UNITED NATIONS

UNEP/OzL.Pro.WG.1/46/2/Add.1

Montreal Protocol on Substances that Deplete the Ozone Layer

Distr.: General
23 May 2024

Original: English

Open-ended Working Group of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer
Forty-sixth meeting
Montreal, Canada, 8–12 July 2024
Items 3–8 of the provisional agenda*

Issues for discussion by and information for the attention of the Open-ended Working Group of the Parties to the Montreal Protocol at its forty-sixth meeting

Note by the Secretariat

Addendum

I. Introduction

1. The present addendum to the note by the Secretariat on issues for discussion by and information for the attention of the Open-ended Working Group of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer at its forty-sixth meeting (UNEP/OzL.Pro.WG.1/46/2) contains information that has become available since the preparation of that note. Section II of the addendum sets out new information provided by the Technology and Economic Assessment Panel in its 2024 report in relation to items 3–8 of the provisional agenda, as well as a report by the Ozone Secretariat on enhancing the global and regional atmospheric monitoring of controlled substances by the Montreal Protocol in relation to agenda item 5.

2. The 2024 report of the Technology and Economic Assessment Panel currently consists of three volumes:[1]

(a) Volume 1: Technology and Economic Assessment Panel May 2024 progress report;

(b) Volume 2: Evaluation of 2024 critical-use nominations for methyl bromide and related issues – interim report;

(c) Volume 3: Decision XXXV/11 task force report on life-cycle refrigerant management.

II. Summary of issues for discussion by the Open-ended Working Group at its forty-sixth meeting

3. The issues covered in the present addendum are set out below in the order of the respective items on the provisional agenda of the meeting.

* UNEP/OzL.Pro.WG.1/46/1/Rev.1.

[1] Available on the portal for the forty-sixth meeting of the Open-ended Working Group at https://ozone.unep.org/meetings/46th-meeting-open-ended-working-group-parties/pre-session-documents.

Agenda item 3

Presentations by the Technology and Economic Assessment Panel and the Scientific Assessment Panel

4. As indicated in the note by the Secretariat (UNEP/OzL.Pro.WG.1/46/2, paras. 5–12), under this agenda item, the parties will consider information provided in the 2024 progress report of the Technology and Economic Assessment Panel,[2] prepared in cooperation or consultation with the Scientific Assessment Panel, in response to decisions related to very short-lived substances, feedstock uses of controlled substances and emissions of carbon tetrachloride. Summaries of the panels' responses to those decisions are provided in the following paragraphs.

(a) Very short-lived substances (decision XXXV/6)

5. In decision XXXV/6, the Thirty-Fifth Meeting of the Parties requested the Technology and Economic Assessment Panel, in cooperation with the Scientific Assessment Panel, to include in its 2024 progress report updated information on very short-lived substances, including their ozone-depleting potential and the impact of each of the very short-lived substances on the stratospheric ozone layer, in quantifiable terms, and information on alternatives to very short-lived substances in the main applications for which they are currently used, including information on availability, technical feasibility, economic viability, safety and sustainability.

6. The response to decision XXXV/6 is set out in section 5.2 of the progress report, and includes background information on very short-lived substances and an update of the information provided in the 2022 quadrennial assessment of the Medical and Chemicals Technical Options Committee of the Technology and Economic Assessment Panel. The information provided by the Panel is summarized in the following paragraphs.

7. Very short-lived substances are halogen compounds with an atmospheric lifetime of less than six months and a very low, but non-zero, ozone-depleting potential (ODP), and that some originate from natural sources. As a result of their short lifetimes, the fraction of their emission that reaches the stratosphere to deplete stratospheric ozone is smaller than that of the long-lived controlled substances; however, their stratospheric impact depends on the location of their emission and the season, which determines the speed at which they and their degradation products are transported to the stratosphere.

8. Chlorinated very-short lived substances have a relatively small but growing contribution to total tropospheric chlorine, assessed at 4 per cent in 2020. The increasing influence is a result of increases in the abundance of these substances overall and decreases of chlorine from the controlled substances.

9. The report focuses on five chlorinated substances that occur in very high-volumes: dichloromethane (DCM), trichloromethane (chloroform, CFM), 1,2-dichloroethane (ethylene dichloride, EDC), trichloroethylene (TCE) and perchloroethylene (PCE). Each of these chemicals is used as feedstock, and some also have considerable emissive solvent use.

10. The existing information on the ODPs of very-short lived substances collated in the annex to the 2022 quadrennial assessment of the Scientific Assessment Panel[3] remains unchanged. The only ODP value available for the five very-short lived substances discussed in the progress report is that for TCE, at less than 0.004. The Scientific Assessment Panel will update the annex with new information about the ODPs of such substances in its 2026 assessment report.

11. Studies of ozone depletion due to very-short lived substances evaluate the transport of chlorine through the troposphere and subsequent injection into the stratosphere. Recent studies providing updates on the ozone depletion impact of these substances indicate that during the period 2010–2019, chlorinated very-short lived substances reduced total column ozone by, on average, ~2–3 Dobson units[4] in the springtime high latitudes and by ~0.5–1 Dobson units in the tropics. The impact of these substances during the cold Arctic winter of 2019/2020 is also estimated to have resulted in ozone

[2] https://ozone.unep.org/system/files/documents/TEAP-May2024-Progress-Report.pdf.

[3] https://ozone.unep.org/system/files/documents/Scientific-Assessment-of-Ozone-Depletion-2022.pdf, pp. 468–471.

[4] The Dobson unit is the most common unit for measuring ozone concentration. One Dobson unit is the number of molecules of ozone that would be required to create a layer of pure ozone 0.01 millimetres thick at a temperature of 0 degrees Celsius at the surface of the Earth. By way of comparison, the ozone layer's average thickness at the Earth's surface is about 300 Dobson units, or 3 millimetres.

reductions of up to 6 per cent in the lower stratosphere and ~6 Dobson units in the total column by the end of March.

12. As very-short lived substances are not controlled under the Montreal Protocol and parties are therefore not required to submit data to the Ozone Secretariat on production and consumption of such substances, the information provided in the progress report is based on information obtained from industry experts and publicly available government and industry data. The salient points regarding developments since the 2022 assessment report of the Medical and Chemicals Technical Options Committee are the following:

(a) DCM is used predominantly as a solvent but also as feedstock in the production of HFC-32. Global annual production for all uses since 2020 is expected to have remained at the same level or decreased modestly to 1.75–1.9 million metric tons.

(b) CFM is used predominantly as feedstock in the production of HCFC-22. Given the continued global increase in HCFC-22 production, global CFM production in 2022 was estimated to be in the range of 1.7–1.9 million metric tons, of which up to 30,000–60,000 metric tons were likely used as a process agent solvent in the pharmaceutical industry. Natural emissions from sea and land are reported to contribute more than 50 per cent of detected global CFM emissions.

(c) EDC is used almost 100 per cent as feedstock in the production of vinyl chloride monomer, which in turn is tied to demand for polyvinyl chloride (PVC). It is believed that, following the 2020 decrease in PVC production owing to the coronavirus disease (COVID-19) pandemic, global annual EDC output has now approached the 2018 levels of 53–55 million metric tons.

(d) TCE is used mainly as feedstock in the production of HFC-134a (75 per cent), with the balance of consumption in emissive solvent applications. Global HFC-134a production output is believed to have risen by about 20 per cent since 2020, elevating annual TCE use as feedstock to close to 300,000 metric tons.

(e) PCE is used as feedstock in the production of CFC-113, HFC-125 and HFC-134a. PCE production increased during the period 2021–2022, almost entirely because of growing use as feedstock in the production of fluorocarbons, which consumes 70 per cent of overall production. Solvent consumption appears to be stable.

13. In feedstock applications, the report indicates that there are some limited regional downward TCE and PCE trends in parties not operating under paragraph 1 of Article 5 (non-Article 5 parties) owing to measures to implement the Kigali Amendment. The effect of this trend is limited, however, because the production of controlled fluorocarbons in those parties represents only a small percentage of global production of fluorocarbons, which has increased since 2020 overall. In the case of solvent applications, small growth could be seen in 2021 and 2022 in some regions compared to the COVID-19-influenced levels of 2020.

14. The discussion on alternatives to very short-lived substances is focused on three main uses: open and emissive uses, such as use as a foam blowing agent or general solvent; contained use as a process agent solvent;[5] and feedstock use.

15. In the case of open and emissive uses, the Panel refers to extensive studies on alternatives reported on by the Solvents, Coatings and Adhesives Technical Options Committee (STOC) in its 1998 and 2002 assessment reports,[6,7] noting that those reports remain useful sources of information on alternatives. Furthermore, it is noted that the implementing agencies of the Multilateral Fund for the Implementation of the Montreal Protocol have acquired a great deal of knowledge in this area in connection with the phase-out of HCFC-141b and HCFC-225 as part of the HCFC phase-out management plans.

16. References to recent studies on available alternatives are also provided for the category of contained use as a process agent solvent; however, both for this and the former category of uses, the Panel advises that the selection of alternatives should be determined on a case-by-case basis, as needed.

17. In terms of alternatives for feedstock use, the Medical and Chemicals Technical Options Committee directs parties to its 2022 assessment report.[1] It also provides examples of products and

[5] Process agent solvent applications are similar to the process agent uses of controlled substances defined under the Montreal Protocol, used to provide a specific effect, often a combination of selective solvation, volatility, solubilization of the reaction product and inertness in the desired reaction process.

[6] https://ozone.unep.org/sites/default/files/2019-05/STOC1998.pdf.

[7] https://ozone.unep.org/sites/default/files/2019-05/STOC2002.pdf.

processes that exist as potential alternative routes to very short-lived substance feedstocks in table 5.4 of its 2024 progress report, for all the very short-lived substances except DCM, which has much less use as feedstock.

18. The Open-ended Working Group may wish to consider the report and recommend a way forward.

(b) Feedstock uses of controlled substances (decision XXXV/8)

19. In decision XXXV/8, the Thirty-Fifth Meeting of the Parties requested the Technology and Economic Assessment Panel, in cooperation with the Scientific Assessment Panel as appropriate, to provide in its 2024 progress report an update on the emissions from feedstock production, as by-products and from feedstock use of controlled substances, including the sources of such emissions, a comparison of estimates of annual global emissions of controlled substances by species based on bottom-up calculations and estimates made by the Scientific Assessment Panel on the basis of atmospheric observations, the methodology adopted for estimating the emissions, updated information on alternatives, and information on best practices and technologies for minimizing emissions.

20. The response to decision XXXV/8 is set out in section 5.3 of the progress report. Background information is provided first, specifying that controlled substances used as feedstocks in the production of other chemicals are converted to other products, except for de minimis residues and emissions of unconverted raw material. Emissions from the use of feedstocks consist of these residual emissions and fugitive leaks in the production, storage and/or transport processes.

21. The work of the panels, based on data reported by parties to the Ozone Secretariat on production and import of controlled ozone-depleting substances used as feedstock for the years up to and including 2022, is summarized in the following paragraphs.

22. In both 2021 and 2022, 15 parties reported the use of ozone-depleting substances as feedstock. Ten of those that reported such use in 2022 also produced ozone-depleting substances for feedstock uses. In 2022, total production and import reported for feedstock uses of ozone-depleting substances was 1,943,134 metric tons (685,204 ODP-tonnes), a significant increase from 2021 (1,755,171 metric tons). Over the last 10 years, there has been an overall increase of 66 per cent, mostly due to the increase in feedstock uses of HCFCs, particularly HCFC-22, used to produce tetrafluoroethylene (TFE), which can in turn be used in the production of fluoropolymers with many applications.

23. The use of carbon tetrachloride (CTC) as feedstock has also increased in recent years, due to growing demand for lower-global-warming-potential (GWP) hydrochlorofluoro-olefins/hydrofluoro-olefins (HCFO/HFOs) and perchloroethylene (PCE). In addition, there has been a marked increase in reported feedstock use of HCFC-244 and HCFC-21, which are both used as feedstocks in the manufacturing of HFO-1234yf.

24. In 2022, HCFC-22 comprised 50 per cent of the total mass quantity of feedstock uses (up from 48 per cent in 2021), followed by CTC (18 per cent) and HCFC-142b (12 per cent), used in the production of vinylidene fluoride (HFO-1132a).

25. A comparison was done of estimates of annual global emissions of selected controlled substances (1,1,1-trichloroethane, CFC-114 and CFC-114a, CFC-113 and CFC-113a, HCFC-124, HCFC-133a and CFC-115 by-product) based on available bottom-up calculations and global emissions estimated by the Scientific Assessment Panel on the basis of atmospheric observations at remote sites (top-down estimates). While for several of the selected substances there was reasonable agreement between the bottom-up and top-down estimates, for others, such as CFC-114 and HCFC-133a, there were noticeable differences on a global scale.

26. For halon 1301, a representative bottom-up calculation was not considered possible; the situation with halon 1301 emissions from feedstock use is discussed in the progress report of the Fire Suppression Technical Options Committee (see also annex II to the present addendum). In that report, the Committee hypothesizes that the detected unexplained temporary increases in emissions of halon 1301 are related to its production and use as feedstock for fipronil (insecticide) and some pharmaceuticals.

27. In terms of the methodology adopted for estimating emissions, the report includes a discussion of emission factors for production, distribution and use of feedstocks and gaps in understanding of the sources of emissions from chemical pathways with substantial emissions.

28. In response to the request for updates on alternatives, the Medical and Chemicals Technical Options Committee reviewed and updated the existing information on alternatives for ozone-depleting substance feedstocks and expanded it to include HFC feedstocks. Additional information on technical

feasibility, economic viability, safety and sustainability is also provided for large-scale (>100,000 metric tons per year) feedstock uses. According to the Medical and Chemicals Technical Options Committee, the list of alternatives to ozone-depleting substance and HFC feedstocks has not changed significantly from previous reports. Recognizing that not all such feedstocks have viable alternatives, the Committee notes that the ongoing use of a range of controlled substance feedstocks, even where alternative feedstocks are technically feasible and economically viable, suggests that there is currently insufficient incentive for industry to move to alternative feedstocks for many applications.

29. Regarding best practices and technologies for minimizing emissions, the Medical and Chemicals Technical Options Committee indicates that no new information has become available since its 2022 assessment report and the 2023 progress report of the Technology and Economic Assessment Panel. According to the information in those reports, reproduced in the progress report for completeness, best practices available to control emissions include optimizing plant design, equipment, operation and maintenance; instrumentation and monitoring of process and emissions; training and instruction for plant operators; periodic mass balancing; technologies for destruction or for separation and chemical transformation to treat unwanted co-products or by-products and abate their emissions; and regulatory controls to provide the economic framework to ensure that any or all emissions mitigation measures are implemented by operators, and to require emissions and other reporting.

30. The Open-ended Working Group may wish to consider the report and recommend a way forward.

(c) Emissions of carbon tetrachloride (decision XXXV/9)

31. In decision XXXV/9, the Thirty-Fifth Meeting of the Parties requested the Technology and Economic Assessment Panel, in consultation with the Scientific Assessment Panel, to provide in its 2024 progress report an update on emissions of carbon tetrachloride, including emissions by source category, updated information on alternatives to carbon tetrachloride use for feedstock applications, and updated information on best practices and technologies for minimizing carbon tetrachloride emissions.

32. The Panel's response is set out in section 5.4 of the progress report, which indicates that global CTC production was 317,000 metric tons in 2019, declining to 289,000 metric tons in 2020 and then increasing to 320,000 metric tons in 2021 and 358,000 metric tons in 2022 (a 11.9 per cent increase from 2021).

33. Most of the growth in CTC production is from its consumption as feedstock in the HFC and HFO/HCFO sector, as the demand for the major CTC-based products (HFO-1234yf, HFO-1234ze and HCFO-1233zd) has been increasing due to the phase-down of hydrofluorocarbons (HFCs) in non-Article 5 parties and in regions where they are regulated.

34. On the basis of Article 7 reporting of CTC production data for 2022 (358,000 metric tons), the Medical and Chemicals Technical Options Committee estimates that 15,000 metric tons (4.2 per cent of total CTC production) of the global anthropogenic CTC emissions arose from CTC production, handling, supply chain activities and use. A further 5,000 metric tons of CTC emissions are estimated from anthropogenic non-chloromethanes production, notably in the vinyl chain. In addition, 7,500 metric tons are estimated to come from anthropogenic legacy CTC emissions (historic landfill, industrial sites and contaminated soil). On the basis of new information, an additional 2,000 metric tons of anthropogenic CTC emissions are estimated to arise from unknown industry sources that are not yet fully characterized.

35. The Committee also reports that it is unaware of alternatives to CTC or alternative processes and would welcome information from parties that have carried out the relevant analyses, including information on the technical feasibility, economic viability and safety of alternatives.

36. Regarding information on best practices and technologies for minimizing CTC emissions, the Committee directs the parties once more to its 2022 assessment report and the 2023 progress report of the Technology and Economic Assessment Panel, noting that no further information is available on the matter (see also para. 29 above).

37. The Open-ended Working Group may wish to consider the report and recommend a way forward.

Agenda item 4

Life-cycle refrigerant management (decision XXXV/11)

38. As is mentioned in the note by the Secretariat (UNEP/OzL.Pro.WG.1/46/2, paras. 13–15), in paragraph 1 of decision XXXV/11, the Thirty-Fifth Meeting of the Parties requested the Technology and Economic Assessment Panel to prepare a report on available technologies for managing refrigerants, including leakage prevention, recovery, recycling, reclamation and destruction, the obstacles and challenges associated with effective refrigerant management, the costs and climate and ozone benefits associated with such management, and policies and incentive schemes for ensuring effective management.

39. The Technology and Economic Assessment Panel's response to that request is set out in a report prepared by a task force established by the Panel.[8] The key conclusions of the task force are reproduced in annex I to the present addendum, as provided in the report, without formal editing by the Secretariat.

40. The Open-ended Working Group may wish to consider the report, while noting that the workshop on life-cycle refrigerant management will be organized by the Secretariat back to back with the Thirty-Sixth Meeting of the Parties.

Agenda item 5

Enhancing the global and regional atmospheric monitoring of substances controlled by the Montreal Protocol (decision XXXV/14)

41. As is indicated in the note by the Secretariat (UNEP/OzL.Pro.WG.1/46/2, paras. 16–19), the Thirty-Fifth Meeting of the Parties requested the Secretariat, in consultation with the Multilateral Fund secretariat and relevant experts from the Ozone Research Managers, the Scientific Assessment Panel and the Technology and Economic Assessment Panel, to provide the following information to the parties at the forty-sixth meeting of the Open-ended Working Group:

(a) An update of the information provided under decision XXXIII/4, including refining, to the extent possible, the cost estimates associated with enhancing atmospheric monitoring presented in the decision XXXIII/4 report, and providing a list of potential monitoring station locations;

(b) Options for sustainable funding to establish new regional monitoring capacities, including an assessment of their advantages and disadvantages, of potential implementation options and a description of the administrative processes required to operationalize any potential funding options considered, taking into account the discussion at the Thirty-Fifth Meeting of the Parties.

42. The Secretariat's response to the decision is set out in the subsections below. Information in response to the request for sustainable funding options was prepared with the assistance of a financial expert. Further information on this matter will be provided in annexes V and VI to the present addendum and in an information note (UNEP/OzL.Pro.WG.1/46/INF/4).

43. In considering this agenda item, the parties may wish to note that the issue of monitoring of controlled substances was specifically addressed by the Ozone Research Managers at their twelfth meeting, held from 24 to 26 April 2024 in Geneva. Their recommendations, including on gaps in the global coverage of atmospheric monitoring of controlled substances and options to enhance such monitoring, are available as a background document for the Open-ended Working Group at its forty-sixth meeting[9] and will be reproduced in a working document for the Conference of the Parties to the Vienna Convention for the Protection of the Ozone Layer at its thirteenth meeting, to be held jointly with the Thirty-Sixth Meeting of the Parties from 28 October to 1 November 2024 in Bangkok.

(a) Cost estimates associated with atmospheric monitoring of controlled substances at one station

44. In order to better understand the costs involved in setting up a new station for monitoring controlled substances, on 23 February 2024, the Ozone Secretariat and the steering committee of the European-Union-funded pilot project on regional quantification of emissions of substances controlled under the Montreal Protocol[10] held an online workshop on costs of atmospheric monitoring of gases

[8] https://ozone.unep.org/system/files/documents/TEAP-May2024-DecXXXV-11-TF-Report.pdf.

[9] https://ozone.unep.org/system/files/documents/ORM12_Recommendations.pdf.

[10] An outline of the project is available on the Ozone Secretariat website, at https://ozone.unep.org/eu-funded-project-regional-quantification-emissions-substances-controlled-under-montreal-protocol.

controlled under the Montreal Protocol. The workshop was attended by 44 participants, including experts in atmospheric monitoring and representatives of the Ozone Secretariat and the Multilateral Fund secretariat.

45. The discussions focused on the costs associated with establishing a station, comprising capital costs (e.g., construction, maintenance and hardware acquisition) and operating costs (e.g., chemical analyses, consumables, shipments and calibration standards for measurements). The following two major monitoring approaches were considered:

(a) A high-frequency measurement station, involving on-site (in situ) collection of air samples with analysis performed at an on-site laboratory using an analytical instrument, calibrated using established calibration standard scales shared across all measurement sites of the relevant network. Calibrated measurements can be made approximately every two hours. This method requires skilled personnel to conduct routine site visits (though many operations can be highly automated). The fact that such a station runs continuously creates several requirements for the facility, such as a suitable building, reliable electric power (including a backup system), a stable internet connection and road access.

(b) A low-frequency flask sampling station, involving regular (daily to weekly) collection of samples in canisters (flasks) and their shipment to specialized central analytical laboratories for analysis of their constituents. This method requires routine shipment of sampling flasks to and from the central analytical laboratory, with the associated costs and logistical issues (e.g., customs and shipping delays); and a technician to collect the samples at the specified site. Practical constraints limit such sampling to weekly or daily sampling.

46. The outcomes of the workshop are set out in a document that was made available to, considered by and endorsed by the Ozone Research Managers at their twelfth meeting.[11] According to those outcomes, based on the information provided by the workshop participants, the cost of setting up an in-situ high-frequency measurement station is estimated at between $456,000 and $1,245,000, while the cost of setting up a low-frequency flask sampling station with central chemical analysis would be between $50,000 and $1,245,000. The cost estimates are presented as a range of likely values, as they are highly dependent on existing infrastructure, site location and other variables/choices. These figures do not include staffing costs (which are highly variable); the cost of initial site selection experiments (i.e., Observing System Simulation Experiments, OSSEs); the cost of data interpretation; overhead costs charged by any operational research establishment; the cost of travel by scientific personnel; or publication costs.

(b) Potential monitoring station locations

47. The identification of potential monitoring station locations requires knowledge of likely emission source regions (taking into account production, export and import data and consumption estimates by regions) and the availability of sites roughly 1,000 km downwind of the emission regions.

48. Once such sites are identified, atmospheric scientists can conduct OSSEs to forecast whether the sites will indeed intercept air plumes from the emission regions, the height at which samples need to be collected, and the seasons in which the identified sites capture emissions from regions of interest.

49. Any site considered for a monitoring station must be assessed for suitability. The foremost requirements are the availability of a tower (at least 20 metres above ground), electricity, access (i.e., roads), a suitable building to house equipment, and internet connectivity (cell connectivity would be sufficient). The site must also be away from local pollution sources. Furthermore, the ability of the site and infrastructure to withstand unforeseen weather conditions (e.g., hurricanes, storms) also needs to be assessed.

50. Once the above criteria are met and the host country has agreed to the establishment and operation of a monitoring station, survey measurements may be carried out using flask sampling (starting possibly with weekly or biweekly collections) to further confirm the site's suitability for controlled substance monitoring. In that case, it is very important to identify an analytical facility with the expertise to measure the gases that are present in very low concentrations (parts per billion and parts per trillion). Currently, there are only about ten such analytical facilities, located in Europe and North America.

[11] The document is also available on the meeting portal, at https://ozone.unep.org/system/files/documents/Monitoring_Costs_Workshop_Outcomes.pdf.

51. Once a site's suitability has been confirmed through flask sampling over an appropriate time period, monitoring can take place, either through the continuation of flask measurements or through transitioning, if possible, to high-frequency measurements at the station.

52. A similar approach for site identification was followed by the steering committee overseeing the implementation of the aforementioned European-Union-funded pilot project. Many of the excellent operational sites used for measuring greenhouse gases and air pollution gases were found not to be the best for measuring controlled substances because of wind patterns and the emission regions that they sample. OSSEs have been run for 11 such existing, operational stations (Shenzen, China; Maldives; Mount Lan Biang, Viet Nam; Gunung Besar, Indonesia; Darjeeling, India; Oroundo, Cyprus; Mount Mugogo, Rwanda; three stations in Morocco; and Bhola Island, Bangladesh). Bhola Island was chosen as a site for sampling air from the South Asian region using flask sampling, an activity that is still ongoing.

53. A useful next step in identifying locations and sites would be to map some of the existing facilities (e.g., stations, laboratories, communication towers and other types of towers) under other relevant networks in locations/regions where monitoring gaps exist. Some such networks may include the Global Atmospheric Watch, ambient air quality monitoring of the Global Environmental Monitoring System of UNEP, the Convention on Long-range Transboundary Air Pollution (particularly for the Eastern European region, which has been identified by OSSE analysis as a gap for monitoring of controlled substances), the Comprehensive Nuclear-Test-Ban Treaty Organization and the Global Chemicals Monitoring Programme (see also paras. 72 and 73 below). The Secretariat has begun, in cooperation with some of those networks, to map the facilities that could be used as a basis for setting up stations to monitor controlled substances in regions with gaps.

(c) Costs related to a monitoring expansion strategy

54. As a follow-up to the outcomes of the online workshop on costs of atmospheric monitoring of gases controlled under the Montreal Protocol (see subsection (a) above), a monitoring expansion strategy could be developed. The strategy would elaborate on the elements of the broad approach discussed during the twelfth meeting of the Ozone Research Managers, namely the identification of emission source regions; the identification of regions of apparent existing monitoring gaps; the identification of existing local infrastructure that could be used; commitments by relevant countries; project development and fundraising; and cooperation with other international programmes and networks.

55. Establishing and operating monitoring stations and networks can be expensive, and up until now funding has not been sufficient to allow the development of a comprehensive expansion strategy. Funding can take a stepwise (construction of a single monitoring site) or a programmatic approach (construction of multiple sites plus an integrated and coordinated technical assistance programme). On the basis of the costs estimated in the workshop outcomes document, an attempt was made to estimate the average cost (capital and operating) of establishing and maintaining a monitoring site for a period of 5 years, for a step-by-step approach and for a programmatic approach.

(i) Step-by-step approach

56. The essence of the step-by-step approach is that individual sites are identified and assessed, and then monitoring sites are developed based on the funding available. As only a single site is developed at any given time, the demand for funds is reasonably manageable and funds could be sourced through existing trust funds. In terms of financial sustainability, however, it is important to consider the long-term operating costs as well as the upfront capital investment, even for this approach.

57. The core data presented in the outcomes of the online workshop on costs of atmospheric monitoring of controlled substances have been used to generate cost projections for financing both a step-by-step approach and a programmatic approach. Table 1 shows the estimated costs associated with developing and operating a new high-frequency station and a new low-frequency flask-based station using the step-by-step approach. Key assumptions and specifications are listed in the notes to the table. In the case of flask sampling, estimated costs are provided for daily and weekly sampling. Some of the aggregate cost estimates provided here may differ from those in the workshop outcomes, owing to different interpretations of capital and operating costs, different assumptions of when to use variants of high and low costs, and rounding errors.

Table 1
Analysis of the 5-year costs of developing and operating a monitoring site using the step-by-step approach
(United States dollars)

High-frequency measurement station						
	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Total*
Low-cost	**481 000**	**43 000**	**45 000**	**47 000**	**49 000**	**665 000**
- Capital cost	440 000	0	0	0	0	440 000
- Operating costs	41 000	43 000	45 000	47 000	49 000	225 000
High-cost	**1 236 000**	**43 000**	**45 000**	**47 000**	**49 000**	**1 420 000**
- Capital cost	1 195 000	0	0	0	0	1 195 000
- Operating costs	41 000	43 000	45 000	47 000	49 000	225 000

Notes:
- Capital costs (low-cost scenario) include a gas chromatography–mass spectrometry (GC/MS) instrument, calibration standards and adjustments to an existing tower.
- Capital costs (high-cost scenario) include a GC/MS instrument, calibration standards, a 20- to 30-metre tower (full installation), a connection to a source of electrical power, a building to house the GC/MS instrument, and road access.
- Operating costs (high- and low-cost scenarios) include site maintenance, consumables, shipment costs and calibration.
- Annual operating costs are scaled up by 5 per cent per year.
- Personnel costs are not included.

Low-frequency flask measurement station (daily sampling)						
	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Total*
Low-cost	**270 000**	**190 000**	**200 000**	**210 000**	**221 000**	**1 091 000**
- Capital cost	89 000	0	0	0	0	89 000
- Operating costs	181 000	190 000	200 000	210 000	221 000	1 002 000
High-cost	**1 444 000**	**251 000**	**264 000**	**277 000**	**291 000**	**2 527 000**
- Capital cost	1 205 000	0	0	0	0	1 205 000
- Operating costs	239 000	251 000	264 000	277 000	291 000	1 322 000

Notes:
- Capital costs (low-cost scenario) include sampling flasks and adjustments to an existing tower.
- Capital costs (high-cost scenario) include an GC/MS instrument, calibration standards, a 20- to 30-metre tower (full installation), a connection to a source of electrical power, a weatherproof shed and road access. The GC/MS instrument and calibration standards may be housed in a separate location and serve other sites.
- Operating costs (low-cost scenario) include the lower-range estimates for site maintenance, consumables, shipment costs, customs, sample collection and sample analysis.
- Operating costs (high-cost scenario) include the higher-range estimates for site maintenance, consumables, shipment costs, calibration, customs, sample collection and sample analysis.
- Annual operating costs are scaled up by 5 per cent per year.
- Personnel costs are not included.

Low-frequency flask measurement station (weekly sampling)						
	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Total*
Low-cost	**84 000**	**62 000**	**65 000**	**68 000**	**71 000**	**350 000**
- Capital cost	25 000	–	–	–	–	25 000
- Operating costs	59 000	62 000	65 000	68 000	71 000	325 000
High-cost	**651 000**	**85 000**	**89 000**	**93 000**	**98 000**	**1016 000**
- Capital cost	570 000	–	–	–	–	570 000
- Operating costs	81 000	85 000	89 000	93 000	98 000	446 000

Notes:
- Capital costs (low-cost scenario) include sampling flasks and adjustments to an existing tower.
- Capital costs (high-cost scenario) include a 20- to 30-metre tower (full installation), a connection to a source of electrical power, a weatherproof shed and road access. GC/MS instrument costs are not included, assuming that analysis of weekly samples be carried out by an existing analytical laboratory.
- Operating costs (low-cost scenario) include the lower-range estimates for site maintenance, consumables, shipment costs, customs, sample collection and sample analysis.
- Operating costs (high-cost scenario) include the higher-range estimates for site maintenance, consumables, shipment costs, customs, sample collection and sample analysis.
- Annual operating costs are scaled up by 5 per cent per year.
- Personnel costs are not included.

58. In addition to capital and operating costs, a further attempt was made to estimate the total costs involved in constructing and operating a monitoring station for 5 years, taking into account rough estimates of costs associated with preparatory (e.g., OSSEs) and capacity-building activities as well as contingency costs, programme management costs and programme support costs. While all these additional activities need to be carefully costed on an individual basis, for the time being, for budgeting purposes, broad assumptions are made. For a step-by-step approach, these estimates are presented in table 2, with the assumptions indicated in the notes.

Table 2
Total estimated costs of constructing and operating a measurement station in a step-by-step approach for 5 years, including preparatory, capacity-building, programme management and support costs

	In-situ high frequency		*Daily flask sampling*		*Weekly flask sampling*	
Cost scenario	*Low*	*High*	*Low*	*High*	*Low*	*High*
Capital costs	440 000	1 195 000	89 000	1 205 000	25 000	570 000
Operating costs	225 000	225 000	1 002 000	1 322 000	325 000	446 000
Preparatory and capacity-building costs[a]	400 000	400 000	400 000	400 000	400 000	400 000
Total cost of monitoring	**1 065 000**	**1 820 000**	1,491,000	2,927,000	**750 000**	**1 416 000**
Contingency costs (10 per cent)[b]	107 000	182 000	149,000	293,000	75 000	142 000
Programme management costs (10 per cent)[c]	117,000	200,000	164,000	322,000	83,000	156,000
Sub-total	**1,289,000**	**2,202,000**	**1,804,000**	**3,542,000**	**908,000**	**1,714,000**
Programme support costs (13 per cent)[d]	168,000	286,000	235,000	460,000	118,000	223,000
Grand total	**1,456,000**	**2,488,000**	**2,039,000**	**4,002,000**	**1,026,000**	**1,936,000**

Notes:

[a] A lump sum of $400,000 is assumed to support site identification and evaluation, capacity-building for site staff and laboratory staff, and costs associated with external support. This amount would be spent over the 5-year duration of a project.

[b] Contingency costs are calculated as 10 per cent of the total cost of monitoring.

[c] Programme management costs, incurred in the implementation of project activities, are calculated as 10 per cent of the total cost of monitoring plus contingency costs.

[d] Programme support costs are calculated at 13 per cent of the total cost of monitoring plus contingency costs plus programme management costs, based on a standard United Nations rate and applicable to many international organizations.

59. This analysis shows that total costs between the assumed 5-year low-cost and high-cost scenarios lie in the ranges of $1.4 million to $2.5 million for high-frequency monitoring; $2 million to $4 million for daily flask sampling; and $1 million to $2 million for weekly flask sampling.

(ii) Programmatic approach

60. A programmatic approach would entail working with multiple potential sites in a coordinated manner, covering site identification, data monitoring and analysis, capacity-building for the different sites and dissemination of results. While such an approach may appear significantly more expensive because of the number of sites being established, there are likely to be economies of scale in terms of development of training material, bundling of training activities and, potentially, procurement costs. There would also be flexibility to move funds between sites depending on actual needs for each site. Fundraising for larger sums of money can often be simpler, in some respects, than raising smaller sums multiple times for multiple sites. In addition, larger projects afford donors greater visibility.

61. On the basis of the same base-cost estimate for monitoring sites as in a step-by-step approach, four scenarios were explored: two for a modest expansion and two for an aggressive expansion. For each scenario, a mix of high-frequency and flask-based systems has been chosen to achieve a balance between higher/lower capital costs and operating costs. The scenarios that have been considered are as follows:

(a) ***Scenario 1*** *– Low-cost modest expansion:* Five additional monitoring stations comprising two high-frequency and three flask-based daily sampling systems, using pre-existing infrastructure;

(b) ***Scenario 2*** *– High-cost modest expansion:* Five additional monitoring stations comprising two high-frequency and three flask-based daily sampling systems, building new infrastructure;

(c) ***Scenario 3*** *– Low-cost aggressive expansion:* 10 additional monitoring stations comprising four high-frequency and six flask-based daily sampling systems, using pre-existing infrastructure;

(d) ***Scenario 4*** *– High-cost aggressive expansion:* 10 additional monitoring stations comprising four high-frequency and six flask-based daily sampling systems, building new infrastructure.

62. Table 3 shows a comparison of the budgets for the four expansion scenarios based on the programmatic approach, including total monitoring costs and provision for contingency and programme management and support costs.

Table 3
Comparison of budgets for four expansion scenarios based on the programmatic approach
(United States dollars)

	*Costs of expanding the monitoring network, for a 5-year period**			
	Two high-frequency and three daily flask-based sampling systems		*Four high-frequency and six daily flask-based sampling systems*	
	Scenario 1 Low cost	*Scenario 2 High cost*	*Scenario 3 Low cost*	*Scenario 4 High cost*
High-frequency	1 330 000	2 840 000	2 660 000	5 680 000
Flask-based	3 273 000	7 581 000	6 546 000	15 162 000
Preparation and capacity-building[a]	2 000 000	2 000 000	2 500 000	2 500 000
Total cost of monitoring	**6 603 000**	**12 421 000**	**11 706 000**	**23 342 000**
Contingency costs (10 per cent)[b]	660 000	1 242 000	1 171 000	2 334 000
Programme management costs (10 per cent)[c]	726 000	1 366 000	1 288 000	2 568 000
Sub-total	**7 989 000**	**15 029 000**	**14 165 000**	**28 244 000**
Programme support costs (13 per cent)[d]	1 039 000	1 954 000	1 841 000	3 672 000
Grand total	**9 028 000**	**16 983 000**	**16 006 000**	**31 916 000**

Notes:

* Estimates are based on increasing the number of daily flask-based monitoring sites and high-frequency monitoring stations only.

[a] A lump sum of $2,000,000 is assumed for an expansion of 5 monitoring stations and a sum of $2,500,000 for 10 monitoring stations. These funds would support site identification and evaluation, capacity-building for site staff and laboratory staff, and costs associated with external support. The amount would be spent over the 5-year duration of a project.

[b] Contingency costs are calculated as 10 per cent of the capital costs plus operational costs for 5 years plus a lump sum for preparation and capacity-building (i.e., the total cost of monitoring).

[c] Programme management costs, incurred in the implementation of project activities, are calculated as 10 per cent of the total cost of monitoring plus contingency costs.

[d] Programme support costs, incurred by the Secretariat in managing the funds, are calculated at a standard United Nations rate of 13 per cent of the total cost of monitoring plus contingency costs plus programme management costs.

63. This analysis shows that, for the above scenarios, the lowest-cost scenario (modest expansion, assuming existing local infrastructure) would require about $9 million to execute, and the highest-cost scenario (aggressive expansion, assuming all new construction) would require about $32 million.

(d) Potential funding options

64. In the limited time available, the Secretariat was able to analyse the following options for financing the expansion of the controlled substance monitoring network:

(a) Existing trust funds for the Vienna Convention and its Montreal Protocol, namely the Trust Fund for the Vienna Convention, the Trust Fund for the Montreal Protocol, the General Trust Fund for Financing Activities on Research and Systematic Observations relevant to the Vienna Convention, and the Multilateral Fund for the Implementation of the Montreal Protocol;

(b) External funding and in-kind contribution through collaboration from organizations active in the emissions monitoring space, such as the Global Environment Facility (GEF) and its chemicals and waste focal area, the World Meteorological Organization (WMO), the Green Climate Fund and the Comprehensive Nuclear-Test-Ban Treaty Organization;

(c) External funding from two philanthropic institutions, the Bezos Earth Fund and the Gates Foundation.

65. A description of the above funding options, based on the information currently available, including advantages and disadvantages, is set out in annexes V and VI to the present addendum and the information note. All these options present a number of issues that would need to be worked through. Even if existing funds from the Vienna Convention and the Montreal Protocol were to be used, issues such as variations from the standard mandate and the eligibility of funds (i.e., the terms of reference of the trust funds) and alignment with a step-by-step or programmatic approach might need to be addressed.

(e) Potential implementation options

66. Based on the above analysis, potential implementation options are described in the following paragraphs.

67. A relatively quick start in financing projects on atmospheric monitoring of controlled substances could be using the step-by-step approach through funds available in the Vienna Convention and the Montreal Protocol trust funds. As at 30 April 2024, the two trust funds had cash balances of $2,429,351 and $7,078,380, respectively. A possible way forward, and possibly the simplest and the fastest of the funding options considered above, would be to allocate specific amounts from the aforementioned cash balances to the General Trust Fund for Financing Activities on Research and Systematic Observations relevant to the Vienna Convention for onward disbursement to projects for the establishment and operation of controlled substance monitoring stations. Such an approach would require relevant decisions to be adopted on the Vienna Convention and the Montreal Protocol trust funds by the Conference of the Parties and the Meeting of the Parties, respectively.

68. In that regard, it is important to note that paragraph 4 of decision VC VI/2, which called for the establishment of the General Trust Fund for Financing Activities on Research and Systematic Observations relevant to the Vienna Convention, stipulates that, in addition to the support for the continued maintenance and calibration of the existing WMO Global Atmospheric Watch ground-based stations for monitoring column ozone, ozone profiles and ultra-violet radiation, consideration should be given to supporting other activities identified by the Ozone Research Managers, in consultation with the co-chairs of the Scientific Assessment and Environmental Effects Assessment Panels, for the improvement of the observation network and relevant research. The Ozone Research Managers at their twelfth meeting identified the monitoring of controlled substances as an important activity that merits support under the General Trust Fund for Financing Activities on Research and Systematic Observations relevant to the Vienna Convention and noted the viability of this trust fund to finance monitoring of controlled substances, subject to availability of funds. If this trust fund were to be used for such a purpose, some adjustments to its current operation might be necessary – for example, reporting on the contributions received and utilized for the monitoring of controlled substances.

69. The General Trust Fund for Financing Activities on Research and Systematic Observations relevant to the Vienna Convention is a small trust fund that has supported the implementation of activities at a total cost of $635,426 since its inception in 2003 and has a low cash balance ($308,454 as at 30 April 2024). That said, all necessary procedures and mechanisms for funding monitoring stations are already in place for that trust fund. It has been supporting projects for similar activities (related to monitoring of ozone and ultra-violet radiation monitoring) in close cooperation with WMO. Its activities are overseen by an advisory committee that includes experts in atmospheric monitoring, and it receives voluntary contributions from parties and international organizations. Further

information on the trust fund is set out in a document UNEP/OzL/Conv.ResMgr/12/2,[12] prepared for the consideration of the Ozone Research Managers at their twelfth meeting.

70. Another funding option that could be used is the Multilateral Fund for the Implementation of the Montreal Protocol because it is directly linked to the Montreal Protocol, specifically created to assist Article 5 parties in complying with the provisions of the Protocol.[13] Should the parties decide that establishing stations in Article 5 parties for monitoring of controlled substances would qualify for funding under the Multilateral Fund, details of possible administrative processes required to operationalize the use of the Multilateral Fund for that purpose would need to be elaborated, as further described in annex V to the present addendum.

71. Should funding for monitoring of controlled substances be sourced from the Multilateral Fund, consideration could also be given to the possibility of using or involving the General Trust Fund for Financing Activities on Research and Systematic Observations relevant to the Vienna Convention to support relevant activities. Possible administrative processes required to operationalize this option are described in annex VI to the present addendum.

72. Should the parties opt for a programmatic approach, further information from institutions with large budgets, such as GEF, the Green Climate Fund and the larger philanthropic funds, could be obtained to seek to leverage funds for certain common activities. For example, opportunities have been identified for cooperation with the United Nations Environment Programme/GEF unit to collaborate on elements of programme design, specifically with regard to the mapping of physical and scientific infrastructure such as laboratories in the context of the new phase of implementation of a project entitled "Global Chemicals Monitoring Programme to support implementation of Stockholm and Minamata Conventions (GCMP)",[14] which has already established a network of monitoring stations in several countries in Latin America, the Caribbean, Asia, Africa and the Pacific Islands. Furthermore, preparations for the ninth replenishment cycle of GEF are now underway, presenting an opportunity to add the monitoring of substances controlled under the Montreal Protocol explicitly to the mandate of the GEF chemicals and waste focal area.

73. Other opportunities for further exploration include ambient air quality monitoring sites such as those of the Global Environmental Monitoring System of UNEP, the Convention on Long-range Transboundary Air Pollution (particularly for the Eastern European region, which has been identified as a gap for monitoring of controlled substances by OSSE analysis) and the Comprehensive Nuclear-Test-Ban Treaty Organization, which is currently reviewing the capital and operating costs of refreshing its monitoring network of towers and related infrastructure.

74. In all the above options, WMO would be a key partner, given that it has a strong network of scientists, is already heavily engaged in atmospheric monitoring and has extensive experience in managing data and networks. Collaboration with existing WMO monitoring networks such as the Global Atmosphere Watch Programme[15] and the new Global Greenhouse Gas Watch initiative[16] needs to be further explored. As was mentioned above, there has been long-standing, successful cooperation between WMO and the Ozone Secretariat in implementing projects under the General Trust Fund for Financing Activities on Research and Systematic Observations relevant to the Vienna Convention.

(f) Administrative processes

75. Information on the administrative processes required to operationalize any potential funding options, as requested in paragraph (b) of decision XXXV/14, have been touched on in the preceding section, while further information is provided in annexes V and VI to the present addendum and the information note. Should parties wish to have further details on the matter, these could be provided by the Secretariat in the coming months, for example, prior to the Thirty-Sixth Meeting of the Parties.

76. The Open-ended Working Group may wish to consider the report and recommend a way forward.

[12] Available on the Secretariat website at https://ozone.unep.org/system/files/documents/ORM12-2E.pdf. The document will be updated as appropriate prior to the thirteen meeting of the Conference of the Parties to the Vienna Convention, in October 2024, for the parties' consideration.

[13] Decision XXXV/1: Replenishment of the Multilateral Fund for the Implementation of the Montreal Protocol for the triennium 2024–2026; adopted budget of $965 million for the triennium.

[14] https://www.thegef.org/projects-operations/projects/11534.

[15] https://community.wmo.int/en/activity-areas/gaw.

[16] https://wmo.int/activities/global-greenhouse-gas-watch-g3w.

Agenda item 6

Presentation and discussion of the Technology and Economic Assessment Panel 2024 progress report

77. Under item 6 of the provisional agenda, the parties will consider information provided by the Technology and Economic Assessment Panel in volumes 1 and 2 of its 2024 report. The Panel's progress report (vol. 1) includes progress reports by its technical options committees, responses to five decisions of the Meetings of the Parties (XXXV/6, XXXV/8, XXXV/9, XXXV/10 and XXVIII/2(5)) and updated information on per- and poly-fluoroalkyl substances (PFAS) and other matters, including membership and organizational matters.

78. The key messages in the progress reports by the technical options committees are reproduced in annex II to the present addendum, as set out in the Panel's progress report, without formal editing by the Secretariat. To avoid duplication, the issues related to sub-items 3 (a)–(c) of the Medical and Chemicals Technical Options Committee progress report are summarized under the respective agenda items (see paras. 5–37 above).

79. The report of the Methyl Bromide Technical Options Committee of the Technology and Economic Assessment Panel (vol. 2),[17] available on the meeting portal, provides an interim recommendation based on the evaluation of a 2024 critical-use nomination for methyl bromide and associated issues in relation to sub-item 6 (a). A summary of the issues addressed in the report is presented in paragraphs 80–87 below.

(a) Nominations for critical-use exemptions for methyl bromide for 2025

80. As indicated in the note by the Secretariat (UNEP/OzL.Pro.WG.1/46/2, paras. 20–21), the Methyl Bromide Technical Options Committee evaluated one nomination, submitted by Canada in 2024, for a critical-use exemption for 2025. The party noted in its submission that it does not intend to submit a nomination for the 2026 calendar year or subsequent years.

81. According to the Committee, the nomination submitted by Canada for 2025 was attributed to environmental conditions and regulatory restrictions that did not allow partial or full use of alternatives that have been used successfully for this sector in other countries, difficulties in the scale-up of substrate technologies and associated economic costs.

82. The Committee has recommended the approval of the full amount nominated by Canada for 2025, noting that this represents a significant (26 per cent) decrease in the amount approved for 2024. The nomination submitted by Canada for 2025 and the interim recommendation by the Committee are listed in table 4.

Table 4
Nomination for 2025 critical-use exemption for methyl bromide submitted in 2024 and the interim recommendation of the Methyl Bromide Technical Options Committee
(in metric tons)

Party and sector	*Nomination for 2025*	*Interim recommendation for 2025*
Canada		
Strawberry runners	2.850	[2.850]
Total	**2.850**	**[2.850]**

83. In its report, the Committee recalls the reporting requirements under relevant decisions and includes information on trends in methyl bromide critical-use nominations and exemptions for all nominating parties to date, as well as on the reported accounting frameworks for critical uses and stocks of methyl bromide.

84. Pursuant to paragraph 9 (f) of decision Ex. I/4 on conditions for granting and reporting critical-use exemptions for methyl bromide, each party that has been granted a critical-use exemption is requested to submit its accounting framework information together with its nomination. In accordance with that provision, Canada submitted in 2024 its accounting framework for 2023, reporting no available stocks at the end of 2023.

85. The Committee also notes that, while reported stocks for controlled uses in non-Article 5 parties are now small, the accounting information in its report does not accurately show the total

[17] https://ozone.unep.org/system/files/documents/TEAP-CUN-interim-report-may-2023.pdf.

stocks of methyl bromide held globally for controlled uses by Article 5 parties. This is because only parties applying for critical use exemptions are required to report stocks, some parties have no formal mechanism to account accurately for stocks for all uses and there is no requirement for parties to report pre-2015 stocks. The Committee continues to consider that unreported stocks may be substantial (approximately 1,000 metric tons) and would have to be managed in an environmentally sound manner to ensure proper disposal and avoid direct emissions into the atmosphere. Furthermore, there is confusion in some parties as to whether stocks held at the national level are for quarantine and pre-shipment uses.

86. The final report of the Committee will be available prior to the Thirty-Sixth Meeting of the Parties.

87. The Working Group may wish to consider the report and interim recommendations of the Methyl Bromide Technical Options Committee.

(b) Energy efficiency (decision XXXV/10)

88. As indicated in the note by the Secretariat (UNEP/OzL.Pro.WG.1/46/2, paras. 22–24), in decision XXXV/10, the Thirty-Fifth Meeting of the Parties requested the Technology and Economic Assessment Panel to include in its 2024 progress report updates on the information identified in paragraph 1 (a) of decision XXXIV/3, taking into account discussions at the Thirty-Fifth Meeting of the Parties.

89. The Panel's response is set out in section 6.3 of its 2024 progress report, providing updates on energy efficiency in the phase-down of HFCs in the refrigeration, air conditioning and heat pump sectors. The Panel refers to the report entitled "Global Cooling Watch 2023: Keeping it Chill: How to meet cooling demands while cutting emissions", prepared by the United Nations Environment Programme-led Cool Coalition in support of the Global Cooling Pledge,[18] an initiative of the United Arab Emirates as host of the 2023 United Nations Climate Change Conference. The aim of the Global Cooling Pledge is to reduce cooling-related emissions by 68 per cent by 2050, increase access to sustainable cooling by 2030 and increase the global average efficiency of new air conditioners by 50 per cent.

90. According to the report, passive cooling, higher energy efficiency standards and a faster phase-down of climate-warming refrigerants used in the cooling industry could avert up to 60 per cent of the predicted emissions from the cooling sector by 2050, a goal that would require concerted effort. While cooling policies are in place in many parties, the effectiveness of their implementation and their integration vary, with 80 per cent of parties having established regulatory instruments for at least one of the three above-mentioned measures but only 27 per cent having established well-integrated regulatory frameworks. Thirty-five parties have adopted policies such as national cooling action plans, while some other parties have adopted other forms of climate action plan and 70 parties have signed the Global Cooling Pledge.

91. The Panel also reports on progress made with regional approaches, including the approval of harmonized regional minimum energy performance standards for air conditioners and residential refrigerators by the Southern African Development Community and advances in the adoption of regulations related to seasonal energy efficiency in some countries in the Middle East, and on cold chain capacity-building activities, noting that the Africa Centre of Excellence for Sustainable Cooling and Cold-Chain Systems became operational in March 2024.

92. The report also highlights the importance of heat pump technology, which is estimated to have the potential to reduce total global CO_2-equivalent emissions by 500 million metric tons by 2030. Given that current technology and deployment levels only meet 10 per cent of global heating needs, further policy support and technical innovation would be needed.

93. Widespread environmentally harmful dumping of cooling equipment is also noted in the report, along with the importance of leak prevention throughout the lifetime of equipment, which is discussed further in the Panel's response to decision XXXV/11 on life-cycle refrigerant management.

94. Finally, the report notes the creation of a funding window for energy efficiency projects under the Multilateral Fund through the adoption of decision 91/65 by the Fund's Executive Committee at its ninety-first meeting, in December 2022, and the subsequent approval, at its ninety-third meeting, in December 2023, of nine non-investment projects, two investment projects and four preparation projects totalling more than $4.5 million.

[18] https://coolcoalition.org/global-cooling-pledge/.

95. The Open-ended Working Group may wish to continue considering the topic of energy efficiency in the light of Panel's response and recommend a way forward.

(c) Panel membership changes

96. In annex 5 to its 2024 progress report, the Technology and Economic Assessment Panel provides information on the status of its membership and that of its technical options committees as at May 2024.

97. Table 5 lists the members of the Panel whose membership expires at the end of 2024 and whose reappointment requires a decision by the Thirty-Sixth Meeting of the Parties. The members of the technical options committees whose membership expires at the end of 2024 and whose reappointment does not require a decision by the Thirty-Sixth Meeting of the Parties are listed in annex III to the present addendum.

Table 5
Members of the Technology and Economic Assessment Panel whose membership expires at the end of 2024 and whose reappointment requires a decision by the Thirty-Sixth Meeting of the Parties

Name	*Position*	*Country*
Bella Maranion	TEAP co-chair	United States of America
Paolo Altoe	FTOC co-chair	Brazil
Adam Chattaway	FSTOC co-chair	United Kingdom of Great Britain and Northern Ireland
Daniel P. Verdonik	FSTOC co-chair	United States of America
Suely Machado Carvalho	TEAP senior expert	Brazil
Sukumar Devotta	TEAP senior expert	India
Ray Gluckman	TEAP senior expert	United Kingdom of Great Britain and Northern Ireland
Marco Gonzalez	TEAP senior expert	Costa Rica
Shiqiu Zhang	TEAP senior expert	China

Abbreviations: TEAP – Technology and Economic Assessment Panel; FTOC – Flexible and Rigid Foams Technical Options Committee; FSTOC – Fire Suppression Technical Options Committee.

98. Parties may wish to submit nominations, as necessary, in accordance with paragraph 3 of decision XXXI/8, whereby they are requested, "when nominating experts to the Panel, its technical options committees or its temporary subsidiary bodies, to use the Panel's nomination form and associated guidelines so as to facilitate the submission of appropriate nominations, taking into account the matrix of needed expertise, and geographical and gender balance, in addition to the expertise needed to address new issues related to the Kigali Amendment, such as energy efficiency, safety standards and climate benefits". In paragraph 5 of the same decision, the parties are urged "to follow the terms of reference of the Panel, consult the Panel's co-chairs and refer to the matrix of needed expertise prior to making nominations for appointments to the Panel".

99. The matrix of needed expertise, identified by the Technology and Economic Assessment Panel as at May 2024, is included in annex 6 to its progress report, reproduced in annex IV to the present addendum and posted on the Secretariat's website.[19]

100. In accordance with paragraph 4 of decision XXXI/8, the Secretariat will make available, on the meeting portal for the forty-sixth meeting of the Open-ended Working Group and on the meeting portal for the Thirty-Sixth Meeting of the Parties later in 2024, any forms submitted by parties nominating members to the Panel, with a view to facilitating the review of and consultations on the proposed nominations by parties.

101. Nominations to the technical options committees other than for co-chair positions, as well as nominations to temporary subsidiary bodies, can be made at any time. Appointments are made by the co-chairs of the relevant committees in consultation with the Panel.

(d) Any other issues

102. In addition to the issues summarized in the present addendum, the progress report of the Technology and Economic Assessment Panel provides updates on the following key issues:

[19] https://ozone.unep.org/science/assessment/teap/teap-expertise-required.

(a) Metered-dose inhalers and other aerosols: in chapter 5.9 of the Panel's progress report, with the key messages of the Medical and Chemicals Technical Options Committee reproduced in annex II to the present addendum;

(b) Emerging policies and sector information related to PFAS: in chapter 7 of the Panel's progress report, with the key messages summarized in the present section.

103. Should any party wish to discuss the above issues, they could be addressed under sub-item 6 (d), together with any other issues that parties may wish to take up. Parties should request that such issues be included in the agenda during adoption of the agenda.

(e) Emerging policies and sector information related to PFAS

104. As was mentioned above, chapter 7 of the Panel's progress report provides updated information on emerging policies and sector information related to PFAS, including regulatory developments and possible implications for the foams, fire suppression and refrigeration, air-conditioning and heat pumps sectors. As in earlier progress reports, the Panel reiterates that the potential inclusion of replacements for Montreal Protocol controlled substances in PFAS bans is creating uncertainty for industry regarding the long-term availability of certain alternatives to controlled substances. Some manufacturers and other stakeholders have reported that they are delaying decisions on the selection of alternatives and the associated investments owing to concerns about whether some or all of the fluorinated alternatives might become unavailable. This uncertainty could have the unintended effect of delaying the phase-out of ozone-depleting substances and the phase-down of high-GWP HFCs.

105. Definitions of PFAS incorporated into potential future regional policies may or may not include Montreal Protocol controlled substances and their substitutes, or their breakdown products, such as trifluoroacetic acid (TFA) and its salts. The Organisation for Economic Co-operation and Development definition of PFAS encompasses a wide range of chemicals, from gases and liquids to solid polymers. That definition includes TFA and most commercially used HFCs and HFOs but excludes several fluorinated gases, such as HFC-32, HFC-23, CF3I, HFC-152a and HCFC-22.

106. The European Chemicals Agency has opened for public consultation a proposal for the precautionary restriction of around 10,000 PFAS in the European Economic Area, submitted in January 2023 by five parties. Under the proposal, PFAS, as defined, would not be manufactured, used or placed on the market as substances on their own, or in another substance, or in a mixture, or in an article (e.g., component or equipment) above certain concentration levels, with these restrictions applying 18 months after their entry into force. It has been estimated that the process might conclude and the bans enter into force by 2029.

107. Under the proposed European Chemicals Agency restrictions, time-limited use-specific derogations are being considered. Several uses relevant to the Montreal Protocol are proposed for derogation or potential derogation from the proposed restrictions for periods of 5 or 12 years after entry into force, including pressurized metered-dose inhalers (pMDIs), refrigeration, air conditioning, foam insulation, fire protection, technical aerosols, laboratory and analytical uses, precision cleaning and semiconductor manufacturing.

108. Under the Stockholm Convention on Persistent Organic Pollutants, which aims to eliminate or restrict the production and use of persistent organic pollutants, some jurisdictions (e.g., China and Japan) restrict certain PFAS that are specifically listed in the Convention. Actions taken in Canada and the United States of America at both the national and subnational level are also outlined in the report.

109. In the fire suppression sector, agents used as halon alternatives, such as HFCs (except for HFC-23), and the low-GWP alternatives 2-BTP and FK-5-1-12 are all proposed for classification as PFAS. In contrast, current fire suppression agents controlled under the Montreal Protocol, such as ozone-depleting halons and high-GWP HFC-23, would not be considered PFAS. As all known candidate substitutes have already been researched, discovering zero-ODP, low-GWP and non-PFAS alternatives is highly unlikely. Given these factors, there is little to no financial incentive for companies to invest in the research and development of potential new fire suppression agents.

110. In the foam sector, some companies and other stakeholders have reported that they are delaying decisions regarding the selection of alternatives owing to concerns about how the fluorinated alternatives might be limited as a result of proposed regulations. The limitation of mainstream uses of fluorinated gases could have wider implications for investment in HFOs and HCFOs going forward.

111. In the medical and chemicals sector, controlled substances and their technically and economically feasible alternatives used in aerosols, pMDIs, solvents, electronic manufacturing and

magnesium production could be affected by the broad-ranging definitions of PFAS and associated possible restrictions.

112. For pMDIs, propellants HFC-134a, HFC-227ea and HFO-1234ze(E), which are currently used, under development or being invested in, could be affected. The proposed ban 18 months after the entry into force of the restriction is seen as a potential obstacle to the transition of pMDIs from higher-GWP propellants to lower-GWP alternatives. While there were a limited number of derogations, they did not cover the use of HFC-134a, HFC-227ea or HFOs as propellants in pMDIs. This is leading to industry uncertainty that affects multi-million-dollar investments in drug development, and emerging industry concern about the uncertain future of existing products, manufacturing and plans to transition to lower-GWP alternatives. Industry is also concerned for the patients that rely on pMDIs for their asthma and chronic obstructive pulmonary disease treatment and about ensuring an uninterrupted global supply of essential medicine that is affordable and accessible.

113. Several industries with specialist uses of HFCs are also concerned about potentially closing off options where there are currently few alternatives with more suitable properties, such as in electronics manufacturing, magnesium production and precision cleaning for aerospace and military uses, where the remaining options could be continued use of, or a reversion to, substances with higher GWP.

114. In the refrigeration, air-conditioning and heat pumps sector, the proposed broad-range bans on PFAS could include the majority of fluorinated refrigerants used, with the only commonly used HFC refrigerant falling outside the PFAS definition being HFC-32. Such bans on the market would likely slow the uptake of low-GWP alternative refrigerants, limit the energy efficiency of medium-sized systems and slow the roll-out of heat pumps, which are much needed to decarbonize heating. These developments would likely lead to an increase in greenhouse gas emissions from this sector. Uncertainty created by the possible broad-ranging restrictions have spurred investigation of alternative technologies in several end uses in this sector.

115. The Panel also reiterates that one long-time manufacturer of several alternatives has announced its intention to cease production of chemicals falling under the PFAS definition by the end of 2025, owing to the rapidly evolving regulatory and business landscape. Some of those manufactured chemicals are currently used as alternatives to controlled substances in end uses, including solvent applications, semiconductor and electronics manufacturing and magnesium production. This development therefore has the potential to delay the transition to lower-GWP options in such applications.

Agenda item 7

Future availability of halons and their alternatives (UNEP/OzL.Pro.35/12, para. 159)

116. As mentioned in the note by the Secretariat (UNEP/OzL.Pro.WG.1/46/2, paras. 28–30), the Thirty-Fifth Meeting of the Parties discussed the issue of future availability of halons and their alternatives, taking into consideration the report provided by the Fire Suppression Technical Options Committee, set out in section 3 of volume 1 of the Panel's May 2022 progress report and its 2022 quadrennial assessment report. Recognizing that several of the issues raised in those reports deserved further consideration, parties agreed to include the item in the agenda of the current meeting.

117. In considering those issues, the parties may wish to take into account the information provided by the Fire Suppression Technical Options Committee in its 2024 progress report, set out in chapter 3 of, and annex 1 to, the 2024 progress report of the Technology and Economic Assessment Panel. The Committee's key messages are reproduced in annex II to the present addendum, without formal editing by the Secretariat.

118. The Open-ended Working Group may wish to discuss the issue of future availability of halons and their alternatives further and recommend a way forward, as appropriate.

Agenda item 8

Possible compliance deferral for Article 5, group 2 parties: technology review by the Technology and Economic Assessment Panel pursuant to paragraph 5 of decision XXVIII/2

119. Section 8 of the 2024 progress report sets out the Technology and Economic Assessment Panel's response to paragraph 5 of decision XXVIII/2 related to the phasing down of HFCs. In that paragraph, the Panel was requested to conduct a technology review 4 or 5 years before 2028 to

consider a compliance deferral of 2 years from the freeze date of 2028 for Article 5, group 2, parties to address growth above a certain threshold in relevant sectors.

120. Under the Kigali Amendment on phasing down HFCs, Article 5, group 2, parties[20] are required to freeze their production and consumption of HFCs in 2028 at their baseline levels, calculated for the period 2024–2026, and start their phase-down schedule with a 10 per cent reduction from their respective baseline levels in 2032 to an eventual 85 per cent reduction in 2047.

121. The information provided by the Panel is summarized in the following paragraphs.

122. The Panel's review builds on its response to paragraph 4 of decision XXVIII/2, set out in its 2022 report,[21] in which the Panel was requested to conduct periodic reviews of alternatives, using the criteria set out in paragraph 1 (a) of decision XXVI/9, in 2022 and every 5 years thereafter, and to provide technological and economic assessments of the latest available and emerging alternatives to HFCs. The criteria referred to in the decision included whether alternatives were commercially available; technically proven; environmentally sound; economically viable and cost effective; safe to use in areas with high urban densities, considering flammability and toxicity issues; and easy to service and maintain. In decision XXVI/9, the Panel was also requested to describe the potential limitations of the use of such alternatives.

123. While the Panel's 2022 report focused on the global status of HFC alternatives in key sectors (foam; fire suppression; medical and chemical uses; refrigeration, air conditioning and heat pumps), the current technical review focuses on the status of those alternatives in the same sectors but for Article 5, group 2, parties. Updates are provided mainly on the refrigeration, air conditioning and heat pumps sector as, according to the Panel, information on the other sectors is essentially unchanged from its 2022 review.

124. The technical review considers the status of progress in the uptake of lower-GWP refrigerants by Article 5 parties, including Article 5, group 2, parties, and the development of standards for refrigerants and refrigeration and air conditioning equipment since the adoption of decision XXVIII/2 in 2016, some of which have been adopted by Article 5, group 2, parties. The report also includes information on technology conversion, with examples of relevant demonstration and investment projects approved since 2016 by the Multilateral Fund for Article 5, group 2, parties, along with a list of planned activities for those parties included in the adjusted consolidated business plan of the Multilateral Fund for the period 2024–2026.

125. For the refrigeration, air conditioning and heat pumps sector, the Panel states that the information on alternatives remains essentially the same as reported in its September 2022 report. With respect to the criteria for its technical review of the sector, the Panel notes that the only distinguishing criterion for accessibility in Article 5, group 2, parties is whether refrigerants are technically proven. In the light of this consideration, the respective tables of the September 2022 report for the sector have been reviewed and reconstructed to list the applications for each category of product and address the technically proven and globally available alternatives. The information is then presented by listing the accessibility of alternatives for Article 5, group 2, parties, as well as the degree of accessibility in terms of limited use, growing use or widespread use.

126. In the foam sector, an update provided in the report with potential impact for all parties including those in Article 5, group 2, concerns HFC-365mfc, which has been reported to be no longer commercially available after production ceased in September 2023.

127. In the fire suppression sector, updated information is provided for two alternatives: FK-5-1-12 and water mist. Overall, the technical review shows that Article 5, group 2, parties face the same concerns as group 1 parties when it comes to the use of lower-GWP alternatives for fire suppression.

128. Finally, in the case of medical and chemical uses, the Panel again refers to the information in its September 2022 report, noting that Article 5, group 2, parties face the same specific concerns as group 1 parties regarding lower-GWP alternatives for such uses.

129. The Open-ended Working Group may wish to consider the report and recommend a way forward.

[20] Bahrain, India, the Islamic Republic of Iran, Iraq, Kuwait, Oman, Pakistan, Qatar, Saudi Arabia and the United Arab Emirates.

[21] "Volume 5: Decision XXVIII/2 TEAP Working Group Report: Information on Alternatives to HFCs" (Sept. 2022).

Annex I*

Decision XXXV/11 task force report on life-cycle refrigerant management

Key findings

Within the limited timeframe for developing this report, the Task Force was able to draw a number of key findings, which were condensed to emphasize the multifaceted nature of LRM challenges and opportunities, while at the same time highlighting current efforts and policy frameworks which have been put in place to address LRM effectively.

1. Leakage Prevention and Design Considerations

- Effective leakage prevention is integral to LRM and encompasses all stages of the equipment life cycle from equipment design to proper disposal: it requires early actions at the design stage, proper leakage testing during manufacturing and good practices during installation, operation, and maintenance.
- Avoiding venting and leakage of refrigerant during maintenance or at EOL will reduce ODS and GHG emissions from RACHP equipment.
- There are needs for (a) comprehensive training, (b) accessibility to equipment such as appropriate leakage detection methods and (c) regulatory regimes that promote regular RACHP equipment tightness inspection and repair.
- Leak prevention during the operational phase of RACHP equipment lifecycle can maintain performance and energy savings.

2. Refrigerant Recovery

- Effective refrigerant recovery is an essential aspect of ODS and GHG emission reduction from RACHP equipment, and a pre-requisite for reuse or destruction.
- Effective refrigerant recovery requires (a) comprehensive and ongoing technician training, (b) access to appropriate equipment, in particular specialized refrigerant recovery machines, (c) availability of sufficient technician time to ensure good recovery to take place (d) a “reverse supply chain infrastructure” providing technicians access to refrigerant recovery cylinders, and (e) appropriate economic incentives to encourage responsible recovery.
- Ensuring refrigerant recovery during servicing and at equipment EOL for either reuse or destruction, continues to be challenging in most A5 and non-A5 parties, even in parties where policy frameworks have been established and financial support has been made available.
- The drivers that would incentivise the increased recovery rates and leak prevention are highly sensitive to the regulatory environment and to refrigerant prices and availability of alternative technologies. If phasedown of HFCs creates a shortage of refrigerant and leads to price increases, then refrigerant recovery may increase. However, if supply of newly produced refrigerant remains plentiful, other policy and economic measures may be required to incentivise effective recovery.
- Financial support may increase access to recovery equipment and reverse supply chain infrastructure (e.g. cylinder fleets, storage facilities and safe shipping capability) to provide for additional refrigerant reuse or destruction.
- The cost effectiveness of refrigerant recovery has not been fully assessed, as the limited schedule for delivery of this report did not allow for a full evaluation of reverse supply chain costs, especially for LVCs. Additional data would help to develop an assessment of cost effectiveness.

* The annex has not been formally edited.

3. Refrigerant Reuse and Destruction

- In order to maximise the ODS and GHG emission reductions from refrigerant recovery, it is essential that recovered refrigerants in cylinders are either reused or destroyed and not emitted to the atmosphere.
- Recovered refrigerant can be reused as either (a) recycled or (b) reclaimed. The Montreal Protocol definition relates to the degree of purification, with recycled refrigerant undergoing simple cleaning whereas reclaimed is processed to a specified purity standard.
- Reused refrigerant does not count towards consumption targets under the Montreal Protocol; hence reuse can be used as a tool to achieve compliance.
- The market for reused refrigerant under a phasedown or phaseout scenario depends on several factors, including (a) the size and accessibility to the bank of refrigerant in installed RACHP systems, (b) the historical success of technical, economic and policy drivers towards recovery and reuse (c) the cost and availability of lower global warming potential (GWP) or zero ODP alternative technologies and (d) the difference between allowable virgin refrigerant supply relative to demand, which impacts refrigerant price.
- Appropriate testing and identification of recovered refrigerants are essential to ensure safe handling, including for destruction.
- Refrigerant recycling equipment is accessible and is used in many parties, especially for single component refrigerants, with technicians able to perform recycling locally.
- Infrastructure needed for refrigerant reclaim can be capital intensive (i.e., requiring sophisticated separation and testing technologies) and is limited in many A5 parties.
- Recovery, and subsequent reuse is highest in markets that allow for direct recycling with little change of ownership (e.g., auto industry recycling in maintenance garages and commercial refrigeration end-users with multiple pieces of equipment), likely because recycling allows for the simplest processing and lowest cost.
- To minimise emissions, refrigerants that are deemed too contaminated to re-use or for which there is low or nil market demand should be destroyed. For destroyed refrigerants to be accounted for under the definition of consumption, they must be destroyed using Montreal Protocol approved technologies. These are not always accessible in A5 parties. LVCs may have least access to destruction technologies. Some parties mandate that Montreal Protocol approved technologies be used for any refrigerant destruction, regardless of consumption accounting.
- The development of a market for end-of-life management of refrigerants is a driver for incremental improvements in destruction technologies. This opportunity will be dependent on the timely acceleration and effectiveness of LRM, HCFC phaseout and HFC phasedown generally as well as the availability of funding mechanisms to support the management of these legacy waste streams.

4. Disparity in infrastructure and accessibility

- The installed bank of controlled substances is currently dominant in non-A5 parties. In the future, however, there is a high probability that these banks become dominant in A5 parties due to RACHP growth. Fostering LRM capacity development in A5 parties, especially in larger industrialised ones, could represent substantial and sustained environmental benefits beyond 2030.
- In some parties, LRM practices have so far achieved modest success. In addition, most A5 parties and especially LVCs have inadequate access to the reverse supply chains, tools and equipment required for LRM.
- The lack of accessibility of recovery and recycling equipment and tools is more pronounced in A5 parties, especially in LVCs, which rely heavily on ongoing external funding, mainly from the MLF. It should be noted that in addition, there are also gaps in accessibility in non-A5 parties.
- Refrigerant reclamation and destruction are especially limited in LVCs and servicing-only regions with insufficient infrastructure or expertise to manage used

refrigerants, as a lack of economy of scale make both the capital and running costs uneconomic.

- There is a technology accessibility gap between smaller and larger A5 parties. Smaller A5 parties still need to establish fundamental servicing infrastructure, and also may require access to more advanced LRM technologies. In contrast, larger industrialised A5 parties tend to have more developed infrastructure, but often require upgrades or replacements for their existing tools and equipment to maximise LRM.
- Significant benefits could arise from A5 parties working together in regional groups to set up reclaim and destruction infrastructure. It should be noted that recovered refrigerants subject to a transboundary movement for the purpose of disposal may be classified by some Parties to the Basel Convention as hazardous wastes controlled by that Convention.

5. Policy Framework and Capacity Building

- LRM policy enforcement is challenging due to the sheer number of end-users, distributors, and independent contractors that are responsible for leak prevention, refrigerant recovery, recycling and reverse supply chains for destruction and reclamation.
- Various mandatory and voluntary LRM policies and programmes are currently implemented in many parties. Effective LRM necessitates stakeholder support and sufficient capacity, particularly when developing reverse supply chain infrastructure and technician training to manage refrigerants effectively throughout their lifecycle. This is less available in A5 parties.
- The greatest impact on effective LRM is the ease of availability and price of newly produced (virgin) refrigerant. Higher prices for refrigerants create economic incentives for leak prevention and refrigerant recovery and reuse. However high prices may also increase the risk of illegal refrigerant production and trade.
- Additional factors to consider in policies and programmes include complementary policies related to safety and the safe handling/transportation of refrigerants.

6. Barriers, Incentives and Financing Mechanisms

- Lack of consistent policy mandates and enforcement and fluctuating refrigerant pricing of newly produced (virgin) refrigerants make it difficult for reclamation and destruction companies to justify capital investment to support recovery, recycling reclamation and destruction, as well as to fund reverse supply chain infrastructure (e.g., cylinder fleets), even in non-A5 parties.
- Effective implementation of LRM requires comprehensive assessment of the overall costs associated with purchasing, operating, maintaining, and disposing of refrigerants throughout their life cycle. LRM costs could represent a significant economic investment for contractors, end-users, destruction, and reclaim facilities in both A5 and non-A5 parties.
- Expanding current financing mechanisms, including utilising carbon markets and creating innovative ones plus enacting policy changes, may reduce cost challenges linked to implementing LRM, especially in A5 parties.

7. Data Collection and Decision-Making

- Establishing a data collection system could inform decision-making for HFC phasedown initiatives and optimal LRM strategies. Tracking HFC usage by country, sector, and substance provides crucial insights for cost-effective policy development and operational implementation.

8. Ozone and Climate Benefits and Future Outlook

- Ozone benefits:
  Implementing effective LRM practices during the use and end-of-life of RACHP equipment is projected to cut HCFC emissions by about 5 kt ODP between 2025 and 2040.
- Climate benefits:
  Implementing effective LRM practices during the use and end-of-life of RACHP equipment is projected to cut HFC and HCFC emissions by about 39 Gt CO2e between 2025 and 2050. This would achieve substantial additional climate benefits beyond those currently anticipated from the HFC phasedown agreed under the Kigali Amendment to the Montreal Protocol.

Overall conclusions

LRM minimises refrigerant emissions from RACHP equipment and systems. This report aims to provide a comprehensive overview of challenges, opportunities, and strategies for effective LRM, to provide stakeholders with the necessary knowledge to minimise refrigerant emissions as far as possible. In many parts of the world this will require a technical, policy and behavioural shift away from venting refrigerants.

- This first TEAP LRM Task Force Report emphasizes the critical importance of responsible refrigerant management to minimise emissions, alongside phasing out ODS and phasing down HFCs in increasingly energy efficient RACHP equipment.
- LRM can increase available refrigerant supply, especially for servicing-only parties that have less flexibility in their approach to phasing out or phasing down refrigerant consumption. Effective leakage prevention and refrigerant reuse provide additional tools to reduce the production and consumption for parties, which can assist with Montreal Protocol compliance.
- In the long term, the Kigali Amendment will facilitate a phasedown of high GWP HFC refrigerants. However, in the near- and medium-term there may be a build-up of HFCs in banks in A5 parties (both in RACHP equipment and HFCs for servicing) due to the overall rise in cooling demand in advance of technology transfer to lower GWP alternatives. The phasedown regimes in some A5 parties will ensure a continued market for HFC refrigerants for new RACHP equipment and for servicing. As a result, inexpensive new HFCs may be available in A5 parties, and HFC banks will inevitably build up.
- LRM strategies can help to minimise HFC emissions and make more refrigerant available through reuse, especially for A5 parties. LRM can include refrigerant venting prohibitions, leak prevention strategies, and establishing the reverse supply chain and infrastructure to maximise refrigerant recovery, prior to recycling, reclamation and destruction as appropriate.
- In non-A5 Parties, HFC consumption and production is rapidly phasing down in accordance with F-gas regulations and the Kigali phasedown schedule. In many A5 parties the HFC consumption and production phasedown schedules started from 2024, with some others starting in 2028.
- If phasedown of HFCs creates a shortage of refrigerant and leads to price increases, then refrigerant recovery may increase. However, if supply of newly produced refrigerant remains plentiful, other policy and economic measures may be required to incentivise effective recovery.

Annex II*

Technology and Economic Assessment Panel 2024 Progress Report (volume 1)

Key messages from Technical Options Committees

Key messages arising from TOC progress reports are presented in this section.

Flexible and Rigid Foams Technical Options Committee (FTOC)

Insulation demand and subsequent foam blowing agent (FBA) demand continues to increase to reduce energy demand and for other uses. Regulations are driving transitions away from high global warming potential (GWP) hydrofluorocarbons (HFCs) in non-A5 parties, and hydrochlorofluorocarbons (HCFCs) in Article 5 (A5) parties, with emphasis on avoiding adoption of high-GWP HFCs where possible.

Shortages of fluorinated and non-fluorinated (e.g., pentanes) lower GWP FBAs have improved in both A5 and non-A5 parties. As a result of the previous shortages, there had been a significant increase in the use of higher GWP HFCs blends in some A5 parties and a reversion to HFCs in some non-A5 parties, where lower GWP alternatives are not available.

The transition away from ozone-depleting FBAs and/or high-GWP HFC FBAs in some regions and market segments (e.g., spray foam and extruded polystyrene [XPS]) has been delayed because of increased costs of FBAs, as well as additional safety requirements, especially where local codes require higher thermal performance. Significant resources are spent by foam manufacturers in optimising the characteristics and costs of new FBAs and foam systems through optimising blends with new additives. The new FBA additives or co-blowing agents have different toxicity and thermal properties that can result in handling challenges and lower thermal performance of insulation.

It is possible that consolidation among foam manufacturing companies will occur during the phase-out of HCFC blowing agents in A5 parties, as it did in non-A5 parties.

Fire Suppression Technical Options Committee (FSTOC)

The FSTOC is not aware of any new alternatives to halons, HCFCs or high-GWP HFCs under development since the last published progress report. Furthermore, the FSTOC understands the low-GWP blend in-kind total-flooding Halon 1301 replacement agent that was in the process of being commercialised is no longer being developed, owing to commercial and/or per- and polyfluoroalkyl substances (PFAS) considerations.

FSTOC is not aware of any shortage of Halons 1211 or 2402. For Halon 1301, the global availability continues to be a concern of the FSTOC. Discussions with industry stakeholders frequently indicate the mistaken belief that the Montreal Protocol bans the use of halons globally. The FSTOC is continually reinforcing the message that only production and consumption of newly manufactured halons for fire suppression are banned. Additionally, it has been reported to the FSTOC that misapplication and/or local regulations can prohibit or hinder the transboundary shipment of recovered/recycled/reclaimed Halon 1301. These misunderstandings can be linked to a “loss of institutional memory” that the FSTOC has been highlighting for several years which needs to be addressed.

In some instances, this misunderstanding and misapplication of the intent of the Protocol, may be leading to the destruction of halons (especially Halon 1301). The deliberate destruction of Halon 1301 for carbon credits by commercial entities and/or governments, if it becomes a widespread practice, has the potential to significantly reduce the amount of the available Halon 1301, thereby bringing the run-out date closer to 2030.

In light of the above, parties may wish to consider means of strengthening or reinforcing the correct intention of the Montreal Protocol by:

Reinforcing the message that it is only production and consumption of newly manufactured halons that was banned and not the use of halons;

* The annex has not been formally edited.

Facilitating the transboundary shipments of recovered halons for recycling/reclamation in another party that has those capabilities; and

Discouraging parties from destroying halons unless they cannot be reclaimed to an acceptable purity.

The following factors could affect the run-out date:

- The continued uncertainty surrounding the PFAS regulations is delaying or even stopping development of, or transition to, low-GWP alternatives to halons or high-GWP HFCs. Delaying transition to alternatives will prolong reliance on Halon 1301 to support enduring uses, for example, civil aviation, nuclear power plants and the oil and gas sector. This in turn would lead to an earlier runout date. This may also affect parties' compliance to the Kigali Amendment, if transition to lower GWP fire suppressants is an important part of their strategy.
- As global emissions continue to deplete the available Halon 1301 bank (that is, Halon 1301 being used in non-enduring uses, such as computer room, ships, etc.), the relative proportions of the bank that is unavailable (the proportion of the bank that is deployed in or supporting enduring uses, e.g., oil & gas, military, nuclear power plants, etc.) inevitably becomes larger. Logically, in the future, the available bank will be depleted to zero, and even though the unavailable bank (supporting enduring uses) will have significant reserves of Halon 1301, it is likely that there will be requests for Essential Use Nominations.
- As reported in the TEAP 2023 Progress Report, the unexplained temporary increases in emissions of Halon 1301 derived from atmospheric measurements continue to concern the FSTOC. The FSTOC has tried, but has been unsuccessful, in linking these unexplained temporary increases in emissions to the fire suppression bank or use. Since it is known that Halon 1301 is produced as a feedstock for Fipronil and some pharmaceuticals, the FSTOC is hypothesising that these unexplained temporary increases in emissions in Halon 1301 are somehow related to its feedstock production and use. Additional information is provided in Annex 1. The FSTOC seeks more information on emissions from production and use of Halon 1301 for feedstock.

Parties may wish to consider providing information on emissions from production and feedstock use of Halon 1301 to the Ozone Secretariat for confidential use by the TEAP in its assessment.

Methyl Bromide Technical Options Committee (MBTOC)

The phase out of over 60,000 tonnes of non-quarantine and pre-shipment (non-QPS) use of methyl bromide (MB) marks a very significant milestone for the Montreal Protocol as MB was once considered to be an essential fumigant for controlling soil borne diseases and pests impacting production of high value horticultural crops and for controlling pests attacking stored commodities and structures.

The reduction in this anthropogenic MB use to date is also a great outcome for ozone layer recovery as MB is short lived in the atmosphere (0.7 years) and the benefit of any reduction is very quickly felt in the atmosphere.

The phaseout has been underpinned more recently by the large reduction in critical use nomination (CUN) requests for MB declining from requests for 18,600 tonnes in 2005 to just 3 tonnes for 2025. However, concern exists that a significant amount of MB is still being used for non-QPS uses either via diversion from current production for QPS purposes or through incorrect classification of uses as QPS.

As approximately 9,000 tonnes of MB is annually used for QPS uses, the MBTOC report focuses on use of MB for QPS applications currently exempted from phaseout guidelines under the Montreal Protocol. It concentrates on the feasible alternatives for replacing this use, including challenges hindering the adoption of such alternatives.

Global MB **production** for QPS uses has decreased slightly in recent years, from 10,400 tonnes in 2021 to 8,865 tonnes in 2022. While most parties show downward trends, India exhibits a continuing rise in MB production.

Global MB **consumption** for QPS uses has reportedly declined in 2022, reaching 7,526.2 tonnes down from 10,395 tonnes in 2021, although large fluctuations are common with QPS data reported in the past.

When considered over a longer term (i.e., the past 7 years (2016-2022)), there is a surplus of MB produced for QPS compared to that reported for consumption by a total of 3,620 tonnes.

Noted findings in changes in consumption of MB for QPS include: a significant increase in Uruguay; a dramatic drop in New Zealand; unclear reporting from OIRSA (the International Regional Organism for Animal and Plant Health) member parties in Central America.

A lack of sector breakdown for QPS uses makes it difficult for MBTOC to assess the suitability of alternatives for such uses. In particular the correct classification of uses as pre-shipment (i.e., cosmopolitan pests) or quarantine uses (exotic pests) is a key issue for determining the suitability of an alternative.

As evidence demonstrates that alternatives exist for most pre-shipment uses, parties may want to consider a revision of the recategorization of QPS to only allow consideration of the use of MB for quarantine purposes (i.e. against a quarantine pest) only.

The MBTOC report also provides updates on new registrations of effective alternatives to MB for some QPS applications in a range of parties, as well as research and development of promising alternatives like ethane dinitrile (EDN), hydrogen cyanide (HCN), ethyl formate (eFume), methyl iodide and technologies not requiring registration such as microwave technology for soils. Registration of EDN, a key alternative to replace QPS MB use for timber treatments, has been achieved in many parties.

MB has been recommended for listing under Annex III of the Rotterdam Convention, subjecting it to the Prior Informed Consent (PIC) procedure. If approved, this will add another layer of control over international trade of MB. A final decision will be made in 2025.

The report further analyses the changing scene for existing alternatives: controlled atmosphere treatments are emerging for control of the Khapra beetle; the European Union (EU) has stricter regulations on sulfurylfluoride use and is now requiring measures to minimise release of emitted gas using recapture and others; Japan is considering expanding registration of methyl iodide for other products traded for QPS.

Medical and Chemical Technical Options Committee (MCTOC)[1]

Updates on metered dose inhalers and other aerosols

Pressurised metered dose inhalers (pMDIs), dry powder inhalers (DPIs), aqueous soft mist inhalers (SMIs), and other delivery systems such as nebulisers all play a role in the treatment of asthma and chronic obstructive pulmonary disease (COPD).

The development of lower-GWP pMDIs is progressing, though a range of potential challenges are emerging that could risk the consistent supply of affordable medicines. These challenges were discussed in the 2022 MCTOC Assessment Report and 2023 TEAP Progress Report, with further updates given here.

MCTOC understands that there may be ten or more companies globally with active programmes to develop pMDIs containing lower GWP propellants involving two lower GWP propellants (HFC-152a GWP-100 164 (AR6), 124 (AR4); and HFO-1234ze(E) GWP-100 1.37 (AR6)). Generic pMDI manufacturers are also developing lower GWP pMDIs, including in A5 parties. Development is a complex process involving new ways of manufacturing, new clinical trials, and new regulatory approvals.

Three manufacturers have registered clinical studies for three inhalers, involving the two lower GWP propellants and two classes of therapy. These are due to complete in 2025. Allowing time for the subsequent regulatory submissions and approvals, the first lower GWP pMDIs may not reach the market until 2026. Many classes of inhaled therapies have yet to enter clinical trials. The European Medicines Agency has issued guidance on the transition to new propellants, but in other markets, such as the United States, no formal guidance is available.

The 2024 update to EU F-gas regulations accelerates the phase-down of HFCs currently in use in pMDIs; HFC-152a is also scheduled to be phased out by 2050 (unless exemptions for critical use are added). European Chemicals Agency (ECHA) draft regulations for the control of PFAS would, in their current form, ban the use of HFC-134a, HFC-227ea, and HFO-12Ie(E). It is likely that the price of bulk HFC propellant currently used in pMDI will increase as quotas for non-pharmaceutical uses tighten. There has already been a significant increase in the price of HFC-227ea, and it is likely that

[1] The key messages of the response of the Medical and Chemical Technical Options Committee to decisions XXXV/6 on very short-lived substances, XXXV/8 on feedstock uses and XXXV/9 on abating emissions of carbon tetrachloride are set out under agenda 3 of the present addendum (paras. 5–37).

HFC-134a will follow when the next major drop in HFC production for non-A5 parties comes into effect in 2025. This may make some HFC pMDIs less attractive to manufacture from a commercial standpoint.

Although the Kigali Amendment allows A5 parties longer to phase down HFCs, global legislation and corporate policies of major pharmaceutical companies may accelerate the introduction of lower GWP pMDIs in A5 parties well before their scheduled phase down timeline. Pharmaceutical companies may market their lower GWP pMDIs globally at the earliest opportunity, rather than latest. This could potentially mean lower GWP pMDIs are available in Article 5 parties from 2026 onwards. The reduction in use of HFCs in Europe/United States may lead to security of supply and commercial pricing concerns for A5 parties, including India.

The price of some new lower GWP pMDIs will increase as a result of the capital investment, research and development, and increased cost of propellants and valves. It is not clear that there is sufficient manufacturing capacity in the industry for DPIs to make up any shortfall in supply if current pMDI products are withdrawn from the market.

Some international and national respiratory guidelines recommend considering environmental impact as part of inhaler choice and combination inhalers for asthma and COPD treatment. Prioritising combination inhalers could reduce the total number of inhalers needed, and potentially increase uptake of DPIs in some parties. Many patients, especially in low- and middle-income parties, have very limited access to affordable inhalers.

The non-pMDI aerosol market continues to evolve with improvements in aerosol valve technology allowing for effective use of some non-HFC propellants (such as nitrogen and compressed air) in more applications. Liquified petroleum gas (LPG) and dimethyl ether propellants dominate in Europe and Asia.

In the United States, HFC-134a has almost disappeared in aerosol production (less than 1000 tonnes) with the exception of a handful of specialised exempt products (excluding pMDIs). HFO-1234ze has been the primary replacement for HFC-134a; there is modest but constant growth in this propellant category. HFC-152a continues to be the most commonly used propellant in personal care, usually blended with the LPG propellant to control cost and vapour pressure.

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

In residential, commercial, and industrial refrigeration applications, refrigerant options with GWP <30 and <150 and corresponding technologies are known and available.

The air-conditioning and heat pump applications have good technology options with refrigerant GWP <700, but the options with GWP <30 are limited and hurdles (safety and performance) for their widescale adoption persist.

Accessibility to some new refrigerants and technologies is a challenge in several A5 and even some non-A5 parties.

Safety standards for all applications continue to be updated and improved with increased charge size of flammable refrigerant allowed. Awareness, education, training and certification for the safe use of flammable refrigerants continues to be important and requires additional support and attention for greater adoption of the new refrigerants.

Technologies to improve energy efficiency (EE) are well known in all applications, but technical challenges remain to balance the GWP and safety needs while increasing EE, especially in air-conditioning and heat pump applications.

Globally, the lack of clarity around potential PFAS regulations has caused some uncertainty around refrigerant and equipment choices in several applications; this may slow progress towards Kigali Amendment compliance.

Annex III*

Members of the Technology and Economic Assessment Panel technical options committees whose membership expires at the end of 2024 and whose reappointment does not require a decision by the Meeting of the Parties

Name	*Position*	*Country*
Members of technical options committees		
Paul Ashford	FTOC member	United Kingdom
Gwyn Davis	FTOC member	United Kingdom
Mohammed Jana Alam	FSTOC member	Bangladesh
Laura Green	FSTOC member	United States
Elvira Nigido	FSTOC member	Australia
Erik Pedersen	FSTOC member	Denmark
Inderpal Singh Kanwal	FSTOC member	India
R.P. Singh	FSTOC member	India
Mitsuru Yagi	FSTOC member	Japan
Jonathan Banks	MBTOC member	Australia
Guillermo Castellá	MBTOC member	Uruguay
Jordi Riudavets	MBTOC member	Spain
Akio Tateya	MBTOC member	Japan
Andrea Casazza	MCTOC member	Italy
Ryan Hulse	MCTOC member	United States
Fang Jin	MCTOC member	China
Andrew Lindley	MCTOC member	United Kingdom
John G. Owens	MCTOC member	United States
Gerallt Williams	MCTOC member	United Kingdom
Ghina Annan	RTOC member	Lebanon
Jitendra Bhambure	RTOC member	India
Maria C. Britto Bacellar	RTOC member	Brazil
Feng Cao	RTOC member	China
Ana Maria Carreño	RTOC member	Colombia
Radim Čermák	RTOC member	Czechia
Yu Chen	RTOC member	United States
Daniel Colbourne	RTOC member	United Kingdom
Sukumar Devotta	RTOC member	India
Hilde Dhont	RTOC member	Belgium
Gabrielle Dreyfus	RTOC member	United States
Bassam Elassaad	RTOC member	Lebanon
Kylie Farrelley	RTOC member	Australia
Qiang Gao	RTOC member	China
Ray Gluckman	RTOC member	United Kingdom
Samir Hamed	RTOC member	Jordan

* The annex has not been formally edited.

Name	*Position*	*Country*
Herlin Herlianika	RTOC member	Indonesia
Yuki Kamioka	RTOC member	Japan
Michael Kauffeld	RTOC member	Germany
Mary Koban	RTOC member	United States
Juergen Kohler	RTOC member	Germany
Steve Kujak	RTOC member	United States
Lambert Kuijpers	RTOC member	Netherlands (Kingdom of the)
Richard Lawton	RTOC member	United Kingdom
Tingxun Li	RTOC member	China
Carloandrea Malvicino	RTOC member	Italy
Mary Najjuma	RTOC member	Uganda
Petter Nekså	RTOC member	Norway
M. Alaa Olama	RTOC member	Egypt
Tetsuji Okada	RTOC member	Japan
Pallav Purohit	RTOC member	India
Madi Sakande	RTOC member	Burkina Faso
Tao Ren	RTOC member	China
Giorgio Rusignuolo	RTOC member	United States
Leyla Sayin	RTOC member	Turkey
Nihar Shah	RTOC member	India
Andrea Voigt	RTOC member	Germany
Asbjørn L. Vonsild	RTOC member	Denmark
Christian M. Wisniewski	RTOC member	United States
Samuel Yana Motta	RTOC member	Peru

Abbreviations: FTOC – Flexible and Rigid Foams Technical Options Committee; FSTOC – Fire Suppression Technical Options Committee; MBTOC – Methyl Bromide Technical Options Committee; MCTOC – Medical and Chemicals Technical Options Committee; RTOC – Refrigeration, Air-Conditioning and Heat Pumps Technical Options Committee.

Annex IV*

Matrix of expertise needed by the Technology and Economic Assessment Panel as at May 2024

Body	Required Expertise	Article 5/ Non-Article 5
Senior Experts	Experts with extensive experience on TEAP technical and economic assessments, especially sector transitions and challenges in A5 parties; extensive knowledge and experience of Multilateral Fund (MLF) decisions, guidelines, operations, and related funding to meet financial needs of A5 parties under the ODS phase-out and HFC phase-down. Expert in the analysis and assessment (including modelling) of factors, including energy efficiency and regional economics, for forecasting the market penetration and potential future disposition of HCFCs, HFCs, and alternatives	Article 5 or non-Article 5
Foam TOC	Experts in extruded polystyrene production in India and China	Article 5
	Polyurethane system house technical experts (especially from small and medium enterprises)	Article 5 from southern Africa, the Middle East, Southeast Asia, or Mexico
Fire Suppression TOC	Use of HFCs and Alternatives	South America, Middle East and Africa (2)
	Use of halons and alternatives in merchant shipping and recovery from shipbreaking	India, Pakistan
	Nuclear power plants	Article 5 and non-Article 5
	Civil Aviation, (esp. Maintenance, Repair and Overhaul activities)	Article 5 and non-Article 5
	Halon and HFC recycling	Article 5 and non-Article 5
	Halon 1301 feedstock use and emissions	Article 5 and non-Article 5
Methyl Bromide TOC	QPS uses of MB and their alternatives particularly SE Asia	Article 5
	Alternatives to QPS uses of MB adopted in Europe	Non-Article 5
	Members with expertise in disinfestation of agricultural produce and bilateral trade agreements and links to the Technical Panel on Phytosanitary treatments Committee (TPPT) and the International Plant Protection Convention.	Non-Article 5 or Article 5
	Nursery industries, especially issues affecting the strawberry runner industries globally	Article 5 or non-Article 5
Medical and Chemical TOC	Aerosols manufacturing	China, Indonesia, Latin America
	CTC and VSLS global manufacturing and use	Article 5 or non-Article 5
	Semiconductor and other electronics manufacturing	East Asia, non- Article 5
	End-of-life management and destruction technologies	Article 5 and non-Article 5
	Metered dose inhalers	Article 5 and non-Article 5
Refrigeration, Air Conditioning and Heat Pumps TOC	Experts with extensive experience on Industrial Refrigeration, both for the food and pharma cold-chain and for other industrial applications.	Article 5 and non-Article 5

Abbreviations: TOC − Technical Options Committee.

* The annex has not been formally edited.