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the Montreal Protocol on Substances
that Deplete the Ozone Layer**
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Issues for discussion by and information for the attention of the Thirty-First Meeting of the Parties to the Montreal Protocol

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 Thirty-First Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer (UNEP/OzL.Pro.31/2) contains information that has become available since the preparation of that note. The additional information is set out in section II of the addendum, which includes brief summaries of the issues addressed by the Technology and Economic Assessment Panel in its September 2019 report, information on safety standards for flammable, low-global-warming-potential (GWP) refrigerants, along with a nomination to the Panel received by the Secretariat, which is in addition to the two nominations indicated in the note by the Secretariat.

2. The September 2019 report of the Technology and Economic Assessment Panel consists of three volumes:¹

- (a) *Volume 1: Decision XXX/3 Task Force Report on Unexpected Emissions of Trichlorofluoromethane (CFC-11);*
- (b) *Volume 2: Evaluation of 2019 Critical-Use Nominations for Methyl Bromide;*
- (c) *Volume 3: Decision XXX/5 Task Force Final Report on Cost and Availability of Low-GWP Technologies/Equipment that Maintain/Enhance Energy Efficiency.*

II. Overview of items on the agenda for the Thirty-First Meeting of the Parties to the Montreal Protocol

A. Unexpected emissions of trichlorofluoromethane (CFC-11) (item 6 of the provisional agenda for the preparatory segment)

3. The note by the Secretariat (UNEP/OzL.Pro.31/2) outlines the manner in which the issue of unexpected emissions of CFC-11 was dealt with at the forty-first meeting of the Open-ended Working

¹ Available on the Ozone Secretariat meeting portal for the Thirty-First Meeting of the Parties at <http://conf.montreal-protocol.org/meeting/mop/mop-31/presession/default.aspx>.

Group, with regard to the implementation of decision XXX/3, adopted by the Thirtieth Meeting of the Parties, in November 2018 (UNEP/OzL.Pro.31/2, paras. 37–43).

4. In accordance with that decision, the Scientific Assessment Panel is expected to present to the Thirty-First Meeting of the Parties an update to the preliminary summary report it provided to the Open-ended Working Group at its forty-first meeting (see UNEP/OzL.Pro.WG.1/41/5, annex III, section I.A).

5. Following the Technology and Economic Assessment Panel's preliminary report of May 2019 on the unexpected emissions of CFC-11, prepared by the Panel's task force established for that purpose and presented at the forty-first meeting of the Open-ended Working Group,² the task force continued its in-depth analysis of potential sources of CFC-11 emissions and related substances. The full final report, set out as volume 1 of the September 2019 report of the Technology and Economic Assessment Panel, includes new information and updates, highlighted in grey, and is available on the meeting portal of the Thirty-First Meeting of the Parties.³ The executive summary of that report is reproduced in the annex to the present addendum, as received by the Secretariat, without formal editing. The main messages of the report are presented below:

(a) Based on modelling of CFC-11 production, usage and emissions and on comparison against atmospheric-derived emissions, it is unlikely that past production and historic usage can account for the unexpected CFC-11 emissions, including from existing foam banks.

(b) It is unlikely that there has been a resumption of newly produced CFC-11 usage in refrigeration and air-conditioning uses, flexible foams, aerosols, solvents, feedstock uses, tobacco expansion and other miscellaneous applications.

(c) It is likely that there has been a resumption of newly produced CFC-11 usage in closed-cell foams.

(d) There are a number of economic drivers that may have encouraged the reversion to CFC-11 in closed-cell or rigid foam, including price increases and reduced availability of HCFC-141b due to the global hydrochlorofluorocarbon (HCFC) phase-out. Reversion from HCFC-141b to CFC-11 can be made without technical difficulty.

(e) Based on modelling using reported CFC-11 production data, it seems that the expected emissions from the CFC-11 foam banks in Northeast Asia are insufficient to account for the atmospheric-derived emissions from eastern mainland China that were reported by Rigby and others.⁴

(f) Various parties imported up to 7,500 tonnes per year of HCFC-141b in foam systems. Foam systems could be mislabelled and used by a recipient without their knowing which blowing agent is in the system.

(g) The most likely modelling scenario predicts that 40,000 to 70,000 tonnes per year of CFC-11 production would have been required from 2012 onwards to account for the increased CFC-11 emissions.

(h) The most likely production routes are carbon tetrachloride (CTC) to CFC-11 on a micro-scale in plants using minimal equipment (to make low-grade CFC-11 for foam blowing use); and CTC to CFC-11/12 on a large scale in an existing liquid phase plant (HCFC-22 and/or HFC-32 plant).

(i) Between 45,000 and 120,000 tonnes of CTC would be required to supply between 40,000 and 70,000 tonnes of CFC-11 production, depending on the proportion of co-produced CFC-12. The CTC quantity required for CFC-11 production is expected to be at the lower end of the range if, as predicted, the objective is higher CFC-11 selectivity.⁵

² Technology and Economic Assessment Panel. *Volume 3: Decision XXX/3 TEAP Task Force Report on Unexpected Emissions of Trichlorofluoromethane (CFC-11)* (May 2019). Available at <http://conf.montreal-protocol.org/meeting/oewg/oewg-41/presession/SitePages/Home.aspx>.

³ Ibid. *Volume 1: Decision XXX/3 TEAP Task Force Report on Unexpected Emissions of Trichlorofluoromethane (CFC-11)* (September 2019). Available at <http://conf.montreal-protocol.org/meeting/mop/mop-31/presession/default.aspx>.

⁴ Rigby, M. and others. "Increase in CFC-11 emissions from eastern China based on atmospheric observations", *Nature*, vol. 569 (23 May 2019), pp. 546-550. Available at www.nature.com/articles/s41586-019-1193-4.pdf.

⁵ To achieve near 100 per cent CFC-11 production, and almost nil CFC-12 co-production, the range of CTC required would be close to 45,000 to 80,000 tonnes.

(j) The quantity of CFC-12 co-produced as a result of any CFC-11 production is dependent on the exact production option chosen and how the plant is set up and operated. With CFC-11 as the target chemical, for the most likely production routes, the range of CFC-12 co-production is between 0 and 30 per cent of total CFC-11/12 production.

6. The parties may wish to take into consideration the updates provided by the assessment panels during their deliberations on this matter.

B. Issues related to exemptions under Articles 2A–2I of the Montreal Protocol (item 8 (a) of the provisional agenda for the preparatory segment)

Nominations for critical-use exemptions for methyl bromide for 2020 and 2021 (item 6 (a) of the provisional agenda for the preparatory segment)

7. The Methyl Bromide Technical Options Committee evaluated a total of six nominations for critical-use exemptions that were submitted in 2019. Two Article 5 parties (Argentina and South Africa) submitted two nominations each for 2020, and two non-Article 5 parties (Australia and Canada) submitted one nomination each, for 2021 and 2020, respectively.

8. According to the Committee, the general reasons for seeking critical-use exemptions cited by nominating parties were related to environmental conditions and regulatory restrictions that did not allow for partial or full use of alternatives; difficulties in the scaling-up of alternatives; and the fact that potential alternatives were considered uneconomical, insufficiently effective and/or unavailable.

9. The Committee evaluated the nominations and presented its interim recommendations at the forty-first meeting of the Open-ended Working Group, during which bilateral discussions took place. Discussions continued thereafter between nominating parties and the Committee on the information needed for any re-evaluation of the nominations in order for the Committee to make final recommendations for consideration by the Thirty-First Meeting of the Parties. Two parties, Australia and Canada, requested the Committee to reassess their nominations on the basis of new information provided by those parties. That information showed that alternatives were either not available or had not been sufficiently evaluated to be adopted for use in relation to their nominations.

10. In the light of the above, the Committee prepared its final report,⁶ in which it recommended the full amounts nominated by Australia and Canada. The nominations put forward by Argentina and South Africa were reduced by the Committee to account for alternatives that were considered suitable, emissions reduction practices or the reduction of dosage rates required for methyl bromide.

11. The report of the Committee, containing detailed information on the final recommendations, is available on the meeting portal of the Thirty-First Meeting of the Parties. The final recommendations are outlined in table 1 below. The reasons given by the Committee for not recommending the full nominated amounts for some parties are summarized in the footnotes to the table, where relevant.

⁶ Technology and Economic Assessment Panel. *Volume 2: Evaluation of 2019 Critical-Use Nominations for Methyl Bromide* (September 2019). Available at <http://conf.montreal-protocol.org/meeting/mop/mop-31/presession/default.aspx>.

Table 1
Summary of the nominations for 2020 and 2021 critical-use exemptions for methyl bromide submitted in 2019 and of the final recommendations of the Methyl Bromide Technical Options Committee
(Metric tons)

<i>Party</i>	<i>Nomination for 2020</i>	<i>Final recommendation for 2020</i>	<i>Nomination for 2021</i>	<i>Final recommendation for 2021</i>
Non-Article 5 parties and sectors				
1. Australia				
Strawberry runners			28.98	[28.98]
2. Canada	5.261	[5.261]		
Strawberry runners				
Subtotal	5.261	[5.261]	28.98	[28.98]
Article 5 parties and sectors				
3. Argentina				
Tomato	22.20	[12.79] ^a		
Strawberry fruit	13.50	[7.83] ^b		
4. South Africa				
Mills	1.5	[0.30] ^c		
Structures	40.0	[34.0] ^d		
Subtotal	77.2	[54.92]		
Total	82.461	[60.181]	28.98	[28.98]

^a The nominated amount has been reduced by 42 per cent, based on a lower dosage rate (reduced from 26.0 to 15.0 g/m²) for the adoption of barrier films (e.g., totally impermeable films) for the treated area, which is 58 per cent of the 147 hectares (ha) nominated (147 ha x 58 per cent x 15 g/m²), in accordance with the standard presumptions of the Methyl Bromide Technical Options Committee.

^b The recommended amount, which represents a 42 per cent reduction from the amount nominated, includes 2.61 metric tons (t) for Mar del Plata (30 ha x 58 per cent x 15 g/m²) and 5.22 t for Lules (60 ha x 58 per cent x 15 g/m²). The dosage rate of 15 g/m² is based on the standard presumptions of the Methyl Bromide Technical Options Committee for the dosage rate needed for methyl bromide with virtually impermeable films or totally impermeable film and row treatments that make up 58 per cent of the field area.

^c The recommendation represents a reduction of 66 per cent from the approved amount of the critical-use exemption for 2019, and is for pest control in the three specific nominated mills. The reduction is based on a smaller number of treatments for each mill, with an amount of methyl bromide for only one fumigation per year at approximately 20 g/m³ (the standard presumption of the Methyl Bromide Technical Options Committee) considered sufficient. This is only a transitional measure to allow time for the adoption and optimization of alternatives in an integrated pest management system, with the phase-in of an alternative whole-site fumigant (e.g., sulfuryl fluoride), if desired.

^d The nominated amount has been reduced by 15 per cent to account for the uptake of heat, especially in attics or roof spaces, and for commercial treatments with sulfuryl fluoride following its registration in January 2018.

12. The Methyl Bromide Technical Options Committee noted in its report that it had not taken into consideration, in its recommendations for critical-use exemptions, stocks held by nominating parties; it had instead relied on parties to take such stocks into account when approving the amounts recommended by the Technology and Economic Assessment Panel for each nomination.

13. In addition to the final recommendations on parties' critical-use nominations, the report of the Methyl Bromide Technical Options Committee recalled the reporting requirements under relevant decisions and included 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. In brief, the total nominated amount has decreased from 18,700 metric tons in 2005 to 111.4 metric tons in 2020/2021, while the total amount requested in 2019 represents a 22 per cent reduction from that requested in 2018.

14. Based on the accounting frameworks received by three nominating parties in 2019, the stocks of methyl bromide at the end of 2018 were approximately 0.742 metric tons. The Committee reiterates, however, that the accounting information in the final report does not accurately show the stocks of methyl bromide held globally for controlled uses by Article 5 parties, since there is no requirement for parties to report pre-2015 stocks under the Montreal Protocol. According to the Committee, such stocks may be substantial (greater than 1,500 metric tons). More information about stocks is provided by the Methyl Bromide Technical Options Committee in section 1.2.7 of its

May 2019 report⁷ and may be considered by parties under item 8 (b) of the provisional agenda of the current meeting.⁸

15. The parties may wish to consider the final report and recommendations of the Methyl Bromide Technical Options Committee and adopt decisions on critical-use exemptions as appropriate.

C. Access of parties operating under paragraph 1 of Article 5 of the Montreal Protocol to energy-efficient technologies in the refrigeration, air-conditioning and heat-pump sectors (item 9 of the provisional agenda for the preparatory segment)

16. As indicated in the note by the Secretariat (UNEP/OzL.Pro.31/2, paras. 69–72), in response to decision XXX/5, the Technology and Economic Assessment Panel's task force on energy efficiency presented its May 2019 report on the cost and availability of low-GWP technologies and equipment that maintained or enhanced energy efficiency at the forty-first meeting of the Open-ended Working Group.⁹

17. During the ensuing discussion, the Working Group agreed that the Technology and Economic Assessment Panel should update its report with additional information, taking into account the comments made by parties, and present an updated report for consideration by the Thirty-First Meeting of the Parties. The additional elements several representatives wished to see addressed in the updated report included information regarding minimum energy performance standards and their relationship with high-efficiency equipment in different regions; energy-efficiency standards and their association with safety standards; the availability of technologies and related patented technologies; funding of energy-efficiency technologies and new approaches to procurement; not-in-kind technologies, in particular in air conditioning; and ways to improve efficiency in the servicing sector.

18. The task force took into consideration the discussions of the Working Group and prepared its final report on the matter, including relevant updates and additional information.¹⁰ The final report is available on the meeting portal of the Thirty-First Meeting of the Parties. Given that the updates reflected in the final report have not altered the main messages set out in the executive summary of the May 2019 report, they have therefore not been annexed to the present addendum. A summary of the updates, highlighted in grey in the final report, is presented below:

(a) The energy efficiency of an installed unit depends on the installation location, good installation practices, routine and regular maintenance, including cleaning of coil and filters, and ensuring an optimum charge. To achieve and maintain high energy efficiency, there have to be adequate numbers of appropriately trained technicians for expert servicing and maintenance of equipment. As the new technology becomes available, capacity planning is needed to ensure that the number of appropriately trained technicians increases in parallel.

(b) The availability of air-conditioning technologies is predicted to evolve over time. Countries with a manufacturing base are in the process of determining what is best for them in terms of technology, while countries that are dependent on imports are following international market trends and availability. Both groups of countries will have to build capacity for servicing and maintenance. Regulations will drive innovation and changes in the efficiency of imported refrigeration and air-conditioning equipment.

(c) The availability of air-conditioning technologies operating with HCFCs, high-GWP hydrofluorocarbons (HFCs) and low and medium-GWP HFCs¹¹ in all regions of the world is

⁷ Technology and Economic Assessment Panel. *Volume 2: Evaluation of 2019 Critical-Use Nominations for Methyl Bromide* (May 2019). Available at <http://conf.montreal-protocol.org/meeting/oewg/oewg-41/presession/SitePages/Home.aspx>.

⁸ See also UNEP/OzL.Pro.WG.1/41/2/Add.1, paras. 25–30.

⁹ Technology and Economic Assessment Panel. *Volume 4: Decision XXX/5 Task Force Report on Cost and Availability of Low-GWP Technologies/Equipment that Maintain/Enhance Energy Efficiency* (May 2019). Available at <http://conf.montreal-protocol.org/meeting/oewg/oewg-41/presession/SitePages/Home.aspx>.

¹⁰ Ibid. *Volume 3: Decision XXX/5 Task Force Report on Cost and Availability of Low-GWP Technologies/Equipment that Maintain/Enhance Energy Efficiency* (September 2019). Available at <http://conf.montreal-protocol.org/meeting/mop/mop-31/presession/default.aspx>.

¹¹ In the task force report, high- global-warming-potential (GWP) HFC refrigerants are those with GWP greater than 1,000, and medium- and low-GWP refrigerants are those with GWP of less than 1,000, e.g. HFC-32, unsaturated HFC blends (HCFO, HFO) and hydrocarbons (HC-290).

presented in tabular form (see tables 2.2–2.4 of the September 2019 task force report) as a function of three tiers of energy-efficiency that meet minimum energy performance standards.¹² Based on that information, the task force observes that:

- (i) HCFCs used in air conditioning exhibit generally lower energy efficiency than high-, medium- and low-GWP refrigerants, and there is no ongoing research and development to improve energy efficiency in their use;
 - (ii) Air-conditioning units based on high-GWP refrigerants are available around the world across all tiers of energy efficiency;
 - (iii) Air-conditioning units based on medium- and low-GWP refrigerants are available in many parts of the world, but in some important markets (e.g. in the United States of America and in high-ambient-temperature countries), they remain emerging technologies.
- (d) For high-ambient-temperature countries, the design of air-conditioning units requires special consideration in terms of the selection of materials and components. Units with larger heat exchangers contain more refrigerant and have the potential to exceed safety requirements owing to the larger amount of refrigerant used. This can be offset by modern design, especially as seen in microchannel heat exchangers, which require significantly less refrigerant. Energy efficiency in high-ambient-temperature conditions can also be enhanced through the use of variable speed drivers, which give the greatest benefit and savings when there is a significant temperature change over a 24-hour period.
- (e) Low-volume-consuming countries can avoid the continued use of inefficient technologies and refrigerants and increase the availability of lower-GWP and higher-efficiency equipment through import controls, taxes, shipping/transport costs and other policies.
- (f) Although not-in-kind technologies were not assessed in the report, the task force noted that the most promising technology in this field is the two-stage direct/indirect evaporative cooling system, which can provide superior energy efficiency compared to traditional systems. This technology is widely available, and when applied to high-ambient-temperature countries, especially those with low relative humidity during the summer, it yields sizable savings in operating costs.
- (g) Brand reputation and other equipment features have a greater impact on the price paid by consumers than the declared energy efficiency of that equipment. Independent monitoring, verification and enforcement of energy performance standards are essential to ensuring the accuracy of declared energy efficiency.
- (h) The energy-saving potential from properly implemented minimum energy performance standards is known to be substantial. Cost-benefit analyses must be performed before the adoption of such standards to ensure that the associated regulatory measures provide economic benefits to consumers. Stakeholder consultation is required to guarantee that they buy in to the policy. In high-ambient-temperature conditions, the challenge is to attain safety standards while meeting the requirements of minimum energy performance standards. In implementing the HFC phase-down, a strategy of early switching towards energy-efficient, low-GWP air-conditioning equipment would bring long-term economic and environmental benefits.¹³
- (i) To avoid lower-cost and inefficient products being marketed to countries with weak or absent minimum energy performance standards, market transformation interventions may be used at the national level, such as labels, awards, public or private buyers' clubs and incentive programmes.
 - (j) Global experience in regional and institutional cooperation has demonstrated benefits in terms of speed, scale, spending and sustainability that could apply to improving energy efficiency during an HFC phase-down. Based on the experience gained so far under the Montreal Protocol, such cooperation can be categorized into four stages: (i) awareness and information exchange;

¹² Low-tier: Air conditioning units that meet regional or country requirements for minimum energy performance standards relating to energy efficiency;

Mid-tier: Air conditioning units that are up to 10 per cent more efficient than base minimum energy performance standards;

High-tier: Air conditioning units whose energy efficiency is at least 10 per cent higher than base minimum energy performance standards.

¹³ See also sections 2.5 and 2.8 in the report of the Technology and Economic Assessment Panel, entitled *Volume 5: Decision XXIX/10 Task Force Report on Issues Related to Energy Efficiency while Phasing Down Hydrofluorocarbons* (September 2018). Available at <https://ozone.unep.org/science/assessment/teap>.

(ii) technology development and technical cooperation; (iii) policy formulations, standards and labelling; and (iv) testing and labelling, including customs training and prior informed consent.

(k) There are a number of regional forums for cooperation on comparable standards and metrics. A non-comprehensive list of forums and institutions, through which governments are exchanging information on energy efficiency standards and metrics related to refrigeration and air conditioning, is presented in table 4.1 of the September 2019 task force report. Cooperation through various forums could include the alignment of performance metrics and labelling; testing laboratories: the availability, presentation and accessibility of data related to energy performance; and mutual recognition between standards and certification bodies. In addition, resources specifically related to the monitoring, verification and enforcement of energy performance standards and policies are available from other sources indicated in the report.¹⁴

(l) International cooperation drives innovation through incentives. Aligning policies with trading partners to increase access to technologies and economies of scale will drive down prices. Governments, manufacturers and the broader community of researchers and inventors can also benefit from incentives, such as the Global Cooling Prize competition,¹⁵ to accelerate research and development and the deployment of high-efficiency and low-GWP technologies.

19. The parties may wish to take into consideration the final report of the task force during their deliberations on this matter.

D. Safety standards (item 13 of the provisional agenda for the preparatory segment)

20. At its forty-first meeting, the Open-ended Working Group considered the tabular overview on safety standards for flammable low-GWP refrigerants, developed by the Secretariat in response to decision XXIX/11 of the Twenty-Ninth Meeting of the Parties, in November 2017.¹⁶ Consideration was also given to the online tool on such standards developed by the Secretariat. The online tool is now permanently available in the “Resources” section of the Ozone Secretariat website¹⁷ and has been posted on the portal of the current meeting for the parties’ consideration under the relevant agenda item. The information in the online tool is updated continuously to reflect progress in the adoption of safety standards.

21. The Secretariat has informed the international standards organizations with which it holds regular consultations about the online tool and requested their continued feedback and input, as necessary.

E. Consideration of nominations to the assessment panels (item 15 of the provisional agenda for the preparatory segment)

22. At the time of preparation of the present addendum, the Secretariat received a submission from China nominating Mr. Jianjun Zhang, currently a co-chair of the Medical and Chemicals Technical Options Committee, to continue serving on the Technology and Economic Assessment Panel in that role for an additional period of four years. Mr. Zhang’s curriculum vitae is posted on the portal of the Thirty-First Meeting of the Parties.

23. The parties may wish to consider this nomination, along with the two nominations indicated in the note by the Secretariat (UNEP/OzL.Pro.31/2, para. 93).

¹⁴ United Nations Environment Programme and Global Environment Facility. “Accelerating the global adoption of energy-efficient and climate-friendly air conditioners” (2017). Available at <https://united4efficiency.org/wp-content/uploads/2017/06/U4E-ACGuide-201705-Final.pdf>; and

Mark Ellis and Associates, and the Collaborative Labelling and Appliance Standards Programme. “Compliance counts: a practitioner’s guidebook on best practice monitoring, verification, and enforcement for appliance standards and labelling” (September 2019). Available at <https://clasp.ngo/tools/mv-e-guidebook>.

¹⁵ The Global Cooling Prize competition is a new international competition that has evolved to motivate global innovation in the room air-conditioning sector by calling upon international participants to develop breakthrough residential cooling technologies that have at less than one fifth the climate impact of baseline technologies. The solution must meet a variety of climate- and resource-focused criteria while operating within cost and scalability constraints. See <https://globalcoolingprize.org/>.

¹⁶ UNEP/OzL.Pro.WG.1/41/INF/3/Rev.1.

¹⁷ <https://ozone.unep.org/system-safety-standards>.

Annex¹

Report by the Technology and Economic Assessment Panel (September 2019) Volume 1

Decision XXX/3 Task Force report on unexpected emissions of trichlorofluoromethane (CFC-11)

Executive Summary²

The Montreal Protocol was established to protect the stratospheric ozone layer by reducing ozone-depleting substances (ODS), such as chlorofluorocarbons (CFCs), in the atmosphere. Successful measures were taken, with the abundance of ODS peaking in the late 1990s and continuously decreasing thereafter. CFC-11 (trichlorofluoromethane, CFC₁₁) was used primarily as a foam-blowing agent (for flexible and polyurethane (closed cell) insulating foams), as an aerosol propellant, as a refrigerant (for centrifugal chillers used in large buildings and industrial plants), and in a range of other smaller uses, including asthma inhalers, and tobacco expansion. There are alternative chemicals or products available as replacements for CFC-11. A bank of CFC-11 remains in closed cell foams and centrifugal chillers, from which CFC-11 is released slowly into the atmosphere over time.

CFC-11 production peaked between 350,000 and 400,000 tonnes per year, and peak emissions were about 350 gigagrams (or 350,000 tonnes) per year, in the late 1980s.³ Under the Montreal Protocol, production of CFC-11 in non-Article 5 parties was phased out in 1996; production of CFC-11 in Article 5 parties was phased out in 2010, with some limited exceptions authorised by parties.

Montzka *et al.*, in a letter to Nature in 2018, reported an unexpected, global increase in CFC-11 emissions of 13,000±5,000 tonnes per year after 2012. The study strongly suggests a concurrent increase in CFC-11 emissions from eastern Asia although the contribution of this region to the global increase was not quantified. The study also suggests that the CFC-11 emissions increase arises from new production that has not been reported to the Ozone Secretariat, which is inconsistent with the agreed phase-out of CFC production by 2010. Rigby *et al.*⁴, in a letter to Nature in 2019, reported increased emissions of CFC-11 from eastern mainland China, with emissions shown to be 7.0 ± 3.0 (±1 standard deviation) gigagrams per year higher in 2014–2017 than in 2008–2012, arising primarily from the northeastern provinces of Shandong and Hebei. These regional emissions were found to account for at least 40-60% of the global increase in CFC-11 emissions, with no evidence for any significant increase in CFC-11 emissions from any other eastern Asian countries or other regions of the world that were adequately monitored by atmospheric measurements.

In response to these scientific findings of an unexpected increase in global emissions of CFC-11 after 2012, at their 30th Meeting, parties requested the Technology and Economic Assessment Panel (TEAP) to provide them with relevant information on potential sources of emissions of CFC-11 and related controlled substances, as given in decision XXX/3. In response, TEAP formed a temporary subsidiary body, in the form of a Task Force, which combines expertise from TEAP and its Technical Options Committees (TOCs), and also outside expertise, to address the requirements of this decision.

Decision XXX/3 requests TEAP to prepare a preliminary report, to be provided in time for the Open-ended Working Group at its forty-first meeting and a **final** report, to be provided in time for the Thirty-First Meeting of the Parties. This report is the final report. A submission in response to decision XXX/3, paragraph 3, was received from China, which the Task Force has considered in its assessment. As noted in the report of the contact group on unexpected emissions of trichlorofluoromethane (CFC-11) at the 41st meeting of the OEWG, parties were invited to provide any relevant information that they may have on these issues to the Ozone Secretariat by 31 July 2019, in order to give the Task Force time to review it and finalize their report for submission to the Thirty-First Meeting of the

¹ The present annex has not been formally edited.

² The new and updated information included in the final report appears is highlighted in grey. For ease of reference to the reader, the Secretariat has omitted text that has been stricken through by the task force in its final report.

³ Montzka, S. *et al.*, An unexpected and persistent increase in global emissions of ozone-depleting CFC-11, *Nature*, 2018, **557**, 413–417. <https://doi.org/10.1038/s41586-018-0106-2>.

Rigby, M. *et al.*, Increase in CFC-11 emissions from eastern China based on atmospheric observations, *Nature*, 2019, **569**, 546-550. <https://doi.org/10.1038/s41586-019-1193-4>.

Parties. Detailed additional information was provided by China, the European Union, Japan, Mexico, Russia, and the United States. The Task Force utilised information in the analysis and findings of this final report, to confirm or correct its assumptions used in the preliminary report. The Task Force also took into consideration feedback and questions raised at the 41st meeting of the OEWG, as documented in the meeting report.

The final report is structured to address the different elements in responding to the decision: production of CFC-11 and related controlled substances; foams uses; refrigerant uses; aerosols, solvents and miscellaneous uses; emissions modelling and analysis. It analyses the likelihood of potential sources of emissions. The final report adds directly to the preliminary report, with new text shown in grey highlights, and deleted text in strikethrough. Headings have been renumbered where needed, and some material moved to appendices, to make way for new, updated analysis and information.

Production options for CFC-11 and related controlled substances

The possible production plant options for the manufacture of CFC-11 have been considered.

The main process routes to CFC-11 production use carbon tetrachloride (CTC) as feedstock; the possible availability of CTC has been considered to meet a range of potential CFC-11 production quantities annually from small-scale ($\leq 10,000$ tonnes per year) to large-scale ($\geq 50,000$ tonnes per year).

The Task Force considered 22 potential alternative CFC-11 production routes. The most likely production routes are CTC to CFC-11 on micro-scale plants using minimal equipment (to make low grade CFC-11 for foam blowing use); and CTC to CFC-11/12 on a large-scale in an existing liquid phase plant (HCFC-22⁵ and/or HFC-32 plant). Less likely but possible is CTC to CFC-11/12 on a large-scale in an existing vapour phase plant (dedicated CFC plant). If new CFC-11 production is occurring, emissions related solely to the production stage may occur but at relatively low rates, which are dependent on the production process used.

Based on modelling of CFC-11 production, usage and emissions and comparison against atmospheric observations, the “most likely” modelling scenario predicts 40,000 to 70,000 tonnes per year CFC-11 production would have been required from 2012 onwards to account for the increased CFC-11 emissions. This places CFC-11 production at the large-scale end of the production ranges considered.

If, as predicted, larger scale CFC-11 production ($\geq 50,000$ tonnes per year) were required to account for the increased emissions, then it seems less likely that a large number of micro-scale plants would be solely responsible, although this does not preclude some micro-scale plants from contributing to the production.

The production of CFC-11 (and CFC-12) is possible in HCFC-22 plants. Spare annual capacity to produce CFC-11 in a HCFC-22 plant is estimated to be available in: Argentina, Mexico, Russia, and Venezuela for small-scale CFC-11 production ($\leq 10,000$ tonnes); the United States⁶ for medium-scale CFC-11 production (between 10,000 and 50,000 tonnes); and China and the European Union, for large-scale CFC-11 production ($\geq 50,000$ tonnes)⁷.

Similarly, the production of CFC-11 (and CFC-12) is possible in liquid phase HFC-32 plants. The production of 50,000 tonnes per year CFC-11 would require at least 20,000 tonnes per year spare HFC-32 capacity. An estimated 50,000 tonnes per year of spare HFC-32 capacity is estimated to have been available in 2012-2016 and is likely to remain available.

It is possible to produce almost 100% CFC-11 in a detuned CFC-11/12 or adapted modern HCFC-22 or HFC-32 plant. Near 100% CFC-11 production is also considered possible in a micro-production plant that is purposefully designed and operated on a batch basis to produce CFC-11 using similar feedstock and catalyst. The quantity of CFC-12 co-produced as a result of any CFC-11 production is dependent on the exact production option chosen, and how the plant is set up and operated.

⁵ Overall likelihood of production route being a significant cause has been revised in light of information received from the parties. CTC to CFC-11/12 on large-scale existing HCFC-22 liquid phase plant remains technically possible but is also considered unlikely due to compliance monitoring. Owing to the technical feasibility of this route, it remains as one of the most likely potential production routes.

⁶ It is considered possible that maximising the CFC-11 production capabilities when adapting the HCFC-22 lines could increase the theoretically available CFC-11 production capacity of the United States to above > 50,000 tonnes of CFC-11 per year.

⁷ For the year 2017, China and the European Union had spare capacity for HCFC-22 production of less than 50,000 tonnes. For the years 2013-2016, China and the European Union had estimated spare capacity greater than 50,000 tonnes per year.

With CFC-11 as the target chemical, for the most likely production routes, the range of CFC-12 co-production is between 0-30% of total CFC-11/12 production.

CTC is produced in chloromethanes plants as an unavoidable part of the production of dichloromethane and chloroform. China, the European Union, and the United States have the largest chloromethanes capacities, and therefore also the largest potential availability of CTC. In 2016, the global maximum amount of potential CTC available from chloromethanes production, after existing local supply commitments had been met, was 305,000 tonnes. A number of regions have the spare annual capacity that might allow CTC production in the amounts required for small-scale CFC-11 production. Only China has the spare annual capacity that might allow CTC production to supply the larger amounts of CTC required for large-scale CFC-11 production.

CTC is also produced in perchloroethylene/CTC (PCE/CTC) plants, which have the flexibility to produce either substance according to demand. Five PCE/CTC plants are operative in Europe and the United States. Spare global capacity to produce CTC by this process is estimated to be between 50,000-100,000 tonnes per year, existing mainly in the European Union.

Between 45,000 to 120,000 tonnes of CTC would be required to supply between 40,000 to 70,000 tonnes of CFC-11 production, as predicted to account for the increased CFC-11 emissions, depending on the proportion of co-produced CFC-12. The CTC quantity required for CFC-11 production is expected to be at the lower end of the range if, as predicted, the objective is higher CFC-11 selectivity.

There does not appear to be evidence through customs or other agency activities, including seizures or interceptions, that illicit international trade in significant quantities of CFC-11 or CTC has occurred in recent years. However, there have been indications of recent marketing of CFC-11 for use in foams.

Foams

Based on its current assessment, the Task Force finds that the production of certain foam products using CFC-11 may be a potential source of the sudden and increased emissions of CFC-11. It is likely that there has been a resumption of newly produced CFC-11 usage in closed-cell foams.

It seems unlikely that the unexpected emissions have resulted from the traditional handling of foams at end-of-life alone unless there has been a significant change in those processes from appliances and construction for a very large volume of foams. This has been further validated in the final report by more closely examining the expected timing of increased emissions associated with the dismantling of foams.

There are indications of CFC-11 marketing into foams use. The Foams Technical Options Committee was provided with a copy of an offer for sale of CFC-11 for 2,200 USD/tonne through distribution, has seen offers for sale on internet websites, and has learned more through industry discussions.

Although technically feasible, the Task Force questions the economic incentive for open-cell flexible foams of broadly replacing methylene chloride, given its very low cost, with CFC-11. Nevertheless, the Task Force continues to explore the possibility of use of CFC-11 to reduce volatile organic compound emissions from flexible foams as limited in some parties or limitations in the use of methylene chloride due to toxicity concerns. After reviewing low-cost alternatives available to produce flexible foams, the Task Force has concluded that it is very unlikely that there has been renewed use of CFC-11 in flexible foams.

Further investigation was completed into the use of CFC-11 for polyurethane (PU) foams and polyol systems for PU rigid foams as it is technically feasible and more economically advantageous than reverting to use CFC-11 in flexible foams. The increased CFC-11 emissions imply volumes of CFC-11 usage that seem to go beyond that of smaller or local system houses. It is likely that there has been a resumption of newly produced CFC-11 usage in closed-cell foams.

The conversion of enterprises in the spray foam sector and small and medium enterprises (SMEs) has created technical and economic challenges that might drive the use of CFC-11. Whether or not this has resulted in the actual usage of CFC-11 blowing agents, or to any significant degree, has not been confirmed.

There is a difference between the projected estimated CFC-11 emissions from foams in banks (including landfills), based on emission rates found in the literature, and the derived atmospheric emissions, including in regions where CFC-11 has not likely been used in foams in decades (< 1.5% and 3-4%, respectively). It is possible that further processing of foams before disposal, through shredding and crushing of foams, accounts for at least some of that difference. Further

investigation into emission rates from foams banks is warranted. Parties have provided information in their submissions that has helped to address the gap in the emissions rates when foams are dismantled.

Any scenario where significant CFC-11 is used in rigid or closed cell polyurethane foams would require significant CFC-11 production and would also result in an increase of the foam banks (e.g., emissions of 1,000 tonnes of CFC-11 from the manufacture of closed-cell foams would imply an increase in the foam bank of 3,000 tonnes or more). Further analysis of the potential use of CFC-11 in rigid or closed-cell polyurethane foams was completed for the final report. Even the most extreme bank emissions scenarios do not account for the unexpected emissions of CFC-11. Additional information regarding banks and emissions is included in the emissions chapter.

It is considered economically attractive and technically straight-forward to revert to using CFC-11 from HCFC-141b, or another fluorocarbon, as the other raw materials and equipment used to produce foams are compatible with only slight modifications to ingredient ratios. In addition, there are a number of regulatory, cost and technical drivers that might further encourage the transitions backward to the use of CFC-11, including a shortage in HCFC-141b resulting from the phase-out commencing in 2013.

The MLF Secretariat provided data indicating that up to 7,500 tonnes per year blowing agent had been reported as being incorporated into foam systems and imported by various parties. Foam systems could be mislabeled and used by a recipient without knowing what blowing agent is in the system.

The higher pricing and lack of availability of HCFC-141b related to the ODS phase-out combined with the technical ease of conversion to CFC-11 could be a driver for reverting to use of CFC-11 as a blowing agent. CFC-11 as a blowing agent could also be of interest to companies who erroneously believe that it may reduce foam flammability without using expensive fire retardants.

Refrigeration and air conditioning

Centrifugal chillers using CFC-11 (some used CFC-12) have always been a relatively small part of the total CFC refrigerant inventory and emissions of all refrigeration and air-conditioning (R/AC) subsectors. While CFC-12 centrifugal chillers have been virtually phased out, a small number of CFC-11 chillers are still in operation and expected to reach their end of life in the next 1 to 5 years, at the latest. Based on estimates of CFC-11 banks and emissions, emissions from CFC-11 chillers do not constitute a major portion of the global CFC-11 emissions calculated from atmospheric observations in 2002-2012, and similarly emissions from chillers cannot be a cause for the sudden increase of global CFC-11 emissions since 2013, as derived from atmospheric calculations. It is unlikely that CFC-11 production would be employed to maintain a very small number of centrifugal CFC-11 chillers in operation.

It is also unlikely that there is a significant resumption of CFC-12 usage in any R/AC subsector in both non-Article 5 and Article 5 parties. This implies that no significant new CFC-12 production would be needed for all R/AC subsector uses, and that this would not be the reason for possible CFC-11 co-production. There might be a continuing small CFC-12 demand for a limited number of CFC-12 mobile ACs in certain vehicles, namely some luxury or special vehicles built before 2002 in Article 5 parties. However, this small demand is likely to be supplied from the recycling of refrigerant from aged CFC-12 equipment.

Aerosols, solvents, and other applications

The main use of CFCs was as a pressurized liquid in aerosols, which is an emissive use. While CFC-11 worked very well in combination with CFC-12 to obtain variations in propellant pressure, CFC-11 could not be used alone as a propellant. It is technically feasible to use mixtures of hydrocarbon propellants and CFC-11 in aerosols. If CFC-11 were readily available, it would be technically feasible to use it in aerosol products. However, it seems unlikely that CFC-11 would be produced or used nowadays for aerosols; the main reason is that hydrocarbons are much cheaper than CFCs. While it would be technically possible to make an MDI mixing CFC-11 and HFC-134a or HFC-227a, it seems highly unlikely that any MDI producer would choose this route.

Production of synthetic fibre sheet with CFC-11 is listed in decision XXIX/7 Table A as a process agent and is permitted for use only in the United States, for which emissions are very low. It is extremely unlikely that CFC-11 would be used in a newly established (illicit) plant to manufacture synthetic fibre sheet and that this would be highly emissive. Similarly, it seems extremely unlikely that CFC-11 might be used as a solvent. With the alternatives available, there are also no technical or economic reasons to believe that the recent increase in CFC-11 emissions would be due to tobacco expansion or the processing of uranium.

Emissions and banks modelling

Based on updated modelling and analysis of CFC-11 emissions and banks, it is unlikely that past production, historic usage, and the resulting bank can account for the unexpected CFC-11 emissions, unless there has been a significant change in the treatment of large quantities of banked CFC-11. The final report confirms no evidence of a significant change in the treatment of large quantities of CFC-11 at the end-of-life.

Atmospheric-measurement derived emissions from banks in Western Europe, where CFC-11 has not been used for several decades, continue to generally decline (2-4% per year). If it is assumed that CFC-11 emissions from banks in other regions generally decline in a similar fashion, it appears that the unexpected increases in global CFC-11 emissions cannot be explained by bank emissions. Unless banks are treated very differently in other regions where CFC-11 has been used more recently, or where there is no atmospheric data collected, it seems unlikely that the source of the increased CFC-11 emissions is from CFC-11 banks. Further analysis of regional banks was completed for the final report, incorporating the duration of foam use and the subsequent timing for emissions from dismantling foams. The Task Force concluded that in no region are the unexpected emissions likely to have originated from the existing foam banks.

Scenarios were evaluated combining estimated sales of newly produced CFC-11 into multiple markets (combinations of foams, emissive uses, and chillers). Although technically feasible, the Task Force believes that widespread use of newly produced CFC-11 in sectors other than closed-cell foam is unlikely.

Most of the closed-cell foam as of 2006 was produced in Europe and North America with smaller quantities produced regions in the Southern Hemisphere. It is anticipated that most of the global emissions of CFC-11 would have occurred in those regions during foam manufacturing and installation and during the lifetime of products containing those foams. Destruction of foams is increasing in these regions and there are significant quantities of CFC-11 blown foams still in use in building.

Based on modelling using reported CFC-11 production data, it seems that the expected emissions from the CFC-11 foam banks in Northeast Asia are insufficient to account for the atmospheric-derived emissions from eastern mainland China in Rigby *et al.*

Estimated bottom-up CFC-12 emissions are consistently lower than the atmospheric-measurement derived emissions, indicating high underlying uncertainty in the bottom-up model's assumptions. As a result, estimates of bottom-up CFC-12 emissions are inconclusive.
