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Open-ended Working Group of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer
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Geneva, 4–8 April 2016
Items 3 of the provisional agenda*

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

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-seventh 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-seventh meeting (UNEP/OzL.Pro.WG.1/37/2) contains a summary of the initial report of the Technology and Economic Assessment Panel on information on alternatives to ozone-depleting substances that has been prepared for presentation and consideration under agenda item 3 of the provisional agenda of the meeting.

* UNEP/OzL.Pro.WG.1/37/1.

II. Report by the Technology and Economic Assessment Panel on information on alternatives to ozone-depleting substances (decision XXVII/4) (item 3 of the provisional agenda)

2. As mentioned in the note by the Secretariat, the Twenty-Seventh Meeting of the Parties in decision XXVII/4 requested the Technology and Economic Assessment Panel to prepare a report for consideration by the Open-ended Working Group at its thirty-seventh meeting,[1] and thereafter an updated report to be submitted to the Twenty-Eighth Meeting of the Parties to the Montreal Protocol in 2016, that would update and provide new information on alternatives to ozone-depleting substances listed in the September 2015 decision XXVI/9 task force report and consider the specific parameters outlined in decision XXVII/4.

3. Given that two meetings of the Open-ended Working Group will be convened in 2016, the Panel has taken the approach of providing two reports responding to decision XXVII/4. This first March 2016 report submitted to the Open-ended Working Group at its thirty-seventh meeting focuses on the refrigeration and air-conditioning sector, and includes updates on alternatives, testing on alternatives under high ambient temperature conditions, discussion of other parameters outlined in the decision, and an extension of the business-as-usual mitigation scenarios to 2050. This report also provides revised scenarios for avoiding high global-warming-potential refrigerants and considers how the start date for conversion (2020 versus 2025) and the length of conversion over the extended period will affect climate impacts.

4. The second report to be submitted to the Open-ended Working Group at its thirty-eighth meeting will address comments received at the thirty-seventh meeting as well as focusing on updates, where available, related to the other sectors, including foams, fire protection, medical aerosols, non-medical or technical aerosols, and solvents. An updated report, if appropriate, will be submitted to the Twenty-Eighth Meeting of the Parties.

5. The initial report has been posted on the meeting portal for the thirty-seventh meeting of the Open-ended Working Group, and an executive summary of the report is contained in the annex to the present note.

[1] The Technology and Economic Assessment Panel and its technical options committees and task forces normally issue their reports in May each year to enable parties to consider them at the mid-year meeting of the Open-ended Working Group. Taking into account the additional meetings to be held in 2016, the Panel and its decision XXVII/4 task force has worked to ensure that an initial report is issued in time for the thirty-seventh meeting of the Open-ended Working Group.

Annex

Executive summary of the report of the Technology and Economic Assessment Panel prepared pursuant to decision XXVII/4, "Response to the report by the Technology and Economic Assessment Panel on information on alternatives to ozone-depleting substances"

ES1. Introduction

1. In response to decision XXVII/4, the present report provides an update from the Technology and Economic Assessment Panel of information on alternatives to ozone-depleting substances listed in the September 2015 decision XXVI/9 update task force report, taking into consideration the specific parameters outlined in decision XXVII/4.

2. Given that parties will convene two meetings of the Open-ended Working Group in 2016 and in view of the short time frame until the thirty-seventh meeting in April, which will focus on a discussion of decision XXVII/1 on matters related to hydrofluorocarbons (HFCs), the Panel has taken the approach of providing two reports responding to decision XXVII/4. The first report, submitted in March 2016 to the Open-ended Working Group for its thirty-seventh meeting, focuses on the refrigeration and air-conditioning (R/AC) sector, and includes updates on alternatives, testing of alternatives under high ambient temperature (HAT) conditions, discussion of other parameters outlined in the decision, and an extension of the mitigation scenarios to 2050.

3. The report also provides revised scenarios of avoiding high global-warming-potential (GWP) refrigerants and considers how the start date for conversion (2020 versus 2025) and the length of conversion over the extended period affect overall costs and climate impacts.

4. A second report will be submitted to the Open-ended Working Group at its thirty-eighth meeting, providing updates as new information becomes available and any updates based on feedback on the first report, received at the thirty-seventh meeting of the Open-ended Working Group. It will also cover the other sectors (foams, fire protection, metered-dose inhalers, other medical and non-medical aerosols, and solvents) and other topics not covered in the first report, such as alternatives for refrigeration systems on fishing vessels.

5. Sections ES2, ES3 and ES4 below further elaborate on the highlights and provide the technical summaries of the report's three main chapters.

ES2. Update on the status of refrigerants

6. Chapter 2 mentions 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 assessment report by the Refrigerants Technical Options Committee. The majority of these are new mixtures, but traditional fluids and two new molecules are also included. Chapter 2 includes a discussion on how refrigerants are classified in refrigerant standards and why safety has become more important.

7. There are alternative refrigerants available today with negligible ozone-depleting potential and lower GWP. For some applications, however, it can be challenging to reach the same lifetime cost level of the 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.

8. Market dynamics are critical to 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.

9. It is difficult to assign energy efficiency to a refrigerant, because energy efficiency of refrigeration systems comes in addition to the refrigerant choice and is further 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 system architecture suitable for this refrigerant, while making a comparison with 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 success on the market depends on a cost-performance trade-off.

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

11. 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, and emissions due to leakage from the air-conditioning and refrigeration 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 kilogram CO_2-equivalent emissions generated during the production of the energy consumed by the refrigeration, air-conditioning and heat-pump equipment, and its operating characteristics, which include the emissions factor of local electricity production facilities. In addition, since the indirect contribution (the largest contributor in very low to no leakage or "tight systems") is a function of energy consumption, it is affected by the operating conditions, operating profile, system capacity and system hardware, among other factors, which in many instances renders comparison difficult.

ES3. Suitability of alternatives under high ambient temperature conditions

12. Chapter 3 updates information on research projects testing alternative refrigerants under HAT conditions and on the design of products using alternatives in new and retrofit applications.

13. Results from the three projects, PRAHA, AREP-II and ORNL, indicate a way forward in the search for efficient low GWP alternatives for HAT conditions, especially when coupled with a full system redesign. The scope of the research for AREP-II and ORNL mostly covered soft-optimized testing – in other words, using an 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.

14. Further improvements are likely through optimizing the heat exchanger circuitry for heat transfer properties and the proper sizing and selection of compressors.

15. The full redesign of systems, including new components, will likely be needed to produce systems using new alternative refrigerants that match the performance of existing systems in both capacity as well as energy efficiency. When selecting new refrigerants, it is important to consider further increases in the current energy efficiency requirements.

16. While the commercialization process of refrigerants can take up to ten years, the commercialization of products using these alternatives will take further time.

17. 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.

18. 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 under HAT conditions.

ES4. Business-as-usual and mitigation-demand scenarios for refrigeration and air-conditioning

19. The revised scenarios in this report include an extension of the timescale used for the period 2030–2050 and a consideration of the business-as-usual (BAU) scenario for non-Article 5 countries that includes the European Union F-gas regulation, and also the United States HFC regulations for specific sectors and subsectors. The mitigation scenarios remain the same as in the September 2015 XXVI/9 report, as follows:

(a) MIT-3: conversion of new manufacturing by 2020 (completed in non-Article 5 parties; starting in Article 5 parties;

(b) MIT-4: same as MIT-3 with delayed conversion of stationary air-conditioners (AC) to 2025;

(c) MIT-5: conversion of new manufacturing by 2025 (completed in non-Article 5 parties; starting in Article 5 parties).

20. 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 (June and September XXVI/9 Task Force report) and shortly thereafter. Estimates made for the 2015 global production of the four main HFCs[1] are presented in the table below (some revisions were made in this report); it shows an upper limit for the combined total of about 510 kilotonnes.

Chemical	*Best estimate for global HFC production in year 2015 (kilotonnes)*
HFC-32	94
HFC-125	130
HFC-134a	253
HFC-143a	28

21. Over the period 2015–2050, the revised BAU scenario shows:

(a) 250 per cent growth in the demand in tonnes and in tonnes of CO_2-equivalent in non-Article 5 parties;

(b) 700 per cent growth in tonnes and 800 per cent growth in tonnes of CO_2-equivalent in Article 5 parties;

(c) Growth in demand in the stationary AC and the commercial refrigeration subsectors is particularly significant, where the stationary AC subsector is the one determining the total HFC demand in the sum of the four main HFCs used in R/AC. The total global R/AC demand is calculated to be about 510 kilotonnes for the year 2015 for these four HFCs.

22. *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.

23. *Delaying the start of conversion:* MIT-3 assumes that conversion in all subsectors 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:

(a) BAU: 16,000 Mt CO_2-eq.;

(b) MIT-3: 6,500 Mt CO_2-eq.; a 60 per cent reduction to BAU (2020–2030);

(c) MIT-4: 9,800 Mt CO_2-eq.; a 40 per cent reduction to BAU (2020–2030);

(d) MIT-5: 12,000 Mt CO_2-eq.; a 30 per cent reduction to BAU (2020–2030).

24. With the scenarios extended to 2050 in this report, the BAU demand for the extended period 2020–2050 increases almost fivefold. In this context, although the differences in reduction between the various mitigation scenarios MIT-3, MIT-4 and MIT-5 remain large, they become proportionately less when compared to BAU. Consideration of the intermediate period 2020–2040 may provide a more realistic estimate of the savings that can be realized via the various MIT scenarios in Article 5 countries. The total integrated HFC demand for the R/AC sector in Article 5 parties over 2020–2040 is as follows:

(a) BAU: 42,300 Mt CO_2-eq.;

[1] These are the four main HFCs used in the refrigeration and air-conditioning sector (including mobile air-conditioners); HFC-134a is also used in foams, metered-dose inhalers, aerosols.

(b) MIT-3: 10,600 Mt CO_2-eq.; a 75 per cent reduction to BAU (2020–2040);

(c) MIT-4: 15,600 Mt CO_2-eq.: a 63 per cent reduction to BAU (2020–2040);

(d) MIT-5: 18,800 Mt CO_2-eq.; a 56 per cent reduction to BAU (2020–2040).

25. The MIT-3 and MIT-5 scenarios are given for all parties, but predominantly reflect demand in Article 5 parties:

(a) 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 subsector is the principal source of HFC demand;

(b) MIT-5 delays the manufacturing conversion of all subsectors, including the rapidly expanding stationary AC sector, from 2020 until 2025, so that HFC demand initially rises, but then falls as of 2025. Servicing rises substantially as a consequence, and persists for much longer than in MIT-3. MIT-5 defers the conversion periods for R/AC subsectors and shows the impact of the persisting servicing needs as a result.

26. For demand in Article 5 parties, the following is also of importance:

(a) Peak values determined for the refrigerant demand increase with the 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 2023, with the conversion of stationary AC starting in 2025, is 25 per cent higher (at 1025 Mt CO_2-eq.), whereas the peak value for demand for MIT-5 in 2025 is 62 per cent higher than that for MIT-3 (at 1330 Mt CO_2-eq.);

(b) For MIT-3, the average decline over a period of 10 years after the peak year is 5.3 per cent per year (from 820 down to 390 Mt CO_2-eq. in 2030); for MIT-4 it is 4.5 per cent per year (from 1,025 down to 570 Mt CO_2-eq. in 2033) and for MIT-5 it is 5.5 per cent per year (from 1,330 down to 605 Mt CO_2-eq.). If the freeze year (which coincides with the peak year) is chosen as the starting point, an average annual reduction of 5 per cent in total demand (manufacturing and servicing) seems feasible for all types of scenarios. These values all apply to a manufacturing conversion period of six years;

(c) For each separate Article 5 country, the peak (freeze) value will still be in the same years for the various MIT scenarios considered. However, annual reduction percentages achievable thereafter may be significantly different for each country.