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Twenty-Eighth Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer
Kigali, 10–14 October 2016

Issues for discussion by and information for the attention of the Twenty-Eighth 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 Twenty-Eighth Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer (UNEP/OzL.Pro.28/2) contains additional information for the parties' consideration. Section II presents information related to parties' submissions on policies and measures related to hydrofluorocarbons (HFCs) and section III sets out information that has become available since the preparation of the note by the Secretariat on 23 August 2016.

2. Information that has become available since the preparation of the note by the Secretariat is included in the reports by the Technology and Economic Assessment Panel published in four volumes in September 2016. One of those reports was prepared in cooperation with the Scientific Assessment Panel. The reports are as follows:

(a) Report of the Technology and Economic Assessment Panel, September 2016, volume I: Decision XXVII/4 task force update report: further information on alternatives to ozone-depleting substances;

(b) Report of the Technology and Economic Assessment Panel, September 2016, volume II: Decision Ex.III/1 working group report: climate benefits and costs of reducing hydrofluorocarbons under the Dubai Pathway;

(c) Report of the Technology and Economic Assessment Panel, September 2016, volume III: evaluation of 2016 critical-use nominations for methyl bromide and related matters;

(d) Report of the Technology and Economic Assessment Panel and the Scientific Assessment Panel, September 2016, volume IV: Decision XXVII/7 report: investigation of carbon tetrachloride discrepancies.

3. In addition, the present note presents, for the parties' ease of reference, information on the membership of the Technology and Economic Assessment Panel.

II. Submissions by parties on policies and measures related to hydrofluorocarbons

4. In paragraph 3 of decision XXVI/9, adopted by the Twenty-Sixth Meeting of the Parties in November 2014, parties were encouraged to continue to provide to the Secretariat, on a voluntary basis, information on their implementation of paragraph 9 of decision XIX/6, including information on available data, policies and initiatives pertaining to the promotion of a transition from ozone-depleting substances that minimizes environmental impact wherever the required technologies are available, and to request the Secretariat to compile any such submissions received. In response to that decision, many parties have since submitted the requested information, compiled by the Secretariat in several information notes[1] and summarized in two reports.[2]

5. Following the presentation of the Secretariat's revised summary report to the Twenty-Seventh Meeting of the Parties in November 2015, two parties, Australia and the United States of America, provided updated and new information on national policies and measures related to HFCs. The submissions of those parties are compiled in an information document (UNEP/OzL.Pro.28/INF/3) while a summary of their key points is included in the updated summary of information submitted by parties on their implementation of paragraph 9 of decision XIX/6 to promote a transition from ozone-depleting substances that minimizes environmental impact (decision XXV/5, paragraph 3) (UNEP/OzL.Pro.28/11).

6. The parties may wish to review the updated summary and the compilation and discuss them under agenda item 6, Dubai pathway on hydrofluorocarbons (decision XXVII/1), to which they relate. Parties may also wish to consider whether any follow-up actions are needed.

III. Overview of items on the agenda for the preparatory segment (10–12 October 2016)

A. Report by the Technology and Economic Assessment Panel on updated and new information on alternatives to ozone-depleting substances (decision XXVII/4) (item 4 of the provisional agenda for the preparatory segment)

7. Since the preparation of the note by the Secretariat,[3] the Technology and Economic Assessment Panel and its task force on decision XXVII/4 have completed its third report, taking into consideration the comments and suggestions received from parties at the thirty-eighth meeting of the Open-ended Working Group,[4] as well as additional information available to the task force. The present report is the third and final one prepared by the task force on decision XXVII/4.[5] While the first two reports focused on the refrigeration and air-conditioning sector, the present report also covers the foam, metered-dose inhaler and aerosol sectors. Much of the information contained in the two previous reports remains unchanged but has been consolidated in the final report so it may be used as a single reference document for the Twenty-Eighth Meeting of the Parties.

8. In particular, the Panel's final report includes:

(a) Previously presented information on updates regarding the status of refrigerants;

(b) Further updates on refrigerant alternatives and new technologies currently in use in the refrigeration and air-conditioning sector, as well as updated information on how standards are being developed to address issues such as safety;

(c) Minor updates on alternatives to refrigeration systems on fishing vessels regarding the rating of different options;

[1] UNEP/OzL.Pro.WG.1/34/INF/4, UNEP/OzL.Pro.WG.1/34/INF/4/Add.1, UNEP/OzL.Pro.WG.1/34/INF/4/Add.2, UNEP/OzL.Pro.26/INF/4, UNEP/OzL.Pro.WG.1/35/INF/2 and UNEP/OzL.Pro.WG.1/36/INF/2.

[2] UNEP/OzL.Pro.26/9 and UNEP/OzL.Pro.27/11.

[3] UNEP/OzL.Pro.28/2, paras. 20–24.

[4] UNEP/OzL.Pro.WG.1/38/8, paras. 17–32.

[5] The first and second reports were submitted to the Open-ended Working Group at its thirty-seventh and thirty-eighth meetings (April and July 2016), respectively.

(d) Previously presented information related to the testing programmes on alternatives under high ambient temperature conditions and a limited review of countries subject to such conditions in response to comments received on the high ambient temperature criterion used;

(e) Business-as-usual (BAU) and mitigation demand scenarios as presented in the Panel's second report, based on the same existing regulations considered in that report, but also including additional information on the production of various HFCs that are important for the refrigeration and air-conditioning, foam blowing, fire protection, metered-dose inhaler and aerosol sectors; a comparison of estimated HFC production with the global calculated HFC demand for the refrigeration and air-conditioning and other sectors; and updated tables for total, new manufacturing and servicing demand;

(f) New information on alternative blowing agents for the various types of foam, specified for the various application sectors, and detailed information on the consumption of blowing agents in the BAU and mitigation scenarios for this sector for parties operating under paragraph 1 of Article 5 (Article 5 parties) and parties not so operating (non-Article 5 parties);

(g) Brief background information on all aerosol technologies; an update of available information on alternatives; BAU scenarios for HFC demand for metered-dose inhalers and aerosols, including non-metered dose inhaler medical, consumer and technical aerosols, during the period 2015–2050.

9. The executive summary of the final report is set out in annex I to the present note. It is presented as received from the Panel, without formal editing by the Secretariat.

10. The parties may wish to consider the information set out in the report, seek clarification as required, make comments and adopt decisions as appropriate.

B. Report by the Technology and Economic Assessment Panel on assessment of the climate benefits, and the financial implications for the Multilateral Fund of the hydrofluorocarbon phasedown schedules in the amendment proposals (decision Ex.III/1) (item 5 of the provisional agenda for the preparatory segment)

11. As mentioned in the note by the Secretariat,[6] by decision Ex.III/1, the Third Extraordinary Meeting of the Parties requested that the Technology and Economic Assessment Panel prepare a report for consideration by the Twenty-Eighth Meeting of the Parties containing an assessment of the climate benefits, and the financial implications for the Multilateral Fund for the Implementation of the Montreal Protocol, of the schedules for phasing down the use of HFCs contained in the amendment proposals discussed the Parties at the thirty-eighth meeting of the Open-ended Working Group and the Third Extraordinary Meeting of the Parties. In preparing its report, the Panel deemed it important to first define key terms as follows:

(a) "Climate benefit" is understood to mean a reduction in HFC consumption below that of a BAU scenario integrated over a specified period, expressed in units of tonnes of carbon dioxide-equivalent (CO_2-eq.);

(b) "Financial implications for the Multilateral Fund" is understood to mean costs to the Multilateral Fund for the Implementation of the Montreal Protocol required to implement control measures in parties operating under paragraph 1 of Article 5 following the schedules for the phasedown of HFCs set out in the amendment proposals (HFC reductions only).

12. The report highlights specific factors that were taken into consideration by the Panel and provides estimates for Article 5, non-Article 5 and global production and consumption of the main HFCs in 2015, followed by respective estimates of the baselines contained in the four HFC amendment proposals,[7] expressed in megatonnes (Mt) of CO_2-eq.

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[6] UNEP/OzL.Pro.28/2, paras. 25–26.

[7] UNEP/OzL.Pro.WG.1/resumed.37/3–UNEP/OzL.Pro.WG.1/38/3–UNEP/OzL.Pro.ExMOP/3/3–UNEP/Ozl.Pro.28/5;

UNEP/OzL.Pro.WG.1/resumed.37/3/Add.1-UNEP/OzL.Pro.WG.1/38/3/Add.1–UNEP/OzL.Pro.ExMOP/3/3/Add.1–UNEP/Ozl.Pro.28/5/Add.1;

UNEP/OzL.Pro.WG.1/resumed.37/4-UNEP/OzL.Pro.WG.1/38/4-UNEP/OzL.Pro.ExMOP/3/4-UNEP/Ozl.Pro.28/6;

13. According to the report, for the period up to 2050 the climate benefits of the four amendment proposals are found to yield an integrated total reduction in HFC consumption in the range of 10,000–12,500 Mt CO_2-eq., compared to the BAU scenario for the non-Article 5 parties, with little differences between the proposals; and a corresponding reduction in the range of 26,000–76,000 Mt CO_2-eq. for Article 5 parties.

14. In terms of the financial implications for the Multilateral Fund of the four amendment proposals, the report estimates the total cost for manufacturing conversion, servicing and HFC production phasedown to be in the range of $3,400–14,300 million.

15. In addition to analysing the climate benefits and financial implications of the four amendment proposals, the Panel provided a limited analysis for the six proposals of baseline and freeze dates for Article 5 parties that were put forward by some parties and groups of parties at the Third Extraordinary Meeting of the Parties in July 2016.[8]

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

17. The parties may wish to consider the information set out in the report and make any appropriate recommendations.

C. Issues related to exemptions under Articles 2A–2I of the Montreal Protocol (item 7 of the provisional agenda for the preparatory segment)

(a) Nominations for critical-use exemptions for 2017 and 2018 (item 7 (b) of the provisional agenda of the preparatory segment)

18. As mentioned in the note by the Secretariat,[9] in 2016 three Article 5 parties, Argentina, China and South Africa, submitted five nominations for critical-use exemptions for methyl bromide in 2017, while two non-Article 5 parties, Australia and Canada, submitted one nomination each for 2018 and 2017, respectively.

19. The Methyl Bromide Technical Options Committee finalized its evaluation of the critical-use nominations following the initial evaluation presented at the thirty-eighth meeting of the Open-ended Working Group and taking into consideration all the additional information submitted during and after the bilateral discussions that took place between the nominating parties and the Committee. The report, containing detailed information on the final recommendations, is included in volume III of the Technology and Economic Assessment Panel's September 2016 report. The Panel's final recommendations are outlined in the table 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.

20. The parties may wish to consider the final recommendations and adopt decisions as appropriate.

UNEP/OzL.Pro.WG.1/resumed.37/5-UNEP/OzL.Pro.WG.1/38/5-UNEP/OzL.Pro.ExMOP/3/5-UNEP/Ozl.Pro.28/7;

UNEP/OzL.Pro.WG.1/resumed.37/6-UNEP/OzL.Pro.WG.1/38/6-UNEP/OzL.Pro.ExMOP/3/6-UNEP/Ozl.Pro.28/8.

[8] UNEP/OzL.Pro.ExMOP/3/7, annex II.

[9] UNEP/OzL.Pro.28/2, paras. 34–36.

Summary of the nominations for 2017 and 2018 critical-use exemptions for methyl bromide submitted in 2016 and final recommendations of the Methyl Bromide Technical Options Committee

(Metric tonnes)

Party	*Nomination for 2017*	*Final recommendation*	*Nomination for 2018*	*Final recommendation*
Parties not operating under paragraph 1 of Article 5 and sector				
1. Australia				
Strawberry runners			29.76	[29.73][a]
2. Canada				
Strawberry runners	5.261	[5.261]		
Total	**5.261**	**[5.261]**	**29.76**	**[29.73]**
Parties operating under paragraph 1 of Article 5 and sector				
3. Argentina				
Tomato	75.0	[64.10][b]		
Strawberry fruit	45.3	[38.84][c]		
4. China				
Ginger open field	78.5	[74.617][d]		
Ginger protected	21.0	[18.360][e]		
5. South Africa				
Mills	13	[4.1][f]		
Structures	70	[55.0][g]		
Total	**302.8**	**[255.017]**		

[a] The reduction of 0.03 metric tonnes is for the adoption of alternatives for fumigation of substrate for the production of nucleus and foundation stock use. The party has indicated that industry has a plan to make the transition away from methyl bromide commencing in 2019.

[b] The recommended reduced nomination is based on a reduction of dosage rates from 26.0 to 15.0 g/m^2 for the adoption of barrier films (e.g., totally impermeable film (TIF)) over a transition period of three years.

[c] The recommended reduced nomination is based on decreasing dosage rates from 26.0 to 15.0 g/m^2 for the adoption of barrier films (e.g., TIF) and available alternatives (i.e., 1,3- dichloropropene + chloropicrin (D/Pic)over a transition period of three years.

[d] The recommended reduced nomination is calculated based on the adoption of barrier films on 50 per cent of the nomination area at the rate of 35 g/m^2. Barrier films (TIF and virtually impermeable film (VIF)) are produced in China and can be used in open field cultivation without risk of wind degradation.

[e] The recommended reduced nomination is based on 100 per cent adoption of barrier films, which are considered suitable for the nomination and meet the requirements on emissions reduction of decision IX/6. Barrier films are produced in China and can be used in protected cultivation without risk of wind degradation.

[f] A reduced nomination is recommended for pest control by fumigation in specific mills and food processing facilities, based on an amount sufficient for one fumigation per year per mill as a transitional measure to allow time for the adoption and optimization of alternatives plus an additional 40 per cent for contingencies. The recommendation is based on a dosage of 20 g/m^3 applied to well-sealed structures.

[g] A reduced amount is recommended, representing a reduction of 20 per cent of the approved amount for 2015 for this sector.

(b) Methyl bromide use in India

21. The Methyl Bromide Technical Options Committee, in its report which was included in the Technology and Economic Assessment Panel's June 2016 report (volume 1, section 4.6.2), noted possible unreported methyl bromide use in India; that India had reported methyl bromide production for quarantine and preshipment uses between 1993 and 2002; and that although the party had not reported production or consumption for controlled uses of this substance for more than fifteen years, various Indian companies were trading in methyl bromide manufactured in India.

22. In correspondence to the Secretariat, dated 12 September 2016, India provided information on the reporting procedures pertaining to the production of methyl bromide in the country. It also confirmed that methyl bromide production and consumption was only for quarantine and preshipment uses and provided details of the country's producers along with data on production, sales, import and export for such uses covering some years during the period 2004–May 2016. India also expressed its intention to report that data to the Secretariat in the format required under Article 7 of the Montreal protocol.

D. Report by the Technology and Economic Assessment Panel and the Scientific Assessment Panel on analysis of the discrepancies between observed atmospheric concentrations of and reported data on carbon tetrachloride (decision XXVII/7) (item 9 of the provisional agenda for the preparatory segment)

23. In response to decision XXVII/7,[10] the Technology and Economic Assessment Panel and the Scientific Assessment Panel prepared their joint report in time for the parties' consideration (volume IV of the Panels' September 2016 report).

24. The Panels' report provides background information on efforts by the scientific community to evaluate new data on carbon tetrachloride, and to understand the gap between the top-down and bottom-up emissions estimates. These efforts, which include a workshop entitled "Solving the mystery of carbon tetrachloride," held in Switzerland in October 2015, resulted in a report released by the World Climate Research Programme under its Stratosphere-troposphere Processes And their Role in Climate (SPARC) project, entitled "The mystery of carbon tetrachloride" (hereafter referred to as the SPARC 2016 report).[11]

25. The Panels' report also discusses the difference in top-down and bottom-up emission estimates of carbon tetrachloride included in the SPARC 2016 report, and provides a number of conclusions and recommendations. A key finding of this report is that previous assessments omitted carbon tetrachloride emissions sources from unreported additional pathways and, therefore, the current Article 7 data reports to the Ozone Secretariat are not adequate on their own for deriving bottom-up global emissions estimates for this substance. The Panels' report also underscores the need for:

(a) Further scientific research in order to tighten observation-derived top-down emissions estimates of carbon tetrachloride, including regional emissions estimates;

(b) Developing bottom-up methodologies for estimating carbon tetrachloride emissions in a consistent way.

26. With a view to the two Panels continuing to investigate the issue of carbon tetrachloride emissions as part of their quadrennial assessment processes in order to address a number of remaining questions, they have made the following recommendations for the parties' consideration:

(a) To include a "research direction suggestions" section in the SPARC 2016 report; parties may request the Ozone Secretariat to forward the report to the meeting of the Ozone Research Managers of the Vienna Convention for the Protection of the Ozone Layer[12] for their consideration;

(b) To arrange a joint Technology and Economic Assessment Panel/Scientific Assessment Panel workshop in coordination with the Ozone Secretariat in order to further evaluate the emissions pathways outlined in the SPARC 2016 report. This workshop could also be tasked with developing improved methodologies for estimating bottom-up carbon tetrachloride emissions;

(c) To establish a joint Technology and Economic Assessment Panel/Scientific Assessment Panel working group for estimating emissions of carbon tetrachloride in support of the Panels' quadrennial assessments.

E. Membership of the Technology and Economic Assessment Panel (item 12 of the provisional agenda for the preparatory segment)

27. Information on the status of the membership of the Technology and Economic Assessment Panel and its technical options committees was included in volume 1 of the Panel's June 2016 progress report[13] and discussed at the thirty-eighth meeting of the Open-ended Working Group.[14] In accordance with the terms of reference for membership of the Panel and its technical options

[10] See also UNEP/OzL.Pro.28/2, paras. 39–41.

[11] The SPARC 2016 report along with a factsheet on the findings prepared by the Scientific Assessment Panel can be found on the Secretariat's website at: http://conf.montreal-protocol.org/meeting/oewg/oewg-38/publications/SitePages/Home.aspx.

[12] The tenth meeting of the Ozone Research Managers of the Vienna Convention is to be held from 28 to 30 March 2017.

[13] http://conf.montreal-protocol.org/meeting/oewg/oewg-38/presession/Background%20Documents%20%20TEAP%20Reports/TEAP_Progress_Report_June2016.pdf.

[14] See also UNEP/OzL.Pro.28/2, paras. 47–50.

committees,[15] at the thirty-eighth meeting of the Open-ended Working Group parties were invited to submit nominations for membership of the Panel for final decision by the Twenty-Eighth Meeting of the Parties.

28. Following a correction to the list of members of the refrigeration technical options committee made by the committee's co-chairs, the Secretariat has issued corrigenda as appropriate.[16] The corrected list of the co-chairs and members whose membership expires at the end of 2016 is presented in annex III to the present note. The parties may wish to consider nominating or renominating and appointing or reappointing co-chairs and members as appropriate. In doing so, the parties may wish to consider the expertise currently required by the Panel and its technical options committees as set out in the "matrix of needed expertise" contained in annex 2 to the progress report and as posted on the Ozone Secretariat website (http://ozone.unep.org/en/teap-experts-required).

29. To date, the Secretariat has received nominations for membership in the Technology and Economic Assessment Panel from two parties, Brazil and India. Brazil has nominated Mr. Paulo Altoé, currently a member of the Flexible and Rigid Foams Technical Options Committee, to serve as the committee's co-chair and member of the Technology and Economic Assessment Panel. India has nominated Mr. Rajendra Shende to serve on the Technology and Economic Assessment Panel as a senior expert member. The curriculum vitae of Mr. Shende can be found on the meeting portal of the thirty-eighth meeting of the Open-ended Working Group under background documents.

30. In accordance with paragraph 2.3 of the terms of reference of the Panel, the parties may wish to consider the two nominations for possible appointments by the Meeting of the Parties.

[15] Decision XXIV/8, annex.

[16] TEAP June 2016 Progress Report (vol. 1): Corrigendum; UNEP/OzL.Pro.WG.1/38/2/Add.1/Corr.1.

Annex I

Report by the Technology and Economic Assessment Panel on updated and new information on alternatives to ozone-depleting substances (decision XXVII/4)

Executive summary

ES1. Introduction

- Decision XXVII/4 requested TEAP to provide an update of information on alternatives to ozone-depleting substances listed in the September 2015 Update XXVI/9 Task Force report and considering the specific parameters outlined in the current Decision.
- Given that Parties held two Open-ended Working Group (OEWG) meetings this year, TEAP had taken the approach to provide three total reports responding to Decision XXVII/4. TEAP provided its first March 2016 report to OEWG-37 focused on the refrigeration and air conditioning (R/AC) sector, and included updates on alternatives, results of testing on alternatives under high ambient temperature (HAT) conditions, discussion of other parameters outlined in the decision, and an extension of the mitigation scenarios to 2050. Based on comments and informal discussions on the report at OEWG-37, TEAP completed its second report for submission to OEWG-38, again focusing on the R/AC sector.
- TEAP’s approach with its third and final report under Decision XXVII/4 is to provide Parties with a single reference document as much as possible for MOP-28. This final report contains much of the same information as in the first two reports with a focus on the R/AC sector, plus new chapters on foams, MDIs and aerosols. Updates and additions in bold are indicated at the beginning of each existing chapter or section, as appropriate.
- In particular, TEAP’s final report under Decision XXVII/4 for MOP-28 provides the following:
    - A response to comments on the high ambient temperature criterion (chapter 5);
    - A response to comments related to scenarios including further information related to HFC production (Annex 4 of this report contains updated tables for total, new manufacturing, and servicing demand (in relation to Chapter 6)).
    - A new chapter (Chapter 7) responds to the decision request to provide new and updated information on the availability of alternatives for foam blowing.
    - A new chapter (Chapter 8) responds to the decision request to provide new and updated information on the availability of alternatives for MDIs and aerosols.
- This report focuses on relevant sectors, including on R/AC, foams, MDIs and aerosols sectors. The summaries of the chapters 1 to 6 from the second Task Force report submitted to OEWG-38 remain essentially the same with **any specific update or additional information indicated in bold upfront.**

ES2. Update on the status of refrigerants

- No further updates were provided on the status of refrigerants (Chapter 2) since the Task Force June report, so the information, as summarized below, remains unchanged for this report.
- Chapter 2 lists 80 fluids which have either been proposed or are being tested in industry programmes, or are pending publication, or have been published in ISO 817 and ASHRAE 34 refrigerant standards since the 2014 RTOC Assessment Report. The majority of these are new mixtures, but traditional fluids and two new molecules are also included. Chapter 2 includes discussions on how refrigerants are classified in refrigerant standards and increased safety risks of some of low-GWP refrigerants that need to be addressed.
- There are alternative refrigerants available today with negligible ODP and lower GWP, however, for some applications it can be challenging to achieve the same lifetime cost level of conventional systems while keeping the same performance and size. The search for new alternative fluids may yield more economical solutions, but the prospects of discovering new, radically different fluids are minimal.

- Market dynamics are critical in the rate of adoption of new refrigerants. There is a limit to the number of different refrigerants that a market (customers, sales channels, service companies) can manage. Hence, companies will be selective about where they launch a product, avoiding areas which are saturated, and promoting sales where they see the greatest market potential.

- It is difficult to assign energy efficiency to a refrigerant, because energy efficiency of refrigeration systems is an additional variable to the refrigerant choice also related to system configuration and component efficiencies. One approach when assessing the energy efficiency related to a refrigerant is to start with a specific refrigerant and use a system architecture suitable for this refrigerant, while comparing to a reference system for the refrigerant to be replaced. Other approaches screen alternative refrigerants suitable for a given system architecture. The common methods can be divided into theoretical and semi-theoretical cycle simulations, detailed equipment simulation models, and laboratory tests of the equipment. In practice, the achievable energy efficiency is limited by the cost of the system, as the success in the market depends on a cost-performance trade-off.

- The difficulties in assessing the total warming impact related to refrigerants is discussed, including the difficulty of defining “low global warming potential”, and assessing the energy efficiency related to the use of a refrigerant.

- Total climate impact related to refrigerants consists of direct and indirect contributions. The direct contribution is a function of a refrigerant’s GWP, charge amount, emissions due to leakage from equipment and those associated with the service and disposal of the equipment. The definition of the qualifiers “high”, “medium” and “low” in relation to GWP is a qualitative, non-technical choice related to what is acceptable in specific applications. The indirect contribution accounts for the CO_2-equivalent emissions generated during the production of energy consumed by the refrigeration, air-conditioning, and heat pump equipment. These emissions are affected by equipment's operating characteristics and the emission factor of the local electricity production. Operating characteristics include operating conditions, operating profile, system capacity, system hardware, among others, which makes a comparison difficult in many instances. The indirect contribution is the dominant contributor in very low to no leakage or “tight systems”.

ES3. Update on R/AC alternative refrigerants and technologies

- Based on comments from Parties on TEAP’s report to OEWG-38, this chapter provides further updates on refrigerant alternatives and new technologies, where these are currently in use. It also updates information on how standards are being developed, to address issues such as safety.

- HC-600a and HFC-134a continue to be the primary refrigerant options for production of new domestic refrigeration appliances. It is projected that, by 2020, about 75% of new refrigerator production will use HC-600a, most of the rest will use HFC-134a, and a small share may apply unsaturated HFC refrigerants such as HFO-1234yf.

- In supermarkets, blends such as R-448A, R-449-A, R-449B, R-450A, and R-513A are now beginning to grow in use, starting with Europe and the United States. The same holds true for condensing units and self-contained equipment. In the self-contained equipment category, early trials with HFO-1234yf and HFO-1234ze have started. The use of R-407A and R-407F continues to grow further in many parts of the world.

- Refrigerants such as R-744 are increasingly being used in supermarket systems worldwide – both in cascaded systems (R-744 for low temperature cascaded with a second refrigerant such as HFC-134a or similar and R-717 in limited cases) and in transcritical systems. Transcritical systems are being researched extensively to reduce their energy penalty at high ambient conditions through the use of component and system technologies such as ejector, adiabatic condensing, sub-cooling and parallel compression.

- In industrial refrigeration the major trend, which also is a major challenge, is the focus on refrigerant charge reduction. The market for heat pumps is increasing rapidly. Industrial heat pumps use heat that is considered waste in other parts of production processes.

- In transport refrigeration, R-452A has been introduced during 2015 as a customer option on new truck and trailer refrigeration units. R-404A remains widely available. Activities are ongoing to assess R-744 and other non-flammable (class A1) lower GWP solutions such as R-448A and R-449A. R-513A, R-513B, and R-456A are being considered as future drop-in solutions for HFC-134a. Flammable (A3) and lower flammable (A2L) refrigerant research is continuing, aiming at producing publicly available and technically sound references to support code and standard activities.

- For air-to-air air conditioners and heat pumps, the most substantial recent developments are related to the increased rate of substitution of HCFC-22 and the greater consideration of use of medium and low GWP alternatives. Some manufacturers are adopting HCs and there is also uptake of HFC-32.
- For space heating and water heating heat pumps, legislation on minimum energy efficiency has entered into force in Europe, Japan and the USA, and has decreased the number of air to water heat pumps that can be placed on the market.
- In chillers, after years of research and screening tests, an array of choices is emerging and some commercialisation has begun. Emerging refrigerants are: HCFO-1233zd, HFC-32, R-452B, R-513A, R-514A, HFO-1234yf and HFO-1234ze(E).
- In mobile air conditioners (MACs), the penetration of HFO-1234yf for new vehicles has continued and has spread to many additional models, primarily in non-Article 5 countries, but is still far from complete. In addition, development of R-744 MACs has continued and commercialisation appears imminent. Other alternatives - including hydrocarbons, HFC-152a and additional HFC/HFO blends R-444A and R-445A - have not received much additional consideration and appear unlikely to be chosen for new vehicles in the near future.
- Vapour compression technology has been the primary technology for all R/AC applications in the last 100 years. Technologies that do not employ vapour compression technology are called Not-In-Kind technologies (NIK), of which, during past years, several have been under development. Some studies have classified the development status of those technologies as: (1) most promising (membrane heat pump, thermo-elastic); (2) very promising (evaporative liquid desiccant A/C, magneto-caloric, Vuilleumier heat pump); (3) moderately promising (evaporative cooling, thermo-electric, ground-coupled solid desiccant A/C, absorption heat pump, duplex-Stirling heat pump, thermo-acoustic, adsorption heat pump, thermo-tunneling); and (4) least promising (stand-alone solid desiccant A/C, stand-alone liquid desiccant A/C, ejector heat pump, Brayton heat pump).

ES4. Alternatives to refrigeration systems on fishing vessels

- **Where it concerns fishing vessels refrigeration systems and possible alternatives, some minor updates on the rating of different refrigerant options have been made (see Chapter 4 and Annex 2), following discussions held at OEWG-38.**
- 70% of the global fishing fleet continues to use HCFC-22 as its main refrigerant. Therefore the main challenge for the industry is to find a feasible transition from HCFC-22 to low-GWP alternatives. Considering that 70% of the global fishing fleet is based in Asia/Pacific, this challenge becomes even more important for Asia/Pacific countries and specifically for the Pacific Island region, whose economy is heavily dependent on their fishing industry. For this reason, particular attention was paid to the situation in this region.
- Based on several parameters (age of vessels, availability of alternatives, technical and economic feasibility of conversions, meeting regulatory requirements of product importer), the transition from HCFC-22 to low-GWP alternatives can be implemented following four different options:

    Option 1 – Non-halocarbon refrigerants (i.e., R-717 and R-744);

    Option 2 – Refrigerant replacement with plant adjustments;

    Option 3 – Refrigerant drop-in; and

    Option 4 – Maintaining HCFC-22 systems.

ES5. Suitability of alternatives under high ambient temperature (HAT) conditions

- No further updated information was available related to the testing programs on alternatives under high ambient temperature conditions, so the information remains unchanged in this chapter. Within the discussion of high ambient temperature design considerations (section 5.1) a limited review is provided of the proposal under discussion by parties to define high ambient temperature countries.

- Chapter 5 updates information on three research projects (where more projects will currently be ongoing) testing alternative refrigerants at HAT conditions and on the design of products using alternatives in new and retrofit applications.
- Results from the three projects, PRAHA, AREP-II, and ORNL, indicate a way forward in the search for efficient low-GWP alternatives for high ambient temperature conditions especially when coupled with a full system redesign. The scope of the research for ORNL and that for the reports from AREP-II analysed here mostly covered soft-optimized testing (i.e., adjusted expansion device or adjusted charge amount). While the PRAHA project included a change of compressors, suppliers did not custom-design those compressors for the particular applications.
- Further improvements are likely through optimizing heat exchangers circuitry for heat transfer properties and proper compressor sizing and selection.
- Full redesign of systems, including new components, will likely be needed to realise systems, using new alternative refrigerants to match or exceed the performance of existing systems in both capacity as well as energy efficiency. When selecting new refrigerants it is important to consider further increases on the current energy efficiency requirements.
- While the commercialization process of refrigerants can take up to ten years, the commercialization of products using these alternatives will take further time.
- In HAT conditions, the cooling load of a conditioned space can be up to three times that for moderate climates. Therefore larger capacity refrigeration systems may be needed, which implies a larger refrigerant charge. Due to the requirements for charge limitation according to certain safety standards, the possible product portfolio suitable for HAT conditions is more limited than for average climate conditions when using the same safety standards.
- Although risk assessment work on flammable refrigerants is an on-going research in some countries, there is a need for a comprehensive risk assessment for A2L and A3 alternatives at installation, servicing and decommissioning at HAT conditions.

ES6. BAU and mitigation demand scenarios for R/AC

- This chapter contains the same scenarios as the second version of the TEAP XXVII/4 Task Force Report (June 2016), based on the same existing regulations considered in that report. The chapter also contains the following changes and additions:
  - Additional information on the production of various HFCs important for the R/AC foam blowing, fire protection, MDIs and aerosols sectors.
  - A comparison of estimated HFC production with the global calculated HFC demand for the R/AC and other sectors;
  - Related to this chapter, Annex 4 of this report contains updated tables for total, new manufacturing, and servicing demand.
- These scenarios (for the R/AC sector only) were cross-checked against current estimated HFC production data. The most recent estimates for the 2015 global production of the four main HFCs[1] are presented in the table below (some revisions were made in this September report); it shows a combined total for the four main HFCs of about 525 ktonnes.

Chemical	*Best estimate for global HFC production in year 2015 (ktonnes)*
HFC-32	94
HFC-125	130
HFC-134a	273
HFC-143a	28
Total	**525**

[1] These are the four main HFCs currently used in the R/AC (including MACs) sector; HFC-134a is also used as a foam blowing agent, in MDIs and technical aerosols.

- The other HFCs used are mainly HFC-152a, HFC-227ea, HFC-245fa and HFC-365mfc at an estimated global 2015 production of about 90 ktonnes. For another HFC, HFC-236fa, estimates for Article 5 production are available at about 0.3 ktonnes in 2015. In climate terms, the total global 2015 production of all HFCs amounts to about 1,200 Mt CO_2-eq.

- The revised scenarios in this report include an extension of the timescale used from the year 2030 to 2050 and a consideration of the BAU scenario for non-Article 5 countries that includes the EU F-gas regulation as well as the US HFC regulation in 2015 for specific sectors and sub-sectors. The mitigation scenarios remain the same as in the September 2015 XXVI/9 report as follows:
    - MIT-3: conversion of new manufacturing by 2020 (completed in non-Article 5 Parties; starting in Article 5 Parties)
    - MIT-4: same as MIT-3 with delayed conversion of stationary AC to 2025
    - MIT-5: conversion of new manufacturing by 2025 (completed in non-Article 5 Parties; starting in Article 5 Parties)

- The global calculated bottom-up demand for the R/AC sectors in 2015 amounts to 473 ktonnes (of which 220 ktonnes in non-Article 5, 273 ktonnes in Article 5 Parties). Compared to the total of 510 ktonnes it would imply that the demand from other sectors than R/AC would amount to about 37 ktonnes (this would mainly, but not only, concern HFC-134a, used as a foam blowing agent and used in MDIs and aerosols, as well as some minor use of the other HFCs in other sectors).

- Over the period 2015-2050, the revised BAU scenario shows
    - 250% growth in the demand in tonnes and in tonnes CO2-eq. in non-Article 5 Parties;
    - 700% growth in tonnes and a 800% growth in tonnes CO2-eq. in Article 5 Parties;
    - The increase in total demand for the four main HFCs currently used in R/AC is due primarily to the growth in demand in the stationary AC sub-sector and secondly, to the growth in demand in the commercial refrigeration sub-sector. As mentioned, total global R/AC demand is in the order of 525 ktonnes for the year 2015 for the four main HFCs.

- *Delaying the start of conversion:* MIT-3 assumes that conversion in all sub-sectors starts in 2020, MIT-5 assumes that conversion starts in 2025. 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 was previously estimated in the different scenarios as follows (assuming a 6 years transition):
    - BAU: 16,000 Mt CO_2-eq.
    - MIT-3: 6,500 Mt CO_2-eq.; a 60% reduction to BAU (2020-2030)
    - MIT-4: 9,800 Mt CO_2-eq.; a 40% reduction to BAU (2020-2030)
    - MIT-5: 12,000 Mt CO_2-eq.; a 30% reduction to BAU (2020-2030)

- With the scenarios extended to 2050 in this report, the BAU demand for the extended period 2020-2050 increases almost five-fold. In this context, although the differences in reduction between the various mitigation scenarios MIT-3, -4 and -5 remain large, they become proportionately less compared to BAU. Consideration of the intermediate period 2020-2040 may provide a more realistic estimate of the savings that can be realised via the various MIT scenarios in Article 5 Parties. The *total* integrated HFC demand for the R/AC sector in Article 5 Parties over 2020-2040 is as follows (assuming a 6 years transition):
    - BAU: 42,300 Mt CO_2-eq.
    - MIT-3: 10,600 Mt CO_2-eq.; a 75% reduction to BAU (2020-2040)
    - MIT-4: 15,600 Mt CO_2-eq.: a 63% reduction to BAU (2020-2040)
    - MIT-5: 18,800 Mt CO_2-eq.; a 56% reduction to BAU (2020-2040)

- The MIT-3 and MIT-5 scenarios are given for all Parties, but predominantly reflect 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 sub-sectors as of 2020. As the R/AC manufacturing with high-GWP refrigerants is phased out, the servicing demand becomes dominant. The stationary AC sub-sector is the principal source of the HFC demand.
- MIT-5 delays manufacturing conversion of all sub-sectors, including 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 much longer than in MIT-3. MIT-5 shows the impact of persisting servicing needs as a result.
- *Conversion period:* the longer the conversion period in mitigation scenarios, the greater the climate impacts (see MIT-3 or MIT-5 from 6 to 12 years) and the resulting overall costs in particular because of continuing servicing needs. An 18 years conversion period has been studied for the MIT-3 scenario (costs have not been further addressed compared to what was available in the XXVI/9 TF report). Whereas the 6 and 12 years conversion periods result in a demand decrease starting after 2020-2024, the 18 years conversion period yields a 10% increase in demand first, until the year 2030, then starts to decrease and reaches the 2020 demand value again in the year 2037. For the 18 years conversion period there is still some high GWP servicing demand after 2050. The demand for the period 2020-2050 for a 6 years conversion period is about 15,800 Mt CO_2-eq., increases to 20,500 Mt CO_2-eq. for a 12 years, and to 27,000 Mt CO_2-eq. for an 18 years conversion period. The latter implies a 70% increase in demand compared to demand for a 6 years conversion period.
- For demand in Article 5 Parties, the following is also of importance:
- Peak values determined for the refrigerant demand increase with later start of conversion. The peak value for MIT-3 in *2020* is about 820 Mt CO_2-eq. The peak value for MIT-4 in the year *2023*, with conversion of stationary AC starting in 2025, is 25% higher (at 1025 Mt CO_2-eq.), whereas the peak value for demand for MIT-5 in the year *2025* is 62% higher than the one for MIT-3 (at 1330 Mt CO_2-eq.).
- For MIT-3, the average decline over a period of 10 years after the peak year is 5.3% per year (from 820 down to 390 Mt CO_2-eq. in 2030), for MIT-4 it is 4.5% per year (from 1025 down to 570 Mt CO_2-eq. in 2033) and for MIT-5 it is 5.5% per year (from 1330 down to 605 Mt CO_2-eq. in 2035).
- For each separate Article 5 Party the peak (freeze) values will still be in the same years for the various MIT scenarios considered, however, annual reduction percentages achievable thereafter may be significantly different per country.

ES7. Foam blowing agents

- **This is a new chapter in this final update version of the Task Force report. It presents new information on alternative blowing agents compared to the XXV/5 report in 2014 for the various types of foam, specified for the various application sectors. It also gives detailed information on the consumption of blowing agents in BAU and mitigation scenarios for both non-Article 5 and Article 5 parties in this sector.**
- The foams sector continues to make significant strides in addressing the phase out of ozone depleting materials, while the industry as a whole continues to grow with estimated longer term growth rates of approximately 3 % per year in Article 5 and 1.5% per year in non-Article 5 parties. Growth is driven by the opportunity for energy savings in buildings and in some Article 5 parties to improve food handling and reduce waste through cold chain improvements.
- Hydrocarbons have been a major part of Ozone Depletion Potential (ODP) and Global Warming Potential (GWP) reduction for large parts of the foam sectors, however national and regional regulations regarding ODP and GWP, codes and standards related to thermal performance and energy consumption, fire safety, and volatile organic compound (VOC) emissions are currently driving the choice of blowing agents used by foam manufacturers.
- Thermal performance of foams is often an essential attribute, and in these cases the choice of blowing agent is an important consideration to long term performance. Transitions to new blowing agents may require significant reformulation and in some cases equipment modifications. This is particularly true when moving from non-flammable to flammable blowing agents. Fire safety concerns for small and medium enterprises (SMEs) is a particular concern, however, less flammable hydrofluoroolefins (HFOs) and hydrochlorofluoroolefins

(HCFOs) are expensive and some Article 5 foam manufacturers may wait for advice and direction on how to transition directly from HCFCs to low GWP alternatives.

- HFO/HCFOs (HFO-1234ze(E), HCFO-1233zd(E), HFO-1336mzz(Z) are becoming increasingly available either commercially or in development quantities with additional capacity under construction. In many cases these may be used in blends (such as HCs, and methyl formate) to reduce cost and balance performance (such as thermal performance, flammability, and fire performance). Reformulation efforts are still ongoing however and in some areas, as in use for one component spray polyurethane foam, shelf life stability is a particular challenge.

- Successful transition to low GWP technologies in non-Article 5 parties in the coming years, and availability of these technologies are likely key factors for Article 5 parties to avoid transitioning to high GWP HFCs as part of a phase out of HCFCs.

ES8. Metered Dose Inhalers (MDIs) and aerosols

- **This is a new chapter in this final (update) version of this Task Force report (update of the chapter in the XXVI/9 TF report, September 2015). It presents some brief background on all aerosols technologies, an update of information on alternatives, and BAU scenarios for the HFC demand for 2015-2050 in metered dose inhalers (MDIs). It also deals with aerosols, including non-MDI medical, consumer and technical aerosols.**

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 scenario, for the period 2015 to 2050, *total cumulative* HFC demand in MDI manufacture is estimated as 638 ktonnes (594.5 ktonnes HFC-134a; 43.5 ktonnes HFC- 227ea). This corresponds to direct HFC emissions with a warming impact of approximately 990 Mt CO_2-eq., which would be significantly less than the direct emissions warming impact of CFC MDIs had they not been replaced. Direct emissions from MDIs manufactured in Article 5 Parties are estimated to contribute a warming impact of 506 Mt CO_2-eq., and non-Article 5 Parties 483 Mt CO_2-eq. over the period.

- At present, it is not yet technically or economically feasible to avoid HFC MDIs completely in this sector because there are economic impediments in switching from HFC MDIs to multi-dose DPIs for salbutamol, and because a minority of patients cannot use available alternatives to HFC MDIs.

Aerosols:

- Aerosols can be divided into three categories: consumer aerosols; technical aerosols; and non-MDI medical aerosols. Technically and economically feasible alternatives to ozone-depleting propellants and solvents (CFCs and HCFCs) are available for aerosols. A significant proportion of aerosol propellants have migrated to flammable hydrocarbons and dimethyl ether (DME), which dominate in the consumer aerosol market. Non-flammable and non-toxic HFCs are used in aerosols when flammability or toxicity is a consideration. HFCs are also used where emissions of volatile organic compounds (VOCs) are controlled.

- Based on preliminary data, global HFC demand for aerosols is estimated as 44,000 tonnes for 2015, with 15,000 tonnes HFC-134a and 29,000 tonnes HFC-152a. This corresponds to a warming impact from direct emissions of 25,500 kt CO_2-eq. Consumer aerosols were the largest category (84 per cent), with technical aerosols (14 per cent) and non-MDI medical aerosols (2 per cent) making up the remainder. The majority of consumer aerosols used HFC-152a propellant (74 per cent) and the remainder HFC-134a. The majority of technical aerosols used HFC-134a propellant (80 per cent) and the remainder HFC-152a. The majority of non-MDI medical aerosols used HFC-134a propellant (90 per cent).

- One possible BAU scenario for global HFC demand (HFC-134a and HFC-152a) in aerosols is presented for the period from 2015 to 2050. The total cumulative HFC demand in aerosols is estimated as 2,300 ktonnes (350 ktonnes HFC-134a; 1,950 ktonnes HFC-152a). This corresponds to direct emissions with a warming impact of approximately 740 Mt CO_2-eq. Direct emissions from aerosols manufactured in Article 5 Parties are estimated to contribute a warming impact of 300 Mt CO_2-eq., and non-Article 5 parties 440 Mt CO_2-eq., over the period. Production is expected to expand in Article 5 parties.

- HFC consumption in the Aerosols sector is currently ranked as the third largest after the refrigeration and air conditioning and foams sectors, where aerosols are a totally emissive use. There would be environmental benefits in selecting more climate-friendly options. In many cases, current HFC propellants and solvents can be substituted with lower GWP options, and by NIK alternatives where they are suited for the purpose. In some markets or for some products there may be challenges in adopting lower GWP options, which may not always be feasible.

Annex II

Report by the Technology and Economic Assessment Panel on the climate benefits and costs of reducing hydrofluorocarbons under the Dubai pathway (decision Ex.III/1)

Executive Summary

1. Decision Ex.III/1 requests the Technology and Economic Assessment Panel (TEAP) to *"prepare a report for consideration by the twenty-eighth Meeting of the Parties containing an assessment of the climate benefits, and the financial implications for the Multilateral Fund, of the schedules for phasing down the use of hydrofluorocarbons (HFCs) contained in the amendment proposals as discussed by the Parties at the thirty-eighth meeting of the Open-ended Working Group and the Third Extraordinary Meeting of the Parties."* In preparing its report responding to this decision, TEAP considered it important to define key terms of this decision, as used within the context of this report, as follows:

(a) Although the term "climate benefit" can be defined in a number of different ways, in the context of this report, "climate benefit" is understood as a reduction in HFC consumption below that of a business-as-usual (BAU) scenario integrated over a specified period; this is a simplified climate impact metrics method, based on HFC consumption reductions. It is also consistent with the approach taken by TEAP on mitigation scenarios for high-GWP alternatives in previous reports to parties. It is understood to mean achieved reductions in units of t CO_2-eq from the HFC BAU consumption for both non-Article 5 and Article 5 parties as a result of the future implementation of mitigation measures, i.e., the schedules for phasing down HFCs as contained in the amendment proposals. This report considers the major, specific HFCs only (as opposed to blends in conjunction with ongoing HCFC phase-out) currently produced and used in various sectors in non-Article 5 and Article 5 parties. The reductions in HFC consumption from BAU are calculated over the period from the year the control schedule starts up to and including the year 2050[1];

(b) The term "financial implications for the Multilateral Fund" is understood to mean costs to the Multilateral Fund (MLF) for Article 5 implementation of control schedules following the schedules for HFC phase-down in amendment proposals (HFC reductions only). The costs are calculated based on the current MLF guidelines for costs including the HCFC Phase-out Management Plans (HPMPs) stage II. They do not contain "administrative" elements such as Institutional Strengthening; neither have parameter studies been done varying the criteria for investment and operational costs which remain under discussion by parties.

(c) The term "amendment proposals as discussed by parties" can have a number of meanings given the extensive discussion of parties during the 38th Open-Ended Working Group Meeting (OEWG-38) in the Contact Group on the feasibility and ways of managing HFCs (HFC Contact Group). There are the four amendment proposals originally submitted by parties in 2015. There were also other proposals discussed in the contact group including one that also provided both non-Article 5 and Article 5 schedules with phase-down or consumption reduction steps, and additional proposals providing only baseline and freeze dates. In order to provide an analysis of climate benefits and financial implications of schedules for phasing down HFCs, this report only considered the four amendment proposals formally submitted in 2015, which actually provided HFC phase-down schedules (step reductions) for both non-Article 5 and Article 5 parties (important for calculating the costs to the MLF to achieve HFC consumption reductions), as follows:

(i) The amendment proposal on HFCs submitted in 2015 by Canada, Mexico and the United States of America (with additional text submitted in 2016) (hereafter referred to as "North America");

(ii) The amendment proposal on HFCs submitted in 2015 by India;

(iii) The amendment proposal on HFCs submitted in 2015 by the European Union and its member States (hereafter referred to as "EU");

[1] There are more comprehensive methods of calculating "climate benefits" on the basis of emissions, supported by atmospheric measurements (Velders, 2015)).

(iv) The amendment proposal on HFCs submitted in 2015 by Kiribati, the Marshall Islands, Mauritius, the Federated States of Micronesia, Palau, the Philippines, Samoa and Solomon Islands (hereafter referred to as "Islands"); and

For the further consideration of Parties, this report also considers and provides limited analysis of the additional suggestions contained in a table that came out of the Contact Group discussions related to preliminary proposals for baselines and freeze dates.

2. This report only considers the BAU relevant phase-down schedules for pure HFCs (as listed in many of the amendment proposals) and these pure HFCs if applied in mixtures. It does not consider the possible use of alternative mixtures (for example, those including HFCs and other non-HFC chemicals).

3. This report updates the latest estimates for the global production of the four main HFCs (HFC-32, HFC-125, HFC-134a and HFC-143a) plus other HFCs for the year 2015. There is close agreement between current estimates of HFC production and consumption in R/AC (manufacturing and servicing), foam, MDIs, non-MDI aerosols and fire protection sectors. The report provides projections on HFC consumption under a BAU scenario from 2015 until 2050.

Estimates for non-Article 5, Article 5 and global HFC production in 2015 (ktonnes)

HFCs	*Estimate for non-A5 production (2015)*	*Estimate for A5 production (2015)*	*Estimate global 2015 production*
HFC-32	23.0	71.0	94.0
HFC-125	31.5	98.5	130.0
HFC-134a	97.0	176.0	273.0
HFC-143a	11.0	17.0	28.0
Sub-total			525
Other HFCs (HFC-152a, -245fa, -365mfc, -227ea, -236fa)*, **			140.0
Total			**665.0**

* A substantial part is related to non-feedstock HFC-152a production, global estimate at slightly higher than 60 ktonnes; of this, only 5-10 ktonnes relate to use in foam production
** Estimated global production of HFC-236fa is estimated as small (300-500 tonnes); HFC-236fa is produced in one Article 5 country (Kuijpers, 2016)

4. In 2015, the R/AC sector was estimated to account for almost 75% of the total global consumption of the four main HFCs used in this sector (HFC-32, HFC-125, HFC-134a, and HFC-143a), and for more than 80% of these HFCs in Article 5 parties.

Estimates for non-Article 5, Article 5 and global HFC consumption in 2015 (ktonnes)

Sector	*Estimate for non-A5 consumption (2015)*	*Estimate from various sources A5 consumption (2015)*	*Estimate global consumption 2015 (*)*
R/AC manufacture	106.6	185.8	292.4
R/AC service	94.2	87.0	181.2
Foams	71.0	12.6	83.6
MDIs	10.1	3.9	14.0
Aerosols	50.0	9.0	59.0
Fire protection, others	5.5	9.5	15.0
Total	**334.4**	**305.8**	**645.2**

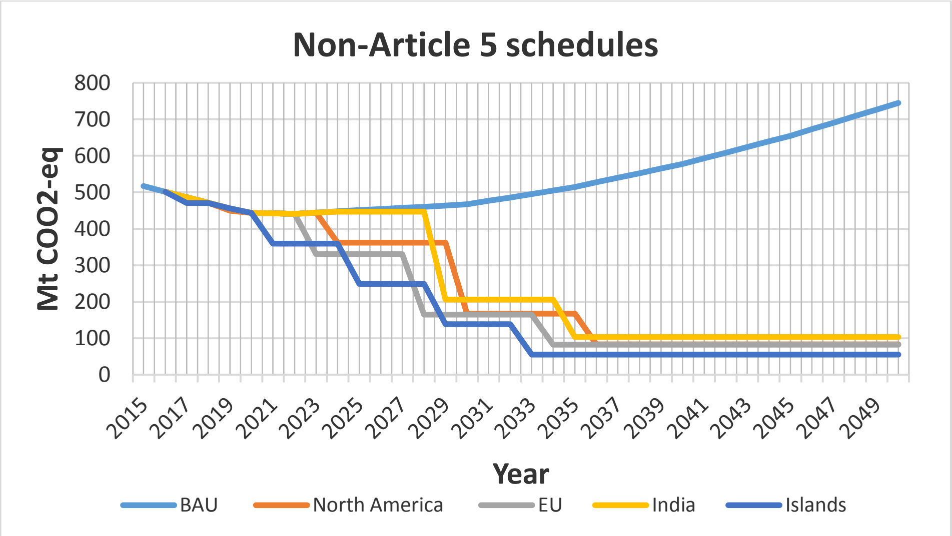
5. Based on the definitions of baselines contained in the four HFC amendment proposals considered in this report, the amounts as given below are calculated for the baselines for the proposed non-Article 5 and Article 5 control schedules.

Non-Article 5 parties proposal	*Non-Article 5 parties baseline ($MtCO_2$-eq.)*		
	HFC part	*HCFC part*	**Total**
North America	488.4	68.5	**556.9**
EU	448.2	102.4	**550.6**
India	524.7	162.7	**687.4**
Islands	488.4	65.1	**553.5**

Article 5 parties proposal	*Article 5 parties baseline ($MtCO_2$-eq.)*		
	HFC part	*HCFC part*	**Total**
North America	418.4	417.2	**835.6**
EU	671.9	700.0	**1371.9**
India	2134.1	283.3	**2417.4**
Islands	710.9	566.6	**1277.5**

6. Non-Article 5 parties: The climate benefits calculated for non-Article 5 parties are given in the table below. For the period up to 2050, the four amendment proposals considered in this report yield an integrated total reduction in HFC consumption in the range of 10-12,500 Mt CO_2-eq., compared to BAU, with little differences between proposals.

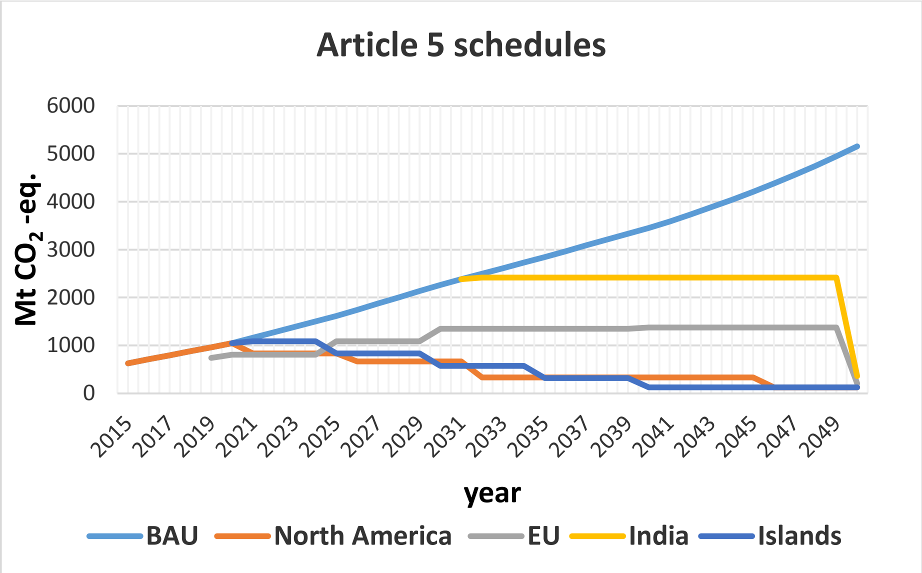
Proposals for non-Article 5 parties	*North America*	*EU*	*India*	*Island states*
Freeze date	n/a	n/a	2016	n/a
Remaining consumption after last reduction step	15%	15%	15%	10%
Climate benefit (Mt CO2-eq.)	**10,690**	**11,500**	**10,000**	**12,470**



7. **Article 5 Parties:** The **climate benefits** calculated for Article 5 parties based on the four amendment proposals are summarized in the table below, however, these may not all be directly comparable and would need to be considered based on the merits of each proposal. Generally, earlier freeze dates combined with adequate lower baseline values provide larger climate benefits (with little difference observed between the two proposals with intermediate reduction steps defined, i.e., North America and Island states).

Proposal for Article 5 parties	*North America*	*EU**	*India***	*Island states*
Freeze date	2021	2019	2031	2020
Remaining consumption after last reduction step	15%	15%	15%	10%
Climate benefit ($MtCO_2$-eq.)	**75 850**	**53 260**	**26 130**	**74 980**

* The calculation for the EU proposal is conservative (leading to “minimum” climate benefits), with no intermediate HFC reductions assumed until a final 85% reduction in 2050. Intermediate reductions should be negotiated. It takes into account the HCFC consumption until 2030 to be considered in a “combined” freeze, leading to a small increase in HFC consumption during the period 2019-2030).
** The calculation for the Indian proposal is of the same type (leading to “minimum” climate benefits), with no intermediate HFC reductions assumed until a final 85% reduction in 2050. Reductions should be negotiated.



8. **Estimating costs to the MLF based upon the various proposals.** Costs have been estimated on the basis of the installed manufacturing capacity in the year the freeze commences (at a specific baseline value). Costs have been estimated in such a way that a virtually complete conversion of manufacturing capacity in many sectors can be achieved, which will be required to achieve the 85-90% reduction in consumption in a given year (in most amendment proposals between 2040 and 2050). This report estimates the total costs for manufacturing conversion, for servicing and for HFC production phase-down. The analysis does not address costs for other activities, including those for preparatory surveys, development of management plans, institutional strengthening, capacity building, and training programmes.

9. **Cost-Effectiveness:** The following cost effectiveness factors were taken into account for the various sectors and sub-sectors. Because potential related costs to an HFC phasedown are currently an ongoing discussion by parties, for the purposes of this report, the factors used are consistent with current MLF cost guidelines and comparable to the factors applied in HCFC HPMPs stage II.

Sector	*US$/kg*
R/AC domestic	7-9
R/AC based on 134a	8-10
R/AC commercial	10-15
R/AC transport/industrial	10-15
R/AC servicing	6-8

Stationary air conditioning (SAC)	11-15
Mobile air conditioning (MAC)	4-6
Foams	7-9
Fire protection	3-5
Aerosols	4-6
MDIs (no conversion assumed)	None
Production	1.5-3.5

10. **Servicing and production phase-down costs:** For the phase-down of HFC consumption in servicing, moving to lower GWP substitutes may need to take account issues such as addressing flammability, which will increase costs. Therefore, TEAP has utilised a cost effectiveness range of US$ 6-8/kg. This is higher than the value of US$ 4.8 per kg used in HPMP stage II plans for HCFC servicing transition. For the closure of HFC production, TEAP has taken into account that conversion of production to low-GWP refrigerants will involve a number of additional issues that could add to cost effectiveness values, including possible intellectual property rights (IPR), and used a range of US$ 1.5-3.5/kg.

11. **Total Costs:** The total estimated costs to the MLF for phase-down following the four HFC amendment proposals, as considered in this report, are given in the table below. In general, although costs are dependent on the baseline levels selected, they are lower the earlier the freeze date sets in.

Proposal	*Freeze date*	*Lower value of the cost range (US$ million)*	*Higher value of the cost range (US$ million)*
North America	2021	3440	5250
EU*, **	2019	5580	8540
India*	2031	9300	14220
Island states	2020	4550	6950

* In the case of the EU and Indian proposal, estimated costs are relatively high because HFC consumption reductions are to be negotiated after the freeze.
** The amount for calculating manufacturing conversions is the baseline amount used after 2040, leading to relatively high amounts. This amount is also sensitive to the HCFC 2015-2016 consumption in the baseline.

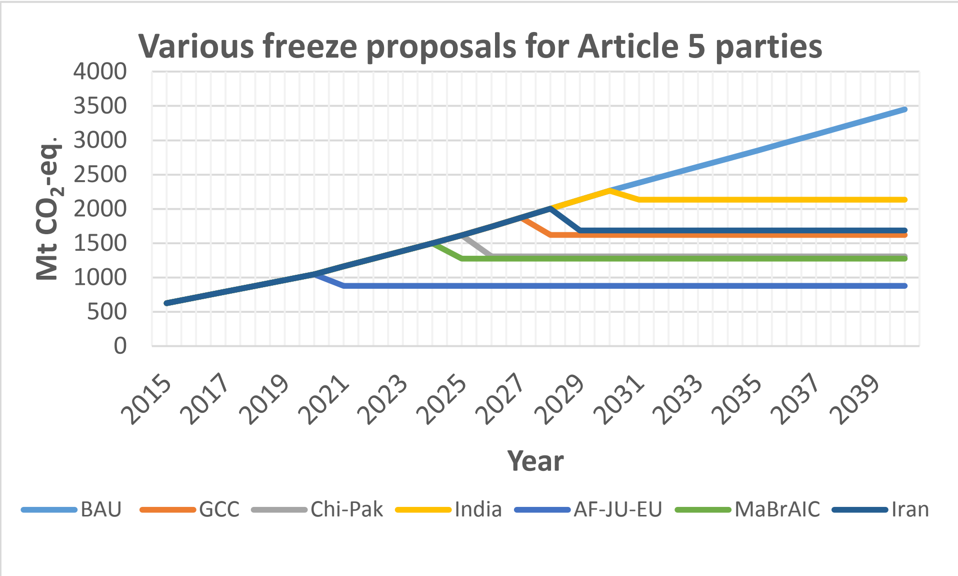
12. **Baseline and freeze date suggestions from the HFC Contact Group:** During the OEWG-38 and ExMOP-3 meetings in Vienna, July 2016, a number of suggestions were discussed in the HFC Contact Group that contained a baseline consisting of an average HFC consumption (averaged over a certain period) and a freeze date, as in the table below. No indication was yet provided for an HCFC baseline component, neither do these suggestions contain reduction percentages for the HFC consumption after the freeze date. Six suggested proposals for baseline and freeze dates for Article 5 parties and two for non-Article 5 parties were presented.

Suggested Article 5 baselines and freeze dates		
Proponents	*Baseline, i.e., HFC component of baseline (average value)*	*Freeze date*
GCC	2024-2026	2028
China, Pakistan	2019-2025	2025-2026
India	2028-2030	2031
African Group, Pacific Island Countries, Latin America like-minded*, EU and JUSSCANNZ	2017-2019	2021
Malaysia, Indonesia, Brazil, Argentina**, English-speaking Caribbean, Cuba	2021-2023	2025
Iran	2024-2027	2029
Suggested non-Article 5 baselines and freeze dates, first reduction step		
EU and JUSSCANNZ	2011-2013	90% of baseline in 2019
Belarus and Russian Federation	2009-2013**	100% of baseline in 2020

*Nicaragua, El Salvador, Guatemala, Venezuela, Chile, Colombia, Honduras, Costa Rica, Mexico, Dominican Republic, Haiti, Panama, Peru, Paraguay (as a basis)
** Subject to confirmation by Government

13. The above suggestions do not contain any reduction percentages after the freeze, as was the case for the amendment proposals considered in sections 3-2 and 3-3 in this report. Nevertheless, TEAP considered that it may be helpful to parties to conduct a limited analysis (see Annex II), for the six proposals for Article 5 parties, of the potential for theoretical climate benefits, defined as the difference between the BAU scenario and the freeze value, which is assumed to remain constant as an HFC consumption limit until 2050. Values for the climate benefit calculated in this way are as given in the table and figure below (n.b., they should not be directly compared to the values given in the climate benefit tables for the four amendment proposals with HFC phasedown schedules as in the sections above and the tables in chapter 3).

Suggestion (assuming constant through 2050)	*Gulf Cooperation Countries*	*China and Pakistan*	*India*	*African group, Pacific Islands, Latin America , JUSSCANZ/EU*	*Malaysia, Brazil, Argentina, Indonesia, Caribbean, Cuba*	*Iran*
Freeze date	2028	2025-26	2031	2021	2025	2029
Benefit ($Mt\ CO_2$-eq.)	**41 510**	**50 440**	**29 660**	**63 150**	**50 890**	**39 720**



Annex III

Technology and Economic Assessment Panel and its technical options committees: co-chairs and members whose membership expires at the end of 2016

Name	*Position*	*Country*
Bella Maranion	TEAP Co-Chair	United States of America
Lambert Kuijpers	TEAP Senior Expert and RTOC member	Netherlands
Dave Catchpole[a]	HTOC Co-Chair and TEAP member	United Kingdom of Great Britain and Northern Ireland
Daniel P. Verdonik	HTOC Co-Chair and TEAP member	United States
Members of the technical options committees[b]		
Samir Arora	FTOC member	India
Ilhan Karaağaç	FTOC member	Turkey
Tareq K. Al-Awad	HTOC member	Jordan
Adam Chattaway	HTOC member	United Kingdom
Erik Pedersen	HTOC member	Denmark
H.S. Kaparwan[c]	HTOC member	India
Hideo Mori	MCTOC member	Japan
Jonathan Banks	MBTOC member	Australia
Eunice Mutitu	MBTOC member	Kenya
J.L. Staphorst	MBTOC member	South Africa
Ken Vick	MBTOC member	United States
Eduardo Willink	MBTOC member	Argentina
Suat Yilmaz	MBTOC member	Turkey
Makoto Kaibara	RTOC member	Japan

[a] Mr. Catchpole will not seek renomination as HTOC co-chair this year.
[b] The five technical options committees are: Flexible and Rigid Foams Technical Options Committee (FTOC), Halons Technical Options Committee (HTOC), Medical and Chemicals Technical Options Committee (MCTOC), Methyl Bromide Technical Options Committee (MBTOC), and Refrigeration, Air-Conditioning and Heat Pumps Technical Options Committee (RTOC).
[c] Mr. H.S. Kaparwan will retire as a Committee member this year.