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Open-ended Working Group of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer
Thirty-sixth meeting
Paris, 20–24 July 2015
Items 3–11 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 thirty-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 thirty-sixth meeting contains information that has become available since the drafting of the note (UNEP/OzL.Pro.WG.1/36/2). Section II presents the new information, including brief summaries of key information provided by the Technology and Economic Assessment Panel and its technical options committees and task force in the three volumes of the Panel's 2015 report, summaries of the quadrennial assessments by the three assessment panels, and information on the intersessional consultations held on the feasibility and ways of managing hydrofluorocarbons (HFCs).

2. Section III of the present addendum sets out additional information on matters that the Secretariat would like to bring to the attention of the parties, updating the information in the note by the Secretariat (UNEP/OzL.Pro.WG.1/36/2).

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

Agenda item 3
2014 quadrennial assessment reports of the Scientific Assessment Panel, the Environmental Effects Assessment Panel and the Technology and Economic Assessment Panel

3. The full reports of the 2014 quadrennial assessments conducted by the Scientific Assessment Panel, the Environmental Effects Assessment Panel and the Technology and Economic Assessment

* UNEP/OzL.Pro.WG.1/36/1.

Panel and its technical options committees are available from the Ozone Secretariat website under the "Assessment Panels" tab and as background documents for the thirty-sixth meeting of the Open-ended Working Group (http://conf.montreal-protocol.org/meeting/oewg/oewg-36/presession/SitePages/Home.aspx). Shortened versions of the summaries of the panels' reports are set out in annex I to the present addendum. The panels will present the key findings of their assessments at the thirty-sixth meeting. The Working Group may wish to take note of the findings and use them in drawing up the terms of reference for the next assessment (agenda item 11).

Agenda item 4
2015 progress report of the Technology and Economic Assessment Panel

4. The 2015 report of the Technology and Economic Assessment Panel consists of three volumes. The volumes of the 2015 report and their contents are as follows:

(a) Volume 1 contains the June 2015 Technology and Economic Assessment Panel essential-use nominations report; the technical options committees' progress reports; a chapter on the response to decision XXVI/7; a chapter entitled "Other TEAP matters"; the list of members of the Panel and its committees as at June 2015; and a matrix of required expertise;

(b) Volume 2 contains the May 2015 Technology and Economic Assessment Panel critical-use nominations report;

(c) Volume 3 contains the report of the task force on decision XXVI/9 on additional information on alternatives to ozone-depleting substances.

5. Under agenda item 4, the Panel will present their findings, conclusions and recommendations as contained in volumes 1 and 2 of their 2015 report.

Agenda item 5
Issues related to exemptions under Articles 2A–2I of the Montreal Protocol

(a) Nominations for essential-use exemptions for 2016

6. China's request for an essential-use exemption for the use of 70 metric tonnes of carbon tetrachloride for testing of oil in water, a laboratory and analytical use, for 2016, was evaluated by the Chemicals Technical Options Committee. The evaluation and recommendation are set out in section 2.2, volume 1, of the 2015 report of the Technology and Economic Assessment Panel. The Committee recommends an exemption of 70 metric tonnes of carbon tetrachloride for 2016. China is expected to implement the new standard and phase out the use of carbon tetrachloride for analytical uses in 2016, thus eliminating the need for further exemptions for this application beyond 2016.

(b) Nominations for critical-use exemptions for 2016 and 2017

7. Eleven nominations for critical-use exemptions submitted by three parties not operating under paragraph 1 of Article 5, namely (Australia, Canada, the United States of America), and four parties operating under paragraph 1 of Article 5 (Argentina, China, Mexico, South Africa) were evaluated by the Methyl Bromide Technical Options Committee. The results of the evaluation, together with the initial recommendations of the Committee, are set out in the evaluation of 2015 critical-use nominations for methyl bromide in volume 2 of the TEAP 2015 report. The table below summarizes the parties' recommendations and the interim recommendations of the Committee with brief explanations in the footnotes to the table where the recommendations differ from the nominated amounts.

8. As usual, the nominating parties and the Methyl Bromide Technical Options Committee are expected to discuss further the interim recommendations and additional information that may be provided to the Committee for its final evaluation and recommendations. The final report of the Committee is expected to be available prior to the Twenty-Seventh Meeting of the Parties to the Montreal Protocol.

Summary of the nominations for 2016 and 2017 critical-use exemptions for methyl bromide submitted in 2015 and interim recommendations of the Methyl Bromide Technical Options Committee

(Metric tonnes)

Party	*Nomination for 2016*	*Interim recommendation*	*Nomination for 2017*	*Interim recommendation*
Parties not operating under paragraph 1 of Article 5 and sector				
1. Australia				
Strawberry runners			29.760	[29.760]
2. Canada				
Strawberry runners			5.261	[unable][a]
3. United States of America				
Cured pork			3.240	[3.240]
Total			**38.261**	**[33.000]**
Parties operating under paragraph 1 of Article 5 and sector				
4. Argentina				
Strawberry fruit	77.000	[unable][b]		
Green pepper and tomato	100.000	[45.000][c]		
5. China				
Ginger open field	90.000	[78.750][d]		
Ginger protected	24.000	[21.000][d]		
6. Mexico				
Raspberry nursery	56.018	[41.418][e]		
Strawberry nursery	64.960	[43.539][e]		
7. South Africa				
Mills	13.000	[5.462][f]		
Structures	68.60	[68.60]		
Total	**493.578**	**[303.769]**		

[a] There is a lack of evidence of a programme or any work on research to secure alternatives. The adoption of chloropicrin (Pic) has been held up by regulatory issues in Prince Edward Island for the past six years, but seems to be allowed in the methyl bromide/Pic formulations. Clarification is needed on both issues.

[b] Information is needed on the studies that demonstrate the plant-back periods for 1,3-dichloropropene (1,3-D)/Pic in Lules and Mar del Plata as compared to methyl bromide; and an economic assessment for applying 1,3-D/Pic annually versus a biennial treatment which may be more effective.

[c] Based on the dosage rate of 17.5g/m^2 in the Methyl Bromide Technical Options Committee's standard presumptions for methyl bromide:Pic formulation of 70:30 the nomination of 100 tonnes using a dosage rate of 35g/m^2 has been reduced by 50 per cent. Considering the availability of effective alternatives and the time required for their adoption, the nominated quantity has been reduced by a further 5 per cent.

[d] The nominated quantity has been reduced after adjusting the dosage rate from 40g/m^2 in the nomination to 35g/m^2 in the Methyl Bromide Technical Options Committee's standard presumptions for methyl bromide use with barrier films.

[e] The reduction was based on decision Ex.I/4 which permits an increase in exemptions only under unforeseen circumstances. The recommended amounts are equal to approved amounts for 2015.

[f] Based on dosage rate of 20g/m^3 in the Methyl Bromide Technical Options Committee's standard presumption for mill treatment and total space volume of 136,540m^3 being fumigated twice per year, a reduced amount is being recommended.

Agenda item 6
Issues related to alternatives to ozone-depleting substances

(a) Report by the Technology and Economic Assessment Panel on the full range of alternatives to ozone-depleting substances (decision XXVI/9, subparagraphs 1 (a)–(c))

9. The task force established by the Technology and Economic Assessment Panel to respond to decision XXVI/9 presented an extract report to the Open-ended Working Group at its thirty-fifth meeting, held in Bangkok from 22 to 24 April 2015. The full report was finalized by the task force and the Panel for consideration by the Open-ended Working Group at its thirty-sixth meeting and it was made available on the Ozone Secretariat website on 20 June 2015. The full report supersedes the extract report of April 2015.

10. The report by the task force on decision XXVI/9 provides updated information on topics outlined in paragraph 1 of decision XXVI/9, primarily for the refrigeration and air-conditioning sector,

including on energy efficiency and high ambient temperature conditions. Updated information is also provided for the fire protection, medical uses, and non-medical aerosols sectors, but no additional updates were available for the foams and solvents sector at this time. Further information may be included in the report to be submitted for the Twenty-Seventh Meeting of the Parties in November 2015. While many of the options for replacing ozone-depleting substances and high global warming potential (GWP) refrigerants have not changed since the finalization of the report of the task force on decision XXV/5 in October 2014, updates have been provided wherever possible, as obtained through comments from parties and review of information from several additional reports and publications, including the 2014 quadrennial assessment reports of the relevant technical options committees and several reports from workshops and conferences, including documents from the 2015 workshop on hydrofluorocarbon management issues.

11. The report also provides two revised mitigation scenarios (MIT-3 and MIT-4) based on avoiding high-GWP refrigerants, which were presented in the report under decision XXV/5. It includes new assumptions on the GWP of the alternatives to be used and the impact of the conversion period for manufacturing. Cost-effectiveness is expected to be higher where technology transitions coincide with process upgrades, and where high-GWP options are avoided at the outset of investment decisions. Scenario analysis has been carried out to show the cost impact of delaying and extending the conversion period.

12. The executive summary of the report is set out in annex II to the present addendum. It is presented as received from the Panel, without formal editing by the Secretariat.

13. The Working Group may wish to consider the information in the report and make recommendations, including providing guidance to the Panel and its task force on the preparation of the final report to be considered by the Twenty-Seventh Meeting of the Parties.

Agenda item 7
Outcome of the intersessional informal discussions on the feasibility and ways of managing hydrofluorocarbons (UNEP/OzL.Pro.WG.1/35/6, paragraph 128 and annex II)

14. The Open-ended Working Group of the Parties to the Montreal Protocol, at its thirty-fifth meeting, agreed that it would continue to work intersessionally in an informal manner to study the feasibility and ways of managing HFCs, including, inter alia, the related challenges set out in annex II to the report of that meeting, with a view to the establishment of a contact group on the feasibility and ways of managing HFCs at the thirty-sixth meeting of the Open-ended Working Group (UNEP/OzL.Pro.WG.1/35/6, para. 128).

15. Accordingly, the Secretariat, in consultation with the co-conveners (Australia and Brazil) of the informal discussion on the matter at the thirty-fifth meeting, organized the intersessional consultation in three parts: (a) an informal meeting among parties; (b) direct, bilateral communication between parties and the co-conveners (or the Secretariat); and (c) written submissions, to contribute ideas and solutions to help address the identified challenges or the way forward. A letter on these arrangements inviting written submissions was sent to all the parties on 27 May 2015.

16. The intersessional informal meeting was held in Vienna on 12 and 13 June 2015. It was attended by the representatives of the following 17 parties: Argentina, Australia, Bahrain, Brazil, Canada, China, European Union, Japan, Kuwait, Micronesia (Federated States of), Pakistan, Saint Lucia, Saudi Arabia, Senegal, Switzerland, United States of America and Zimbabwe, as well as the two co-chairs of the Open-ended Working Group and the representative of the United Arab Emirates as the host of the Twenty-Seventh Meeting of the Parties. The following parties were invited but were unable to attend: India, Mexico, South Africa and Uruguay. The agenda of the meeting and the informal briefing notes prepared by the Secretariat and used as background documents for the discussion on: (a) technical issues on the feasibility of managing HFCs; (b) Montreal Protocol provisions and experience in addressing policy-related challenges; (c) funding issues on the feasibility of managing HFCs; (d) ecological issues focusing on trifluoroacetic acid (TFA); and (e) an update on the Secretariat's interaction with the United Nations Framework Convention on Climate Change on synergies related to HFCs, were made available on the meeting portal for the intersessional informal meeting (http://conf.montreal-protocol.org/meeting/workshops/hfcs-intersessional-informal-consultation/SitePages/Home.aspx).

17. At the informal meeting, participants: (a) discussed the challenges in more detail, addressing in a more focused way some of the key issues related to each item on the list of challenges set out in annex II of the report of the thirty-fifth meeting; and (b) delineated a number of overarching issues that required a common understanding if HFCs were to be addressed under the Montreal Protocol. The discussions of the first day formed the basis of a proposal of the co-convenors on the mandate for a possible contact group, which was circulated on the second day of the meeting. The ensuing discussion largely hinged on the text of the co-convenors' proposal. The text of the co-conveners' proposal is available on the meeting portal for the informal meeting (http://conf.montreal-protocol.org/meeting/workshops/hfcs-intersessional-informal-consultation/SitePages/Home.aspx).

III. Matters that the Secretariat would like to bring to the parties' attention

A. Seventy-fourth meeting of the Executive Committee

18. The seventy-fourth meeting of the Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol, chaired by the United States, was held in Montreal, Canada, from 18 to 22 May 2015. While the Chair of the Executive Committee will be providing a comprehensive report on the work of the Committee at the Twenty-Seventh Meeting of the Parties later, the Secretariat would like to note that the Committee reached agreement on several important issues, including:

(a) Adoption of the draft consumption guidelines for stage II of the HCFC phase-out management plans (HPMPs);

(b) Conduct of surveys on alternatives to ozone-depleting substances in 85 parties operating under paragraph 1 of Article 5 in response to decision XXVI/9 with a view to considering additional information are to include data (where available) and estimates of alternatives currently in use, by sector and subsector, and forecasts of the alternatives most commonly used. Decision 74/53 sets out funding limits based on a country's HCFC baseline consumption and allows the submission of funding requests for such surveys from countries that have not submitted such a request to date. In the decision, the Fund secretariat is also requested, in consultation with the implementing agencies and interested members of the Executive Committee, to prepare a format for the preparation of the surveys and presentation of the resulting data at the seventy-fifth meeting of the Executive Committee meeting, on the understanding that interested countries could initiate the surveys before the format is agreed. An overall analysis of the results of the surveys is to be provided by the secretariat for the Committee's consideration by its first meeting of 2017;

(c) Approval of all institutional-strengthening projects and renewals at a level 28 per cent higher than the historically agreed level, with a minimum level of institutional-strengthening funding of $42,500 per year;

(d) Funding for one feasibility study for district cooling and the preparation of 13 projects to demonstrate low-GWP technologies.

19. Several other important issues were also agreed, strengthening the foundation for continued support to the parties operating under paragraph 1 of Article 5 for their compliance with the provisions of the Montreal Protocol.

B. Update on the interaction of the Secretariat with the United Nations Framework Convention on Climate Change on synergies related to HFCs

20. The representatives of the two secretariats held a one-day meeting in Bonn on 16 June 2015 to discuss synergies between the United Nations Framework Convention on Climate Change and its Kyoto Protocol, and the Montreal Protocol, were HFCs to be managed under the Montreal Protocol. The representatives of the two secretariats reviewed the potential overlaps and gaps in the coverage of HFC gases under the existing Convention framework in relation to their potential scopes of control should an amendment proposal be adopted by the parties to the Montreal Protocol. At the end of the meeting, it was agreed that a joint report would be prepared for internal review by the two secretariats with a view to sharing that information with their respective parties.

21. The joint report will describe the relevant treaty provisions of the Framework Convention on Climate Change and its Kyoto Protocol which apply to HFCs and the relevant treaty provisions on the reporting of information on emissions from HFCs by the parties to the Framework Convention and its Kyoto Protocol. The respective current provisions of the Montreal Protocol will also be addressed. Information on the mechanisms to support the management of HFCs will also be included in the

document with a brief analysis of the financial and technology mechanisms of the Framework Convention on Climate Change, nationally appropriate mitigation actions, Kyoto Protocol flexibility mechanisms and the financial mechanism under the Montreal Protocol.

22. In addition to the factual information on the existing situation regarding the climate and ozone regimes in relation to HFC management, the joint report will also provide an analysis of possible options and implications should a decision be made either to maintain the current status quo or to manage HFCs under the Montreal Protocol.

Annex I

Summaries of the 2014 quadrennial assessments conducted by the Scientific Assessment Panel, the Environmental Effects Assessment Panel and the Technology and Economic Assessment Panel and its technical options committees[a]

I. Executive summary of the assessment for decision makers, scientific assessment of ozone depletion 2014

Actions taken under the Montreal Protocol have led to decreases in the atmospheric abundance of controlled ozone-depleting substances (ODSs), and are enabling the return of the ozone layer toward 1980 levels

- The sum of the measured tropospheric abundances of substances controlled under the Montreal Protocol continues to decrease. Most of the major controlled ODSs are decreasing largely as projected, and hydrochlorofluorocarbons (HCFCs) and halon-1301 are still increasing. Unknown or unreported sources of carbon tetrachloride are needed to explain its abundance.
- Measured stratospheric abundances of chlorine- and bromine-containing substances originating from the degradation of ODSs are decreasing. By 2012, combined chlorine and bromine levels (as estimated by Equivalent Effective Stratospheric Chlorine, EESC) had declined by about 10–15% from the peak values of ten to fifteen years ago. Decreases in atmospheric abundances of methyl chloroform (CH3CCl3), methyl bromide (CH3Br), and chlorofluorocarbons (CFCs) contributed approximately equally to these reductions.
- Total column ozone declined over most of the globe during the 1980s and early 1990s (by about 2.5% averaged over 60°S to 60°N). It has remained relatively unchanged since 2000, with indications of a small increase in total column ozone in recent years, as expected. In the upper stratosphere there is a clear recent ozone increase, which climate models suggest can be explained by comparable contributions from declining ODS abundances and upper stratospheric cooling caused by carbon dioxide increases.
- The Antarctic ozone hole continues to occur each spring, as expected for the current ODS abundances. The Arctic stratosphere in winter/spring 2011 was particularly cold, which led to large ozone depletion as expected under these conditions.
- Total column ozone will recover toward the 1980 benchmark levels over most of the globe under full compliance with the Montreal Protocol. This recovery is expected to occur before midcentury in midlatitudes and the Arctic, and somewhat later for the Antarctic ozone hole.

The Antarctic ozone hole has caused significant changes in Southern Hemisphere surface climate in the summer

- Antarctic lower stratospheric cooling due to ozone depletion is very likely the dominant cause of observed changes in Southern Hemisphere tropospheric summertime circulation over recent decades, with associated impacts on surface temperature, precipitation, and the oceans. In the Northern Hemisphere, no robust link has been found between stratospheric ozone depletion and tropospheric climate.

Changes in CO2, N2O, and CH4 will have an increasing influence on the ozone layer as ODSs decline

- As controlled ozone-depleting substances decline, the evolution of the ozone layer in the second half of the 21st century will largely depend on the atmospheric abundances of CO2, N2O, and CH4. Overall, increasing carbon dioxide (CO2) and methane (CH4) elevate global ozone, while increasing nitrous oxide (N2O) further depletes global ozone. The Antarctic ozone hole is less sensitive to CO2, N2O, and CH4 abundances.

[a] Issued without formal editing; the summaries have been shortened for ease of reference.

- In the tropics, significant decreases in column ozone are projected during the 21st century. Tropical ozone levels are only weakly affected by ODS decline; they are sensitive to circulation changes driven by CO2, N2O, and CH4 increases.

The climate benefits of the Montreal Protocol could be significantly offset by projected emissions of HFCs used to replace ODSs

- The Montreal Protocol and its Amendments and adjustments have made large contributions toward reducing global greenhouse gas emissions. In 2010, the decrease of annual ODS emissions under the Montreal Protocol is estimated to be about 10 gigatonnes of avoided CO2-equivalent emissions per year, which is about five times larger than the annual emissions reduction target for the first commitment period (2008–2012) of the Kyoto Protocol (from the Executive Summary of the Scientific Assessment of Ozone Depletion: 2010).[b]
- The sum of the hydrofluorocarbons (HFCs) currently used as ODS replacements makes a small contribution of about 0.5 gigatonnes CO2-equivalent emissions per year. These emissions are currently growing at a rate of about 7% per year and are projected to continue to grow.
- If the current mix of these substances is unchanged, increasing demand could result in HFC emissions of up to 8.8 gigatonnes CO2-equivalent per year by 2050, nearly as high as the peak emission of CFCs of about 9.5 gigatonnes CO2-equivalent per year in the late 1980s.[c]
- Replacements of the current mix of high-Global Warming Potential (GWP) HFCs with low-GWP compounds or not-in-kind technologies would essentially avoid these CO2-equivalent emissions.
- Some of these candidate low-GWP compounds are hydrofluoroolefins (HFOs), one of which (HFO-1234yf) yields the persistent degradation product trifluoroacetic acid (TFA) upon atmospheric oxidation. While the environmental effects of TFA are considered to be negligible over the next few decades, potential longer-term impacts could require future evaluations due to the environmental persistence of TFA and uncertainty in future uses of HFOs.
- By 2050, HFC banks are estimated to grow to as much as 65 gigatonnes CO2-equivalent. The climate change impact of the HFC banks could be reduced by limiting future use of high-GWP HFCs to avoid the accumulation of the bank, or by destruction of the banks.

Additional important issues relevant to the Parties to the Montreal Protocol and other decision-makers have been assessed

- Derived emissions of carbon tetrachloride (CCl4), based on its estimated lifetime and its accurately measured atmospheric abundances, have become much larger than those from reported production and usage over the last decade.
- As of 2009, the controlled consumption of methyl bromide declined below the reported consumption for quarantine and pre-shipment (QPS) uses, which are not controlled by the Montreal Protocol.
- Increased anthropogenic emissions of very short-lived substances (VSLS) containing chlorine and bromine, particularly from tropical sources, are an emerging issue for stratospheric ozone. The relative contribution of these emissions could become important as levels of ODSs controlled under the Montreal Protocol decline.
- As the atmospheric abundances of ODSs continue to decrease over the coming decades, N2O, as the primary source of nitrogen oxides in the stratosphere, will become more important in future ozone depletion.
- Emissions of HFC-23, a by-product of HCFC-22 production, have continued despite mitigation efforts.

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[b] GWP-weighted emissions, also known as CO2-equivalent emissions, are defined as the amount of gas emitted multiplied by its 100-year Global Warming Potential (GWP). Part of the effect of ODSs as greenhouse gases is offset by the cooling due to changes in ozone.

[c] This is equivalent to about 45% of the fossil fuel and cement emissions of CO2 in the late 1980s

- While ODS levels remain high, a large stratospheric sulfuric aerosol enhancement due to a major volcanic eruption or geoengineering activities would result in a substantial chemical depletion of ozone over much of the globe.

While past actions taken under the Montreal Protocol have substantially reduced ODS production and consumption, additional, but limited, options are available to reduce future ozone depletion

- Emissions from the current banks are projected to contribute more to future ozone depletion than those caused by future ODS production, assuming compliance with the Protocol.
- Possible options to advance the return of the ozone layer to the 1980 level (analyses based on midlatitude EESC) are shown graphically. The cumulative effect of elimination of emissions from all banks and production advances this return by 11 years.

II. Executive Summary, Environmental Effects of Ozone Depletion and its Interactions with Climate Change: 2014 Assessment

Ozone Depletion and Climate Change

- The Montreal protocol continues to be effective.
- As a result of the success of the Montreal Protocol in limiting ozone depletion, changes in UV-B irradiance measured at many sites since the mid-1990s are due largely to factors other than ozone.
- Large short-term increases in UV-B irradiance have been measured at some locations in response to episodic decreases of ozone at high latitudes.
- Future levels of UV-B irradiance at high latitudes will be determined by the recovery of stratospheric ozone and by changes in clouds and reflectivity of the Earth’s surface.
- With continued effective implementation of the Montreal Protocol, future changes in UV-B irradiance outside the Polar regions will likely be dominated by changes in factors other than ozone.

Human Health

- Changing behaviour with regard to sun exposure by many fair-skinned populations has probably had a more significant effect on human health than increasing UV-B irradiance due to ozone depletion.
- Immediate adverse effects of excessive UV-B irradiation are sunburn of the skin and inflammation of the eye (photoconjunctivitis or photokeratitis). Long-term regular low-dose or repeated high-dose exposure to the sun causes melanoma and non-melanoma (basal and squamous cell) carcinomas of the skin and cataract and pterygium (a growth on the conjunctiva) of the eye.
- The success of the Montreal Protocol has been highlighted by model simulations that compare the environmental implications of ozone depletion in the ‘future world avoided’ with that of our expected future with the implementation of the Montreal Protocol. In particular, it has been concluded that the implementation of the Montreal Protocol has been instrumental in preventing serious health risks such as skin cancer and cataract. In simulations taking also climate change into account, the UV index would have increased by more than a factor of three in the second half of this century relative to that at the start of the century.
- The major known beneficial effect of exposure of the skin to solar UV radiation is the synthesis of vitamin D.
- Strategies to avoid over-exposure to solar UV radiation include staying indoors, seeking shade, wearing protective clothing, brimmed hats and sunglasses, and applying sunscreens. These methods should aim to balance the harmful and beneficial effects of sun exposure.
- Climate change may affect personal sun-exposure behaviour, but the impact is likely to vary according to season and location.

Terrestrial Ecosystems

- The effects of UV-B radiation on plants are influenced by various abiotic and biotic factors in ways that can have both positive and negative consequences on plant productivity and functioning of ecosystem.
- Exposure to UV-B radiation can increase or decrease rates of decomposition of dead plant matter (litter), depending on prevailing climate and the chemistry and structure of the litter.
- Solar UV radiation has the potential to contribute to climate change via its stimulation of emissions of carbon monoxide, carbon dioxide, methane, and other volatile organic compounds from plants, plant litter and soil surfaces
- While UV-B radiation does not penetrate into soil to any significant depth, it can affect a number of belowground processes through alterations in aboveground plant parts, microorganisms, and plant litter.
- Terrestrial ecosystems in the Southern Hemisphere are being affected by the Antarctic ozone ‘hole.’

Aquatic Ecosystems

- Climate change and UV radiation affect phytoplankton productivity and species composition of marine ecosystems.
- Interactions between climate change and UV radiation are having strong effects on aquatic ecosystems that will change in the future due to feedbacks between temperature, UV radiation and greenhouse gas concentrations.
- Warming of the ocean results in stronger stratification that decreases the depth of the upper mixed layer.
- Increased concentrations of atmospheric CO2 are continuing to cause acidification of the ocean, which alters marine chemical environments with consequences for marine organisms.
- Climate change-induced increases in concentrations of dissolved organic matter (DOM) in inland and coastal waters reduce the depth of penetration of UV radiation.

Biogeochemical Cycles

- Climate change modulates the effects of solar UV radiation on biogeochemical cycles in terrestrial and aquatic ecosystems resulting in UV-mediated positive or negative feedbacks on climate.
- Solar UV radiation is driving production of substantial amounts of carbon dioxide from Arctic waters.
- The changes in climate associated with the Antarctic ozone ‘hole’ include changes to wind patterns, temperature and precipitation across the Southern Hemisphere.
- The carbon cycle is strongly influenced by interactions between droughts and intensity of UV-radiation at the Earth’s surface.
- Lignin present in all terrestrial vegetation plays a significant role in the carbon cycle, sequestering atmospheric carbon into the tissues of perennial vegetation.

Air Quality

- UV radiation is an essential driver for the formation of photochemical smog, which consists mainly of ground-level ozone and particulate matter. Recent analyses support earlier work showing that poor outdoor air quality is a major environmental hazard.
- Future air quality will depend mostly on changes in emission of pollutants and their precursors; changes in UV radiation and climate will also contribute.
- Decrease in UV radiation associated with recovery of stratospheric ozone will, according to recent global atmospheric model simulations, lead to increases in groundlevel ozone over large geographic scales.
- UV radiation affects the atmospheric concentration of hydroxyl radicals, ·OH, which are responsible for the self-cleaning of the atmosphere.

- No new negative environmental effects of the substitutes for the ozone depleting substances or their breakdown-products have been identified. However, continued measurement of the emissions of TFA and its precursors, HCFC and HFC, will be important for avoiding unexpected consequences of potential increases.

Materials

- A trend towards environmentally sustainable materials in building has increased the use of wood and wood-plastic composites.
- The role of solar UV radiation in creating microplastics debris in the oceans from the weathering of plastic litter on beaches is an emerging environmental issue.
- Nanoscale inorganic fillers can provide superior stability against solar UV irradiation relative to conventional fillers in coatings and plastics.
- Clothing and glass can provide protection against exposure to solar UV radiation.

III. Summary, Technology and Economic Assessment Panel: 2014 Assessment

Overall key message

The Montreal Protocol is working because control measures have created incentives for new technology, because enterprises and organizations have worked hard to implement new technology and because the Multilateral Fund (MLF) has financed the agreed incremental costs of the transition for Article 5 Parties. With reaching each key phase-out milestone and with implementation of each new phase of technology, the Montreal Protocol has succeeded in reducing the production, use, and emissions of ODSs most of which are also potent greenhouse gases. Through these efforts, the world has avoided significant economic, environmental and health consequences of increases in ultraviolet radiation and climate change.

Significant technical progress

Progress in the transition to alternatives continues in every sector, resulting in significant benefits to the ozone layer and climate:

- All major ODS controlled under the Montreal Protocol continue to decline rapidly or have been phased out with a consequent impact on ozone layer recovery.
- Process agent uses are likely to continue to decline in the future as old products and manufacturing processes change, for example because of the use of different feedstocks. Similarly, solvent use of ODS has decreased substantially so that very few uses remain and alternative solvents are widely available.
- The phase-out of CFCs for MDIs is 98% complete. Technically and economically feasible alternatives to ODS are available for other medical aerosols, and there are a range of viable methods that can replace ODS for sterilisation.
- Almost 90% of controlled uses of methyl bromide have been phased out. Because 77% of MB applied is emitted to the atmosphere, the reduction in MB consumption, together with the short half-life of MB (0.7 years) has led to an equivalent 35% fall in stratospheric chlorine levels, a key contribution to ozone layer recovery.
- Adequate amounts of recycled halon stocks appear to be available to meet known needs for the immediate future.
- Even with continued growth in global use of foam blowing agents, progress continues in the transition away from ODS and the search for low-GWP options based on future availability and cost, particularly in the XPS sector. Blowing agent use in non-article 5 parties has doubled in the last decade, but hydrocarbons now account for 50%. One encouraging factor, particularly with HFOs/HCFOs, is that the thermal performance of the foams is, as a minimum, retained and in many cases improved over the HCFCs and HFCs that they are likely to replace. First phase HPMP implementation targeting HCFC-141b phase-out is generally running smoothly and especially within larger enterprises able to justify investment in hydrocarbon technologies.

- The refrigerant options available, and emerging today address the phase-out of ODS, especially HCFC-22, as well as concerns about climate change. However, the perfect refrigerant that is safe, low cost, energy efficient, environmentally sound for all uses is not yet available, nor is it likely to be developed. Refrigerants with a low direct climate impact are often flammable to some degree, and balancing this safety risk is an important issue both for companies and end users in the RAC sector. The use of carbon dioxide in commercial refrigeration is growing rapidly is driving several new refrigeration cycle concepts, such as the use of ejectors in the expansion process.

Challenges

Continuing progress across the various sectors will require Parties to take advantage of opportunities offered by new technologies and to remain vigilant to addressing the significant challenges that remain, and avoid nullifying the benefits achieved under the Protocol:

- Both governments as well as industry are making successful efforts to minimize emissions associated with ODS use in feedstock applications, however this use should continue to be monitored to ensure limited environmental impacts.
- Some progress has been reported by Parties on laboratory analytical methods that do not use ODS, however further work will be needed to ensure that alternative methods are adopted into national and international standards.
- It is technically and economically feasible to phase out remaining HCFC use in medical aerosols and sterilization.
- Exempted QPS uses are offsetting gains from phase-out of controlled use of MB while alternatives are immediately available for 40% of QPS uses. Article 5 Parties face challenges with illegal use and trade of MB because of weak tracking, combined with confusion between controlled and exempted QPS uses.
- In the absence of production for controlled uses of halons, important, continuing uses such as legacy military, aviation, and other systems, and uses on new aircraft are dependent on the global availability of recovered, recycled and reclaimed halons. These should meet international purity standards to reach markets where they are needed. Avoiding disruption in the supply of halon from banks, will require the collective efforts of Parties to address the uncertainty in the global inventory, to ensure purity standards are met, to address barriers to movement, and to ensure the ICAO transition goals for halons in aviation are met where alternatives are available.
- In foams, managing transition for the multitude of SMEs in both Article 5 and non-Article 5 parties remains a challenge, where lack of economies of scale may prevent investment in flammable solutions, leaving high GWP solutions as the only option, often with considerable emissions.
- Global banks of blowing agents in foams have been previously estimated to have grown from around 3 million tonnes in 2002 to an estimated 4.45 million tonnes (inclusive of hydrocarbons) in 2015. The opportunity to realize potential ozone and climate benefits from destroying unwanted ODS within banks, is declining as much of the ODS component of these banks will already be in the waste stream by 2020 as many products with limited lifecycles (e.g. appliances) reach the end of life.
- Due to the wide range of new refrigerants being developed and marketed, it is often quite difficult to identify the best refrigerant for each application. In particular, the challenge to determine the best refrigerants is most important in all commercial refrigeration sub-sectors, with their typical high demand for servicing, as well as in the rapidly growing air-to-air air conditioning sector, particularly in Article 5 countries. There is a major effort underway to address both the energy efficiency of the new refrigerants and the related safety issues in applications. The safe handling of refrigerants is of particular concern to Article 5 countries, and will require the establishment of good practice standards, and intensive education and training.
- Continuing and emerging issues for stratospheric ozone (e.g., carbon tetrachloride, very short-lived substances, and N2O) will require the continued coordination of TEAP and the other Panels in order to inform the discussions and decisions of Parties related to these issues.

Consideration of low-GWP alternatives

- In various decisions during this reporting period, Parties increasingly consider the implications for climate to a greater degree during the ongoing phase-out of ODS and HCFCs in particular, with discussions facilitated by TEAP's review of the status of substitutes.
- There is a complex selection process ahead, where the market will have to determine which of the many proposed new and old refrigerants will and can be used in the wide variety of RAC applications. It is premature to tell how many of the current low GWP refrigerant options will survive, and eventually the number of refrigerants candidates is likely to decrease. The continued rising global demand for refrigeration and air conditioning equipment represents both important environmental protection opportunities and challenges.
- In the short term, during the next 5-10 year period, industry is expected to progressively introduce low GWP alternatives, including carbon dioxide, hydrocarbons and other flammable alternatives. It is likely that different manufacturers and countries will opt first for a variety of alternatives before a single option is chosen (if at all). In the meantime, investigations will continue into "medium" GWP flammable HFCs, blends of saturated and unsaturated HFCs and HCs for both normal operating conditions as well as for high ambient temperature conditions.
- There will be a complex set of factors to be resolved, which once dealt with, will reduce the climate impact of RAC equipment operation. In addition to the choice of low GWP refrigerants, equipment (re-) design and changes in concept, are important drivers. These factors together will define the next generation of RAC equipment in the large variety of sectors.
- Regardless of the sector, technology transitions that can coincide with other process upgrades will be more cost-effective. The costs will be least where new RAC and foam manufacturing capacity investment is directed away from high-GWP options at the outset. Hence, efforts should be focused on ensuring that low-GWP options are well proven at the earliest opportunity in order to inspire investment confidence.

Annex II

Decision XXVI/9 task force report: additional information on alternatives to ozone-depleting substances[a]

Executive summary

ES1. Introduction

- In response to Decision XXVI/9, this report provides an update from TEAP of information on alternatives to ozone-depleting substances listed in the final report October 2014 which responded to Decision XXV/5. The report provides updates considering the specific parameters outlined in the current Decision for various sectors and sub-sectors of use. As these parameters were similar to past Decisions (XXIV/7 and XXV/5), TEAP followed the same methodological approach, where no quantitative threshold or importance of one parameter over others was necessarily assumed.
- With a specific focus on the refrigeration and air conditioning (R/AC) sector, particularly the dramatic, growing demand for this equipment in Article 5 Parties and the resulting increased refrigerant demand, the report also provides further consideration on topics related to energy efficiency and ongoing testing programs on the viability of low-GWP options at high ambient temperature conditions. It is important reiterating that decisions on the selection of alternative technologies may vary depending on the sector being addressed, and the outcomes, even within the same sector, may be very different depending on the local conditions. Ultimate alternative selection has to be made on a case-by-case basis.
- The report provides revised scenarios of avoiding high GWP refrigerants to include new assumptions on the GWP of the alternatives to be used and considers the impact of the conversion period of new manufacturing through two new mitigation scenarios. Technology transitions that can coincide with other process upgrades are likely to be more cost-effective. The costs will be least where new R/AC manufacturing capacity investment is directed away from high-GWP options at the outset. The scenario analysis indicates that by delaying and extending the conversion period, the climate impacts and overall costs may be increased. Assuming no new purchase of high-GWP equipment once conversion takes place, the increased costs would be attributed to addressing continuing servicing needs for an extended period. It would also be important to consider to shorten the length of the manufacturing conversion period as much as possible in order to minimize climate and cost impacts.
- Finally, the report also provides updated information on the alternatives listed in the previous Decision XXV/5 report for the fire protection sector, MDIs, other medical, and non-medical aerosols sectors.

The following section ES2 provides key highlights of this report, and sections ES3 to ES9 further elaborate on the highlights and provide the technical summaries of the report's main chapters. ES10 provides considerations for an updated report.

ES2. Key highlights

- **Refrigerant options**: New information on existing refrigerant options has been obtained from assessments of additional reports and publications. Information is presented on 70 fluids under consideration for testing in industry test programs or proposed for inclusion in standards, with emphasis on the commercial refrigeration and stationary AC subsectors. Updates include the following:
  - Recently published thermodynamic data for 11 of the fluids taking part in the high ambient test programs (with 5 of these refrigerants proposed to replace HCFC-22, while 6 are proposed to replace R-410A).
  - By 2020 about 75% of new domestic refrigeration production would use HC-600a.
  - In supermarket refrigeration systems there is confirmation of the strong growth in CO2 systems; CO2 system costs are decreasing.

[a] Issued without formal editing.

  - Split AC systems using HFC-32 are being commercialized in Japan and other countries. HCFC-22 equipment production capacity is being converted to HC-290 in China and HFC-161 is being tested there.

- **Revised scenarios**: The revised scenarios in this report include new assumptions on the GWP of alternatives to be used and an analysis on the impact of the conversion period of new manufacturing (MIT-3 and -4). These scenarios for the R/AC sector were cross-checked against the estimated global 2015 production of the four main high-GWP HFCs, used in the R/AC sector.

  - BAU predicts a large growth in the demand for HFCs between 2015 and 2030 for the R/AC sector (i.e., 300% further increase in Article 5 Parties, mainly in stationary air conditioning).

  - As shown in MIT-3, conversion periods are important to consider in terms of climate impacts and costs, and the delay of conversion i.e., 12 versus 6 years, would directly lead to significant increased climate impact and increased overall cost, from meeting continuing servicing needs.

  - In terms of overall climate impact, the total integrated HFC demand for the R/AC sector in Article 5 Parties over the period 2020-2030 has been estimated. The approximate values are:

    BAU: 17,900 Mt CO2 eq.

    MIT-3: 7,100 Mt CO2 eq.

    MIT-4: 10,700 Mt CO2 eq.

- The costs of the conversion of new manufacturing in MIT-3 in Article 5 Parties are estimated to be 75% for stationary air conditioning, 10% for commercial, industrial and transport refrigeration, and 10% for mobile air conditioning. Total costs calculated for manufacturing conversion alone in Article 5 Parties are estimated at about US$ 2400 ± 340 million for the period 2020-2030; addressing servicing would add to this amount. The MIT-4 scenario results in additional US$ 700 million costs, with a much larger variation in the cost profile than for MIT-3 over the same period.

- **High ambient temperature conditions:** Designing for high ambient temperature conditions needs special care to avoid extreme operating conditions, which would complicate meeting minimum standards. This report details advantages and limitations of the available refrigerants suitable for use in high ambient temperature conditions. Four separate testing projects are assessing refrigerant performance at high ambient temperature conditions. Data may be available by MOP-27, and if so, TEAP can provide an analysis of entities reporting on them.

- **Fire protection, Metered Dose Inhalers (MDIs), other medical and non-medical aerosols:** Even with the halon transition well underway for new installations in fire protection (with the exception of civil aviation), some reliance on high-GWP HFC solutions is expected for the foreseeable future. Similarly, at present, it is not technically or economically feasible to avoid HFC MDIs, even though all classes of drugs are available in Dry Powder Inhalers (DPIs). While consumption of HFC in non-medical and technical aerosols sector is the third largest after the R/AC and foams sectors, Low-GWP propellants and solvents are commercially and widely available, and “not-in-kind” alternatives are commercially available where they are suited for the purpose.

ES3. Status of ODS alternatives in refrigeration, air conditioning and heat pumps applications

- The options for replacing ODS and high GWP refrigerants have not changed since the finalization of the XXV/5 Task Force report in October 2014 and the completion of this XXVI/9 Task Force report. Nevertheless, new information on these existing options has been obtained from Parties and assessments of additional reports and publications.

- In summary, in the period available for the development of this report the following updates are highlighted:

  - Information is presented on 70 fluids under consideration for testing in industry test programs or for inclusion in the ASHRAE 34 and ISO 817 standards, including recently published thermodynamic data for 11 of the fluids taking part in the high ambient test programs (with 5 of these refrigerants proposed to replace HCFC-22, while 6 are proposed to replace R-410A).

- The testing activities of unsaturated HFCs (HFOs), and blends containing these compounds, continue to be carried out in many companies, independent laboratories, and systems manufacturers.
- Special test programs are being performed with a focus on high ambient temperature conditions.
- Some refrigerants have now been assigned a refrigerant number and their composition now publicly disclosed.
- Regarding R/AC applications, the main points are:
    - *Domestic refrigeration:* No new ODS alternatives have emerged. By 2020 about 75% of new production is predicted to use HC-600a.
    - *Commercial refrigeration:* No new ODS alternatives have emerged; hydro-carbons are being used in condensing units for smaller capacities; in supermarket refrigeration systems there is confirmation of the strong growth in CO_2 systems; information is available that CO_2 system costs are decreasing.
    - *Transport refrigeration:* blends containing unsaturated HFCs are considered to play a role for retrofitting and new systems, and non-conventional eutectic systems are becoming more applied.
    - *Air conditioners:* Split systems using HFC-32 are being commercialized in Japan and other countries; a wide range of blends containing unsaturated HFCs are also being proposed. Split units using HC-290 have been available in Europe and Australia, and are in production in India. HCFC-22 equipment production capacity is being converted to HC-290 in China and HFC-161 is being tested there.
    - *MAC:* Industry is now reporting more testing data on R-445A.

ES4. BAU and mitigation demand scenarios

- Decision XXV/5 requested an assessment of various scenarios of avoiding high GWP alternatives to ODS, and the TEAP Task Force report which responded to that Decision provided projections for high-GWP HFC use for BAU, and two mitigation scenarios (MIT-1 and MIT-2), for R/AC and foams sectors, and for non-Article 5 and Article 5 Parties. MIT-1 and MIT-2 assumed a phase-out date of 2020 for the use of high GWP substances in manufacturing for most R/AC sub-sectors. The XXVI/9 Task Force is unaware of any significant technical uptake that would require a complete revision of these parameters in the scenarios. However, the XXVI/9 Task Force has revised the scenarios for the R/AC sector to include the following new assumptions:
    - an average GWP of 300 for low GWP refrigerants;
    - manufacturing conversion periods of 3 years for non-Article 5 Parties, and 6 years for Article 5 Parties;
    - conversion commencing in 2020 to make a new scenario, MIT-3, and delayed conversion of manufacturing for all stationary AC to 2025 to make a new scenario, MIT-4.
- In the preparation of this report, these scenarios (in principle for the R/AC sector only) were cross-checked against current estimated HFC production data that became available in May 2015. Estimates made for the 2015 global production of the four main HFCs[b] are presented in the table below; it shows an upper limit for the combined totals of about 540 ktonnes.

[b] These are the four main HFCs used in the R/AC sector; HFC-134a is also used in foams, MDIs, aerosols.

Chemical	Estimated global HFC production in year 2015 (ktonnes)
HFC-32	80-95
HFC-125	115-130
HFC-134a	240-280
HFC-143a	25-35

- BAU: Over the period 2015-2030, the revised BAU scenario shows a 50% growth in the demand for high GWP HFCs in non-Article 5 Parties, and a 300% growth in Article 5 Parties, particularly in the stationary AC and commercial refrigeration sub-sectors, where the stationary AC sub-sector is the important one for determining the total HFC demand for the four main HFCs. The total demand is calculated to be in the range of 500-600 ktonnes for the year 2015 for these four HFCs.
- By 2030, under a BAU scenario, the high-GWP HFC demand for the R/AC sector, expressed in CO_2 eq., is expected to be 25-30 times larger than HFC demand for foams.
- In terms of overall climate impact, the *total* integrated HFC demand in Article 5 Parties over the period 2020-2030 has been determined. The approximate values are:
  - *BAU: 17,900 Mt CO_2 eq.*
  - *MIT-3: 7,100 Mt CO_2 eq.; a 60% reduction to BAU*
  - *MIT-4: 10,700 Mt CO_2 eq.; a 40% reduction to BAU*
- The MIT-3 and MIT-4 scenarios focus on demand in Article 5 Parties:
  - MIT-3 substantially reduces the high-GWP HFC demand compared to BAU since it addresses all manufacturing conversions in all R/AC subsectors as of 2020. As manufacturing with high GWP refrigerants is phased down, the servicing demand becomes dominant. The stationary AC sub-sector is determining HFC demand.
  - MIT-4 delays manufacturing conversion of the rapidly expanding stationary AC sector from 2020 until 2025, so that HFC demand initially rises, but then falls as of the year 2025. Servicing rises substantially as a consequence, and persists for longer than MIT-3. MIT-4 defers the conversion periods for R/AC subsectors and shows the impact of the pertaining servicing needs as a result..
- The following is also of importance:
  1. MIT-3 results in a reduction of about 80% in the year 2030, if compared with BAU, at a level of 1,800 Mt CO_2-eq. (on a BAU 2030 total of about 2,250 Mt CO_2-eq.).
  2. By shifting the start of the conversion of stationary AC to the year 2025 in the MIT-4 scenario, the reduction in HFC demand, if compared to BAU, is reduced to about 1,500 Mt CO_2-eq. in the year 2030 (compare “1” above).
  3. Delaying and extending the conversion period for the stationary AC sector that is expected to be dominant significantly increases the climate impact. Even when this seems moderate until the year 2030, the total impact including the period after 2030 is significant and emphasises the impact of conversion delays on total climate impact.

ES5. Demand, benefits and costs

- Costs have been determined from bottom-up calculations for the R/AC sector in Article 5 Parties. The total demand determined for non-Article 5 and Article 5 Parties for the R/AC sector has been shown to be higher than expected based on currently available HFC production estimates. Early indications for refined calculations, to be made for the update report, are that the costs derived here might be 10-20% too high.
- For MIT-3, the HFC amounts estimated for the year 2020 are taken to be the HFC amounts in new manufacturing that require conversion. The conversion can be modelled during 6-12 years; it does not make a difference how long the conversion period would be for the total amounts to be converted. The conversion period, however, would have major impacts on the servicing amounts. Estimates for the conversion in US$ per kg that vary from US$ 4-7 for commercial refrigeration field assembly, to US$ 11-13 for stationary AC. All conversions are based on conversion to a low GWP (300) refrigerant. For the costs of the conversion of new

manufacturing, 75% is estimated to be for stationary air conditioning, 10% for commercial, industrial and transport refrigeration, and 10% for mobile air conditioning.

- The total costs calculated for manufacturing conversion in Article 5 Parties are estimated at about US$ 2400 ± 340 million. If conversions would be spread over six years, this would correspond to costs of about US$ 1200 ± 170 million per triennium. If conversions would be spread over 12 years, this would correspond to costs of about US$ 600 ± 85 million per triennium (with large amounts of servicing refrigerant required after 2025).

- For MIT-3, the servicing amounts are in the order of 100-200 ktonnes during 2020-2030. The amounts decrease substantially between 2025 and 2030, due to the fact that equipment reaches its end of life. Assuming that 40-60 ktonnes HFCs consumption can be reduced in the servicing sector, spread over at least four triennia, it would imply costs of US$ 40-60 million per triennium.

- The costs would change for MIT-4. Spread over 6 years, MIT-4 results in an additional US$ 350 million on average per triennium, which would correspond to a 30% increase in costs. However, because the stationary AC conversion would not start until 2025, the cost profile for conversion would change substantially. Distribution of the total of US$ 3100 million would be more or less US$ 150 million in the first two triennia (as of 2020), followed by US$ 1400 million for the following triennia. This outcome needs further analysis.

ES6. Considerations for high ambient temperature conditions

- Designing for high ambient temperature conditions needs special care to avoid excessively high condensing temperatures and approaching the critical temperature for each type of refrigerant considered in order to meet minimum energy performance standards. Other issues, such as safety and refrigerant charge quantity, also have to be taken into consideration.

- The range of suitable refrigerants for high ambient temperatures has not changed since the Task Force XXV/5 report in October 2014. Additional research and assessment of those refrigerants at high ambient temperatures has been undertaken, for example, through the recent project by the US Department of Energy (DoE), the UNEP/UNIDO PRAHA and EGYPRA projects, and the AHRI initiative of AREP-II for high ambient temperature conditions.

- The schedule for completion of the mentioned projects are as follows:
  - AHRI-AREP II: Autumn 2015;
  - US DoE: Preliminary report - July 2015; Final report - October 2015;
  - UNEP/ UNIDO - PRAHA: 4th quarter 2015;
  - UNEP/ UNIDO - EGYPRA: Early 2016.
  - This report details advantages and limitations of the available refrigerants suitable for use in high ambient temperatures are discussed as follows:
  - *For air conditioners:* R-407C, R-410A, HFC-32, HC-290, HC-1270, R-446A and R-447A, and R-444B. The use of HFC-1234yf and especially HFC-1234ze(E), have not been seriously considered for ACs because their volumetric capacity is low, which would require bulkier systems along with high anticipated refrigerant price.
  - *For chillers:* R-447A, R-410A, R-717, R-718, and R-1233zd. The use of R-744 is not suitable for high temperature climates due to excessive cost.
  - *For commercial refrigeration:* Refrigeration systems at high ambient temperature conditions have the same issues as air conditioning systems; compressor discharge temperatures increase with increasing ambient and condensing temperatures, leading to possible reliability issues and lower efficiency. Unlike AC, refrigeration applications are already subject to high discharge temperatures and use mitigation methods like compressor liquid or vapor injection to improve performance and reliability.

ES7. Fire protection

- The process for assessing and qualifying new fire protection agents for use is complex, time consuming, and is also application specific. Whilst the phase-out of ODS in this sector is well underway, there will be some reliance of high-GWP HFC solutions for the foreseeable future. Control of avoidable emissions continues to improve, thereby minimising impacts.

- Two chemicals are at an advanced stage of testing and development and may be commercialised as fire extinguishing agents in the future. It is not anticipated that high ambient temperatures or high urban densities will affect market uptake of these agents. These new chemicals are

  a) FK-6-1-14

  b) 2-Bromo-3,3,3-trifluoropropene

Note that civil aviation is trying to meet the International Civil Aviation Organisation's (ICAO) 31st December 2016 deadline for the replacement of halon handheld portable extinguishers using this agent. The required regulatory process for commercialisation / manufacturing in Europe (*Registration, Evaluation, Authorisation and Restriction of Chemicals* - REACH registration) has been completed but in the United States the required listing as acceptable under the Significant New Alternatives Policy (SNAP) program and approval under the Toxic Substances Control Act (TSCA) is not yet completed. If successful, from a performance and environmental perspective, this agent will likely be the most effective replacement for halon 1211 applications. However, according to its manufacturer, the agent is anticipated to be at least double the cost of other clean agent alternatives, and will require stabilisers to maintain the material in long-term storage. For these reasons, the agent is only likely to fill the needs of niche applications where its lower weight and superior fire protection performance justify the higher cost.

ES8. Medical uses

- *Metered dose inhalers:* Inhaled therapy is essential for the treatment of asthma and chronic obstructive pulmonary disease (COPD). There are two main types of inhalers for the delivery of respiratory drugs: the metered dose inhaler (MDI) and the dry powder inhaler (DPI). HFC MDI and DPI alternatives are available for all key classes of drugs used in the treatment of asthma and COPD. Under a business as usual model, for the period 2014 to 2025, cumulative HFC consumption in MDI manufacture is estimated as 124,500 tonnes (119,000 tonnes HFC-134a; 5,500 tonnes HFC- 227ea), corresponding to direct emissions with a climate impact of approximately 173 Mt CO_2-eq. This impact would be significantly less than the climate impact of CFC MDIs had they not been replaced. At present, it is not yet technically or economically feasible to avoid HFC MDIs completely in this sector.

- *Other medical aerosols:* Medical aerosols, excluding MDIs, are estimated as a small percentage (1-2 per cent) of total aerosol production. These medical aerosols include a wide range of uses from simple numbing of pain, nasal inhalation, to the dosage of corticosteroids for the treatment of colitis. Technically and economically feasible alternatives to ozone-depleting propellants and solvents (CFCs and HCFCs) used in non-MDI medical aerosols are available. Most aerosols use hydrocarbons and DME propellants. HFCs are used where a non-flammable or safe to inhale propellant is needed, or where emissions of volatile organic compounds (VOCs) are controlled. It is estimated that less than 10 per cent of non-MDI medical aerosols use HFC propellants (-134a, -152a), i.e., less than 1,000 tonnes per year.

- *Sterilants:* There is almost non-existent use of HFCs in the sterilants sector, where a wide variety of alternatives available and the impact of avoiding HFCs would be minimal.

ES9. Aerosols

- Aerosols can be divided into three main categories: consumer aerosols; technical aerosols; and medical aerosols. Technically and economically feasible alternatives to ozone-depleting propellants and solvents (CFCs and HCFCs) are available for aerosol products.

- In 2010, the total GWP-weighted amount of HFCs used in aerosol production was estimated as 54 Mt CO2-eq., or 5 per cent of total GWP-weighted HFC consumption. Consumer and technical aerosols account for about three-quarters of GWP-weighted HFC consumption in aerosol production, and medical aerosols, including MDIs, for the remaining quarter. Global production of HFC-containing aerosols is likely to be growing very slowly, if at all. Nevertheless, there may be individual countries where HFC aerosol production is growing. Production is likely to increase in Article 5 Parties while it flattens or declines in non-Article 5 Parties.

- HFC consumption in this sector is ranked as the third largest after the R/AC and foams sectors, and aerosols are a totally emissive use. There could be significant environment benefits in avoiding high GWP propellants and solvents. Low-GWP propellants and solvents are commercially and widely available, and "not-in-kind" alternatives are commercially available where they are suited for the purpose. In some markets or for some products there may be significant challenges in adopting low-GWP options, and their use may not be feasible. Reformulation would incur costs to industry.

ES10. Considerations for updates to report

- Throughout the report, various topics are noted that could be considered in an update of the information contained in this report. For the update report, Parties may wish to consider asking the TEAP Task Force if a further elaboration of some of the following would be helpful, while taking into account the availability of information and the limited time for the TEAP Task Force to complete this update for MOP-27:

  1. The R/AC sub-sectors where commercialisation of alternatives is not yet clear, and which efforts should be undertaken;
  2. The potential of not-in kind alternatives for all R/AC subsectors;
  3. Further investigation of the use of certain parameters -and their values- in the various HFC demand scenarios, which should also result in modelling outcomes for the year 2015 that are consistent with the estimated 2015 HFC production for R/AC;.
  4. Further elaboration on a shift of manufacturing conversion to later years for certain sub-sectors;
  5. Further investigation of the HFC demand scenarios on conversion costs calculated for all R/AC subsectors;
  6. An analysis and conclusion of possible results of the refrigerant testing programs particularly including issues related to high ambient temperature conditions, since results were not available in the current report, and the resulting consequence of a possible uptake of certain alternatives;
  7. Further quantification of foams, MDIs, other medical and non-medical aerosols, where it concerns the demand predicted for the next 15 years, as far as new information will become available to the TEAP XXVI/9 Task Force.