

Figure 4.5 Estimated Future Halon 1211 Requirements for Non-Defence Uses Based on NHB Sales or Aviation Analysis (Tonnes)

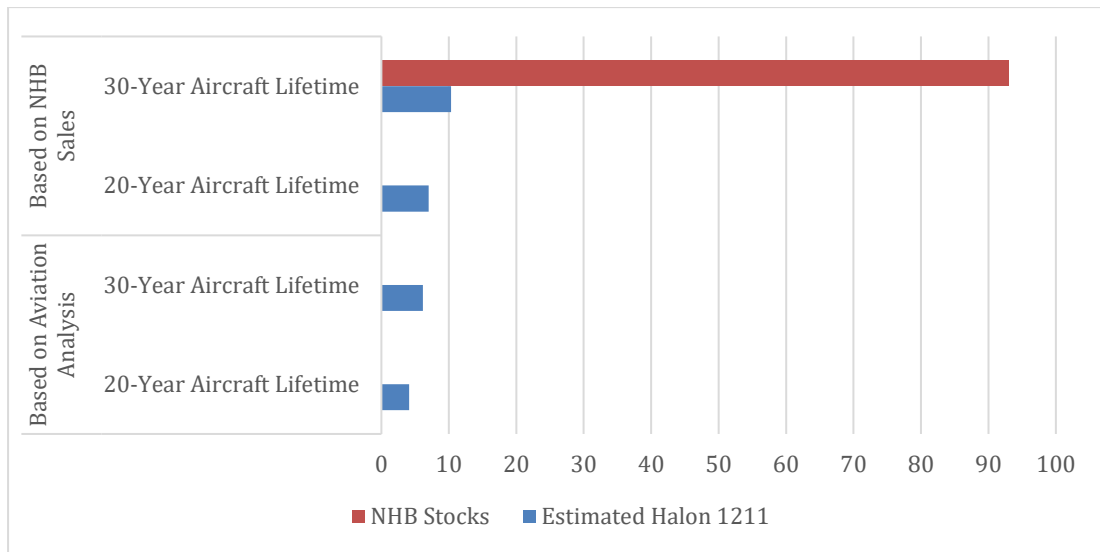


Table 4.3 Estimated Future Halon 1301 Requirements for Non-Defence Uses Based on NHB Sales (Tonnes)

Forecast of NHB Sales of Halon 1301 into Non-Defence Uses Only															
2020 start year: 2-Year An. Av. Sales = 0.973 tonnes															
Current NHB Halon 1301 Stocks = 165.87 tonnes															
2025 New Design Aircraft				2030 New Design Aircraft				2035 New Design Aircraft				2040 New Design Aircraft			
20-Year Aircraft Lifetime End 2055		30-Year Aircraft Lifetime End 2065		20-Year Aircraft Lifetime End 2060		30-Year Aircraft Lifetime End 2070		20-Year Aircraft Lifetime End 2065		30-Year Aircraft Lifetime End 2075		20-Year Aircraft Lifetime End 2070		30-Year Aircraft Lifetime End 2080	
4%	6%	4%	6%	4%	6%	4%	6%	4%	6%	4%	6%	4%	6%	4%	6%
35.03	40.14	42.81	49.38	45.24	53.03	54.00	63.73	56.43	67.38	66.16	79.54	68.60	83.19	79.30	96.81

Figure 4.6 *Estimated Future Halon 1301 Requirements for Non-Defence Uses Based on NHB Sales (Tonnes)*

Average NHB sales of halon 1301 are 0.973 tonnes in 2020.

Halon 1301 consumption increases at 4% (left) and 6% (right) annual growth rates until new production aircraft adopt halon replacements.

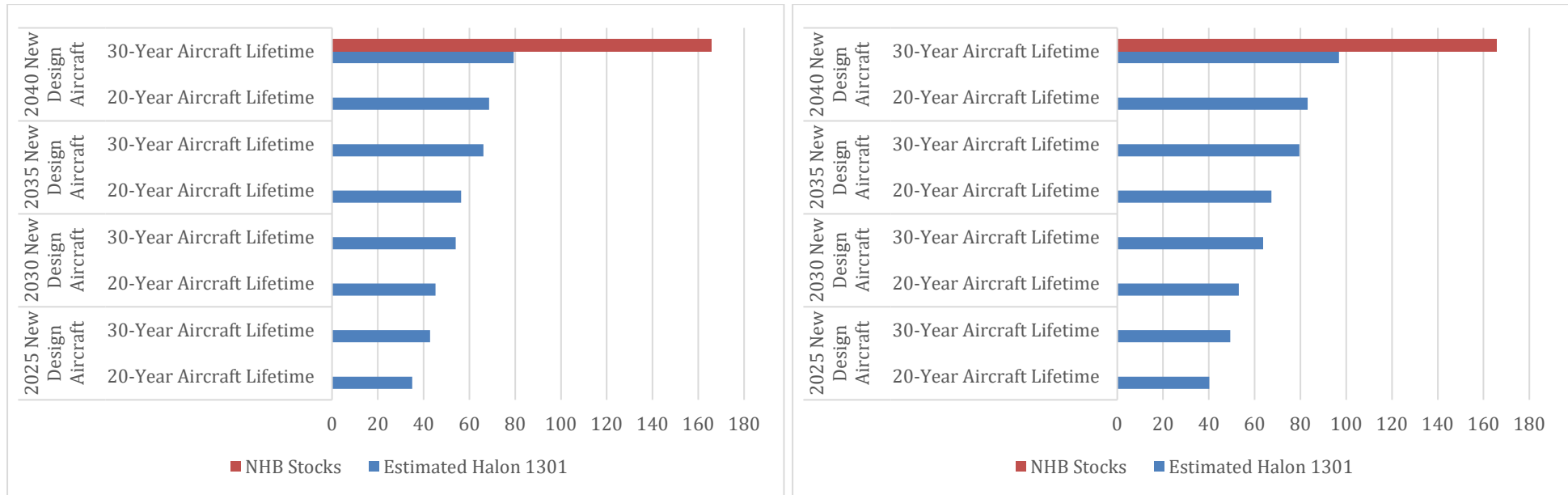


Table 4.4 Estimated Future Halon 1301 Requirements for Non-Defence Uses Based on Aviation Analysis (Tonnes)

Forecast of Halon 1211 Demand into Non-Defence Uses Only Current NHB Halon 1301 Stocks = 165.87 tonnes															
2025 New Design Aircraft		2030 New Design Aircraft				2035 New Design Aircraft				2040 New Design Aircraft					
20-Year Aircraft Lifetime End 2055	30-Year Aircraft Lifetime End 2065	20-Year Aircraft Lifetime End 2060	30-Year Aircraft Lifetime End 2070	20-Year Aircraft Lifetime End 2065	30-Year Aircraft Lifetime End 2075	20-Year Aircraft Lifetime End 2070	30-Year Aircraft Lifetime End 2080	20-Year Aircraft Lifetime End 2065	30-Year Aircraft Lifetime End 2075	20-Year Aircraft Lifetime End 2070	30-Year Aircraft Lifetime End 2080	20-Year Aircraft Lifetime End 2070	30-Year Aircraft Lifetime End 2080	20-Year Aircraft Lifetime End 2070	30-Year Aircraft Lifetime End 2080
4%	6%	4%	6%	4%	6%	4%	6%	4%	6%	4%	6%	4%	6%	4%	6%
2020 start year: Aviation Analysis Consumption Halon 1301 = 0.750 tonnes (2.3% annual emission factor)															
27.00	30.94	33.00	38.06	34.88	40.88	41.63	49.13	43.50	51.94	51.00	61.31	52.88	64.13	61.13	74.63
2020 start year: Aviation Analysis Consumption Halon 1301 = 2.479 tonnes (7.6% annual emission factor)															
89.24	102.26	109.08	125.81	115.27	135.11	137.58	162.37	143.78	171.67	168.57	202.66	174.77	211.95	202.04	246.66
2020 start year: Aviation Analysis Consumption Halon 1301 = 4.892 tonnes (15% annual emission factor)															
176.11	201.80	215.25	248.27	227.48	266.61	271.51	320.43	291.35	348.28	344.70	414.98	353.26	428.92	411.95	503.62

Figure 4.7a Estimated Future Halon 1301 Requirements for Non-Defence Uses Based on Aviation Analysis (Tonnes)

In 2020, aviation analysis consumption of halon 1301 is 0.750 tonnes (2.3% annual emission of aviation halon 1301 inventory).

Halon 1301 consumption increases at 4% (left) and 6% (right) annual growth rates until new production aircraft adopt halon replacements.

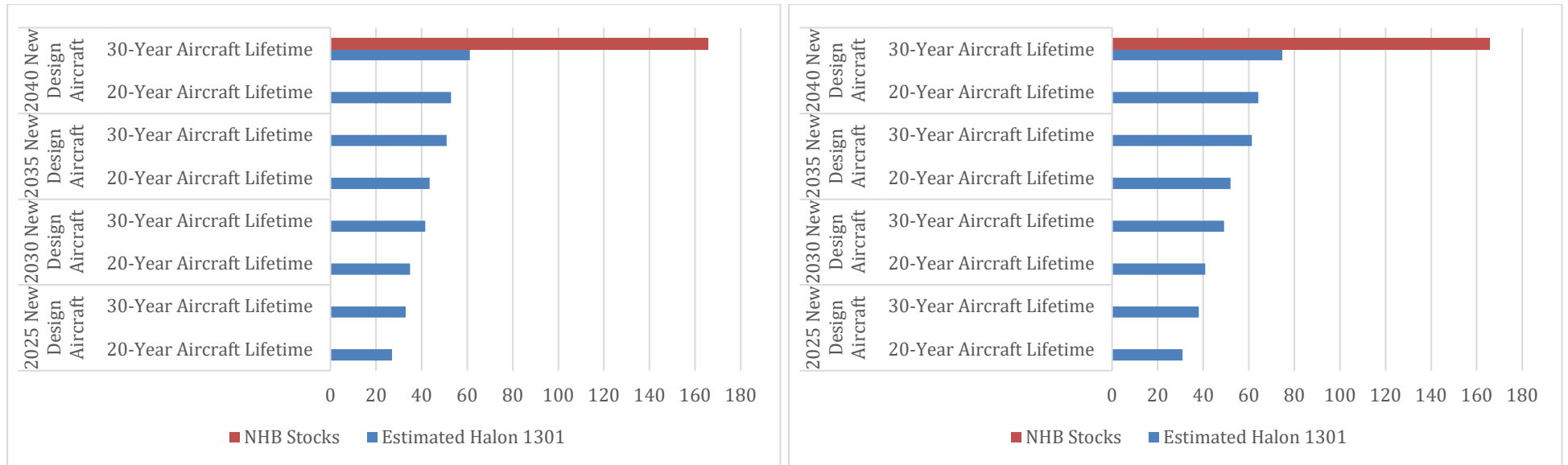


Figure 4.7b Estimated Future Halon 1301 Requirements for Non-Defence Uses Based on Aviation Analysis (Tonnes)

In 2020, aviation analysis consumption of halon 1301 is 2,479 tonnes (7.6% annual emission of aviation halon 1301 inventory).

Halon 1301 consumption increases at 4% (left) and 6% (right) annual growth rates until new production aircraft adopt halon replacements.

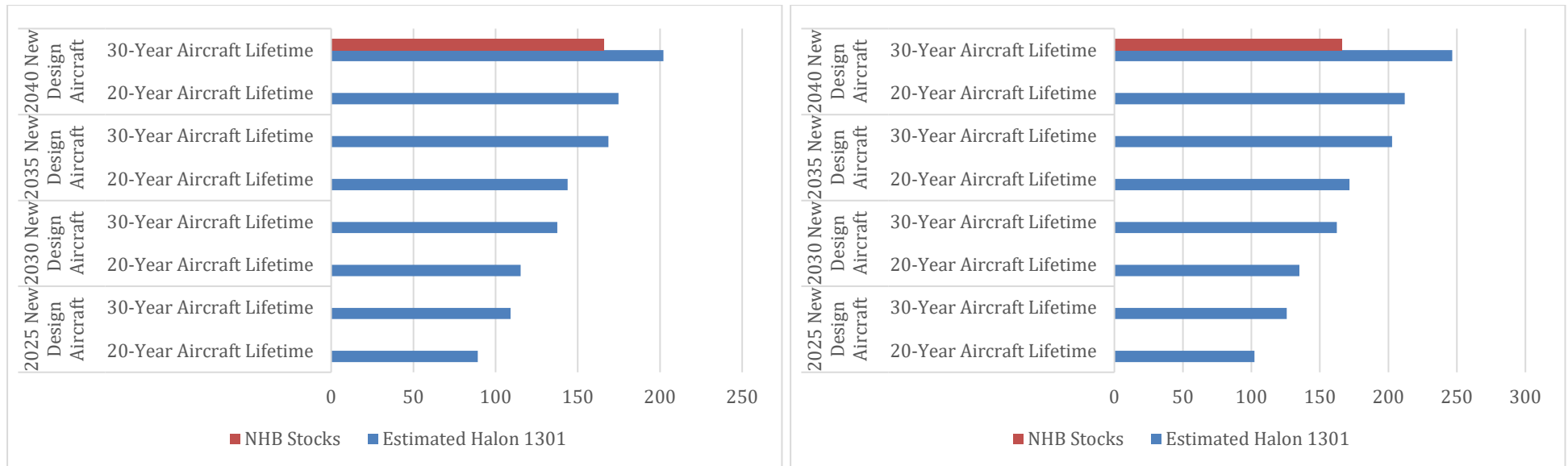
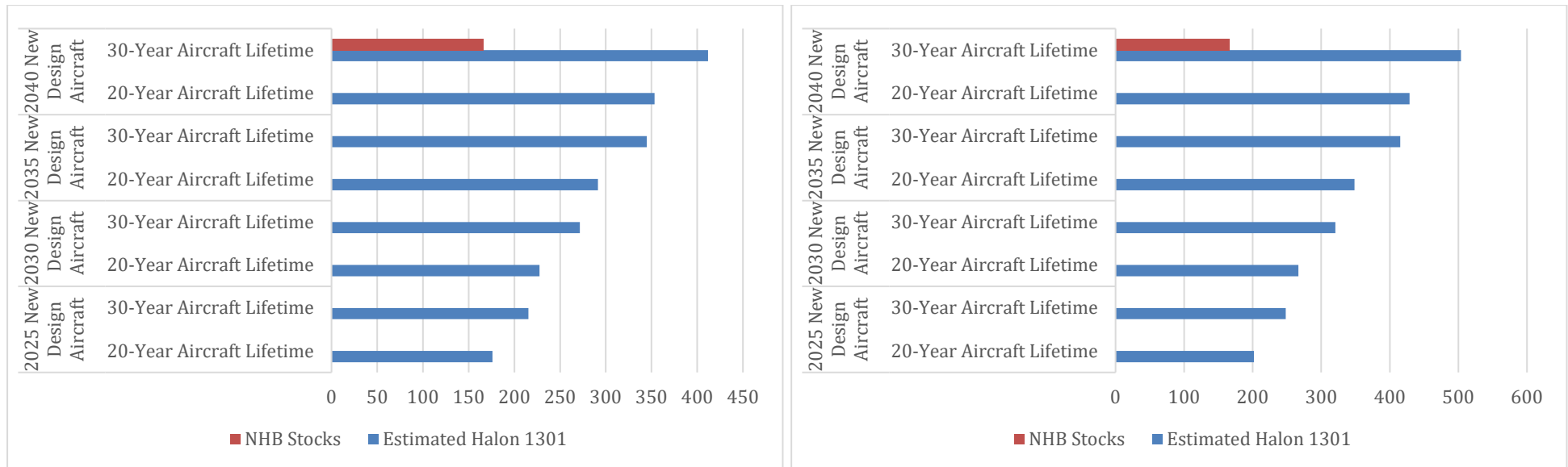


Figure 4.7c Estimated Future Halon 1301 Requirements for Non-Defence Uses Based on Aviation Analysis (Tonnes)

In 2020, aviation analysis consumption of halon 1301 is 4.892 tonnes (15% annual emission of aviation halon 1301 inventory).

Halon 1301 consumption increases at 4% (left) and 6% (right) annual growth rates until new production aircraft adopt halon replacements.



For halon 1211, based on the NHB sales analysis, between 7.01 and 10.35 tonnes, depending on aircraft lifetime variables, are estimated to be needed to supply non-defence uses until halon 1211 is no longer required. Based on the aviation inventory analysis, between 4.12 and 6.17 tonnes halon 1211, depending on aircraft lifetime variables, are estimated to be needed to supply non-defence uses until phase-out. These estimations can be compared with the available NHB inventory of 93.03 tonnes of halon 1211.

The different estimated range of quantities resulting from the two methodologies for halon 1211 could be due to potential uncertainties associated with assumptions, including:

- A portion of NHB halon 1211 sales into non-aviation uses being mis-assigned as aviation uses (leading to over-estimation of annual average sales into aviation in the NHB sales analysis); or
- A larger actual aviation inventory of halon 1211 than has been estimated for smaller aircraft or higher actual annual emissions of halon 1211 from the aviation inventory (leading to under-estimation of consumption of halon 1211 in the aviation analysis).

There would appear to be a wide margin within the limit of the NHB's reserves of halon 1211, which minimises the risks of inadequate supply of halon 1211 until replacements are installed.

For halon 1301, based on the NHB sales analysis, between 35.05 and 96.81 tonnes are estimated to be needed to supply non-defence uses until halon 1301 is no longer required. The range of estimated quantities is dependent on the variables of new design aircraft dates, aircraft lifetime, and aviation industry growth rates. Based on the aviation inventory analysis, between 27.00 and 503.62 tonnes halon 1301 are estimated to be needed to supply non-defence uses until halon 1301 is no longer required. The range of estimated quantities is dependent on the variables of the starting level of consumption estimated for 2020 (which are based on different emission factors for the aviation inventory), new design aircraft dates, aircraft lifetime, and aviation industry growth rates. These estimations can be compared with the available NHB inventory of 165.87 tonnes of halon 1301.

The different estimated range of quantities resulting from the two methodologies for halon 1301 could be due to potential uncertainties associated with assumptions. The comparison between each set of results highlights the sensitivity associated with the consumption quantity used as starting point in 2020, and the importance of having an accurate estimate of current annual halon consumption into non-defence uses.

The broad range of possible outcomes for halon 1301 within each set of results

indicates the potential impact of the different variables, including the risks associated with delays in implementing halon replacements.

For example, using the NHB sales analysis, a 10-year delay in implementing halon replacements, beyond the current International Civil Aviation Organization 2024 date, could nearly double the quantity of halon 1301 that would be required to supply non-defence uses until replacements are available; a 15-year delay could more than double the total demand for halon 1301. Longer delays will increase the total demand for halon 1301 and narrow the margin within the limit of the NHB's reserves of halon 1301, which increases the risks of inadequate supply of halon 1301 until replacements are installed.

The aviation analysis for halon 1301 brings the potential increased risks into sharp focus. Using the same variables as for the NHB sales analysis (date of introduction of new aircraft design, aircraft lifetimes, and aviation growth rates), but varying the annual consumption quantity of halon 1301 in 2020 (based on different rates of emissions from the aviation inventory), a much broader spread of future halon 1301 demand is estimated. With lower annual emissions (2.3%) from the estimated aviation inventory, future total halon demand remains within the limits of the NHB's reserves of halon 1301. However, at higher annual emission rates (e.g., 7.6%), future total halon 1301 demand can exceed the available supply from the NHB. At the highest 15% annual emission rate, all scenarios exceed the available supply of halon 1301 from the NHB. The 15% emission rate was one possible estimate based on actual international industry feedback. From a risk perspective, this clearly underlines the importance of Australia's suite of halon management controls aimed at minimising emissions in fire protection applications.

It is interesting to recall the previous advice from international experts that halon consumption may not reduce until at least 2050. This advice would be consistent with the scenarios for halon 1301 with a 2040 new design aircraft implementation date and 10-year delay in production of new aircraft without halon from 2050 onwards. In these scenarios, depending on aircraft lifetime, halon requirements do not cease until 2070 or 2080. In the aviation analysis, at medium or higher emission rates, halon 1301 demand far exceeds halon availability for the scenarios where 2040 is the new design aircraft date for halon replacements. This underlines the on-going importance of active international aviation industry investigation and implementation of halon 1301 replacements at the earliest possible dates.

Assuming the average annual sales of halon 1301 from the NHB represent total annual non-defence consumption, using the estimated halon 1301 aviation inventory, an annual emission rate of 3% can be derived for Australian aviation. Similarly, assuming the average annual sales of halon 1211 from the NHB represent total annual non-defence consumption, using

the estimated halon 1211 aviation inventory, an annual emission rate of 10% can be derived for Australian aviation.

The 2020 Halon Review estimates of halon requirements differ from the estimates derived in the 2012 Halon Review⁵⁴. While different scenarios, assumptions and methodologies have been applied, such as using lower average annual growth rates, a significant methodological difference is that the 2012 Halon Review included halon consumption from the NHB reserve for all purposes, non-defence and defence uses, as an unavoidable result of limitations with the then available data, whereas the 2020 Halon Review has only considered designated (NHB sales analysis using only NHB sales designated as non-defence) or estimated (aviation analysis) halon consumption in non-defence uses (primarily aviation).

Uncertainties in the analysis surround halon special permit holder activity that is unable to be accurately quantified (such as potential reuse and supply of recovered halon by industry stakeholders that could add to overall halon consumption in non-defence uses) and reporting (such as NHB sales designated by purchasers into a certain halon end-use category potentially being used in a different end-use category). These uncertainties could increase or decrease the total halon requirements for non-defence uses estimated from NHB sales. Improved or validated reporting that more accurately captures halon usage activities would meaningfully inform future estimations of halon requirements.

4.4.7 Halon Quantity and Quality

As halon is no longer being manufactured, the quality of recovered halon used for filling new equipment or refilling or replacing existing equipment is becoming a more important issue, particularly for critical applications such as civil aviation. Uncertainties therefore also surround the available quantities of halon of appropriate quality for use in civil aviation.

Recycled halon often refers to halon that has been decanted from the original equipment, processed and cleaned. Civil aviation procedures specify halon certified to meet international standards (either ASTM D 5632 Type 2 for halon 1301 or ISO 7201 for halon 1211), essentially the same specification as newly manufactured halon. Halon recovered and recycled from original equipment may not necessarily meet international standards because of contamination or non-condensable gas content. A small number of service providers have indicated that they are able to reclaim halon to ISO 7201 or

⁵⁴ *Review of Australia's Halon Essential Use Requirements 2012*, by Energy International Australia for the Department of Environment and Energy, May 2012, <https://www.environment.gov.au/protection/ozone/publications/review-australias-halon-essential-uses-requirements>.

ASTM D5632 Type 1 or Type 2, while others are not.

There is some uncertainty about the effects of long-term storage (30+ years), particularly whether the storage containers, seals, valves and fittings could degrade and contaminate the halon. If there was substantial contamination in stocks of halon held either by the NHB or other halon special permit holders due to the extraordinary length of time it is stored for, this could materially reduce the net amount of ISO 7201 or ASTM D5632 Type 2 halon that can be produced from halon stocks.

Estimates of the quantity of future halon required for civil aviation should provide value as an input to policy considerations. The quality of available stocks of halon and the capacity of the industry to meet demand for ISO 7201 or ASTM D5632 Type 2 will become increasingly important. If there were substantial contamination in stocks of halon held either by the NHB or other halon special permit holders, or any significant losses of agent due to processing used to meet the required standards, these could materially reduce the net amount of ISO 7201 or ASTM D5632 Type 2 halon that could be produced from halon stocks.

To maximise future available halon, any methods or equipment implemented to reclaim halon to meet international standards should be designed to be efficient and minimise any potential loss of halon during the process and any potential contamination.

5 International Sale Price of Halon

Internationally the sale price of halon can vary greatly depending on:

- Location of vendor and purchaser
- Momentary supply and demand considerations
- Contamination levels
- Whether halon is laboratory certified
- Whether the sale is occurring from a reputable source
- Bulk quantities vs single fill quantities vs filled systems vs filled extinguishers

Unless otherwise described, the following price estimates are for bulk purchases where the smallest bulk tank was 0.5 tonne. Most bulk purchases are by either large users, such as aircraft manufacturers or fire protection service companies. The latter would use the material to re-charge system cylinders (halon 1301) or portable extinguishers (halon 1211). The price charged to the end customer would be significantly higher than the bulk price.

5.1 Sale Price of Halon 1301

One industry source suggests that international market pricing for bulk halon 1301 can vary from US\$40/kg to US\$140/kg depending on location, reputation of supplier and whether the halon quality is laboratory certified.

Another industry source⁵⁵ has provided an observed price trend for 2006 to 2018 data and forecasts for 2019 and 2020 based on US\$ prices. This data suggests that, while halon 1301 prices remained relatively stable between 2006 and 2011, there has been a year on year increase since then and the price of bulk halon in 2020 will reach almost five times the 2011 US\$ price.

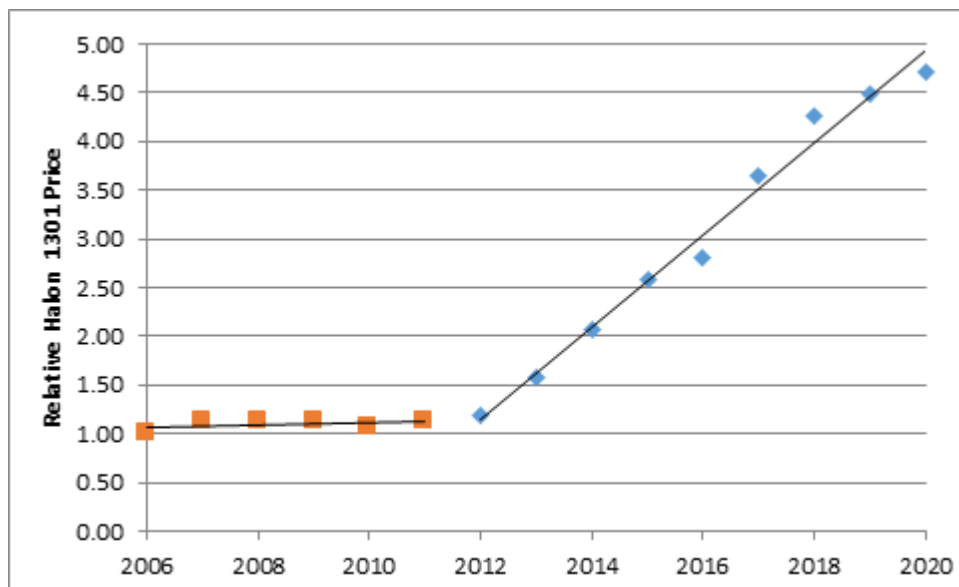
The 2012 Halon Review⁵⁶ reported an estimated price in 2011 for bulk purchases of halon 1301, where the smallest bulk tank is 0.5 tonne, of US\$20/kg to US\$39/kg. Applying the observed trend to this 2011 base year price leads to an estimated implied current price of between US\$100/kg and

⁵⁵ Adam Chattaway, HTOC co-chair, personal communications, 2019.

⁵⁶ *Review of Australia's Halon Essential Use Requirements 2012*, by Energy International Australia for the Department of Environment and Energy, May 2012, <https://www.environment.gov.au/protection/ozone/publications/review-australias-halon-essential-uses-requirements>

US\$195/kg.

Figure 5.1 *Relative Halon 1301 Price for the Years 2006-2020*



On ebay, individual second-hand halon 1301 extinguishers of unknown quality are being offered for sale at prices ranging from US\$250 for a 0.9 kg extinguisher to US\$395 for a 2.25 kg handheld extinguisher and US\$950 for an ex-Boeing aircraft 12.7 kg spherical fire extinguisher.

5.2 Sale Price of Halon 1211

It has been reported that halon supply of 1211 is generally available but there are occasional shortages. The current price for bulk supply is approximately US\$31-US\$33/kg and is expected to rise to US\$37/kg in 2020. From 2012 until 2019, it has been reported that the price has risen by approximately US\$2/kg per year.

On the Alibaba online portal, new 1-4 kg halon handheld extinguishers are being offered ex-Ningbo Port/Shanghai Port at US\$120 to US\$135 each for a minimum of 100 pieces, excluding freight and insurance.

6 Recommendations

Recommendation 1 (Monitor Halon Consumption and Periodic Halon Review):

- It is recommended that halon consumption (e.g., purchases from the NHB) is monitored and if usage varies significantly from projections to perform another review of Australian halon requirements, when and as appropriate, taking into account any changed purchasing patterns and any developments in the aviation sector that may have affected consumption.

Recommendation 2 (Monitor Developments in Civil Aviation Halon Use and Alternatives):

- It is recommended that the global situation for civil aviation halon use is monitored for engine, auxiliary power unit (APU), and cargo applications, including the pace of introduction of alternatives in response to the International Civil Aviation Organization and/or European Union requirements, to ensure that the risk of long-term halon shortages can be avoided.
- The triennial International Civil Aviation Organization General Assembly is scheduled to convene before the end of 2022, with updates expected from working groups investigating non-halon replacement systems for cargo, engine and auxiliary power units, including on the ability to meet already scheduled deadlines.

Recommendation 3 (Halon Quality for Civil Aviation): It is expected that demand for ASTM D 5632 Type 2 halon 1301 will become increasingly important for civil aviation.

- a) It is recommended that the capacity of the NHB and industry to meet demand for ASTM D 5632 Type 2 halon 1301 is monitored.
- b) It is recommended that the Department explore the ability of reclamation equipment/techniques to minimise losses of halon 1301 and to maintain purity (e.g., ensuring halon 1211 contamination levels in halon 1301 remain within specification), and that any identified material risk is investigated further and quantified and, if deemed necessary, guidelines are considered for the reclamation process to minimise potential losses of halon 1301.

Recommendation 4 (Halon Special Permit Holders' Record Keeping):

- It is recommended that measures are considered to validate and/or improve halon special permit holder reporting to attain more accurate

data on halon usage activities (to allow for better quantitative analysis, eliminating double counting for data accuracy and better identifying sources and end-uses for sectoral analysis).

Recommendation 5 (Halon Special Permit Holder Historic and Future Dataset):

- If reporting practices were to be modified, it is recommended that these changes are well documented and selected, where possible, to preserve comparability and continuity with the historic dataset.

Recommendation 6 (NHB Historic and Future Dataset):

- It is recommended that consistent practices in record keeping and reporting are maintained in the operation of the NHB, and if reporting practises were to be modified to ensure that these are well documented and selected so as to preserve comparability and continuity with the historic dataset.