INTERNATIONAL

APPROACHES TO STRUCTURING A HIGH AMBIENT TEMPERATURE EXEMPTION

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As parties to the Montreal Protocol consider an amendment to phase down hydrofluorocarbons (HFCs), one critical concern is whether suitable alternatives for air-conditioning applications are available and adequately demonstrated for cooling capacity and energy efficiency under conditions of high ambient temperatures. Given the critical importance of these applications, one option being considered by parties is to provide a time-limited exemption for those uses in countries that could be adversely impacted by high ambient temperatures. This paper looks at a number of options for how such an exemption might be structured.

PAST EXEMPTIONS UNDER THE MONTREAL PROTOCOL

The success of the Montreal Protocol in phasing out 98 percent of ozone-depleting substances can be attributed in part to the flexibility in which the parties have structured the treaty's control requirements. One key aspect of this flexibility has been the targeted and judicious use of exemptions. Parties have felt confident in setting stringent control schedules for ozone-depleting substances because they also allowed for exemptions where alternatives were not available. When necessary, these exemptions have been implemented in a reasonable and time-limited manner and have included commitments to identify and implement alternatives as soon as available. Narrowly defined and limited in scope, exemptions have taken several different forms depending on the specific context. A brief review of the different ways the parties have structured the use of exemptions could help inform discussion of possible approaches to an exemption for high ambient temperature applications under an HFC phase down.

FEEDSTOCK AND PROCESS AGENT APPLICATIONS

Ozone-depleting substances (ODS) have been use used as chemical feedstocks in the production of three groups of chemicals: other ODS (e.g. HCFCs, CFCs), HFCs, and fluoropolymers. For example, HCFC-22 is extensively used in the manufacture of tetrafluoroethylene (TFE) and carbon tetrachloride is a key input in the manufacture of tetrachloroethene (perchloroethylene). When used as a feedstock, controlled substances are chemically transformed. To the extent that ODS used as feedstock do not result in emissions, they do not contribute to ozone depletion. As a result, ODS used in feedstock applications were excluded from the definition of a controlled substance by the parties at their 4th Meeting (1992).[1]

Ozone-depleting substances have also been used as process agents in the production of chlorine, certain adhesives and pharmaceutical products, and other substances. Because these uses can be tightly controlled to reduce emissions, they were initially exempt from the definition of controlled substances.[2] Over time, the parties have decided that these emissions should be closely monitored and reported, but should only continue to be exempt if they are used for applications where no alternatives are available and if emissions fall below specified limits set by the parties.[3]

ESSENTIAL AND CRITICAL USE EXEMPTIONS

With the addition of requirements to phase out CFCs, halons, carbon tetrachloride (CTC), and methyl chloroform as part of the amendments and adjustments agreed to in 1990, the parties added provisions allowing for essential use exemptions. These provisions permit continued production and consumption by parties "necessary to satisfy uses agreed by them to be essential."[4] Essential uses are submitted by parties in specified quantities on an annual basis for specific applications and must be approved through the essential use review process created under this provision.[5] A similar provision with a different set of eligibility criteria was included for "critical " uses of methyl bromide following its phase-out.[6]

While not technically a critical use exemption, at their 15th meeting, the parties addressed a special case where several countries consumed a large percentage of their methyl bromide consumption for a particular application for which no substitutes were available. Faced with a possible noncompliance situation, the parties decided to instruct the Implementation Committee to defer consideration of this issue until two years after the Technology and Economic Assessment Panel (TEAP) had determined that substitutes had become available.[7] This is another way in which the Montreal Protocol has demonstrated flexibility in managing reductions in the use and emissions of controlled substances where alternatives were not available.

EMERGENCY USE EXEMPTIONS

Another mechanism created by the parties allows for an emergency use under certain circumstances without prior authorization. These emergency exemptions have been applied in a small number of cases to uses including torpedo and rocket manufacture, testing of oil in water, and fumigation of a food storage and processing facility.

In the case of ODSs other than methyl bromide:

> ***"…the Secretariat, in consultation with the Technology and Economic Assessment Panel, to authorize, in an emergency situation, if possible by transfer of essential-use exemptions, consumption of quantities not exceeding 20 tonnes of ODS for essential uses on application by a Party prior to the next scheduled Meeting of the Parties. The Secretariat should present this information to the next Meeting of the Parties for review and appropriate action by the Parties."***[8]

In the case of methyl bromide:

> ***"…a Party (is allowed), upon notification to the Secretariat, to use, in response to an emergency event, consumption of quantities not exceeding 20 tonnes of methyl bromide. The Secretariat and the Technology and Economic Assessment Panel will evaluate the use according to the 'critical methyl bromide use' criteria and present this information to the next meeting of the Parties for review and appropriate guidance on future such emergencies, including whether or not the figure of 20 tonnes is appropriate."***[9]

LABORATORY AND ANALYTICAL USES

Ozone-depleting substances have long been used in small quantities for certain laboratory and analytical procedures and processes. The parties provided a "global" exemption for these applications. Under this exemption, parties were not required to apply to exempt individual uses as long as they were covered under the general category of laboratory and analytical uses. Over time to limit the scope of this emption, parties have removed specific uses where acceptable alternatives have become available.[10]

BOX 1: Key Elements of an Exemption

Key elements of any decision by the Parties to include an exemption provision should include:

- Clear criteria for what constitutes high ambient temperature conditions;
- Identification of those end use sectors where alternatives with appropriate cooling capacity, energy efficiency, and reliability have not been identified;
- Process for parties to opt in to the exemption;
- Time limit of 2-5 years for the exemption before reapplication required; and
- Timetable for future decisions by the Parties to extend, modify or eliminate the exemption provision with periodic reviews of the state of alternatives by the Technology and Economic Assessment Panel.

QUARANTINE AND PRE-SHIPMENT APPLICATIONS USING METHYL BROMIDE

The levels of consumption and production controlled for methyl bromide specifically exempt the amounts used by parties for quarantine and pre-shipment applications. These particular uses were excluded because methyl bromide is often required by nations in their phytosanitary provisions governing the international shipment of various goods (agricultural products, wood products and packaging). Parties are required to report on the quantities used in these applications and to take steps to reduce these emissions.[11]

SUMMARY OF APPROACHES

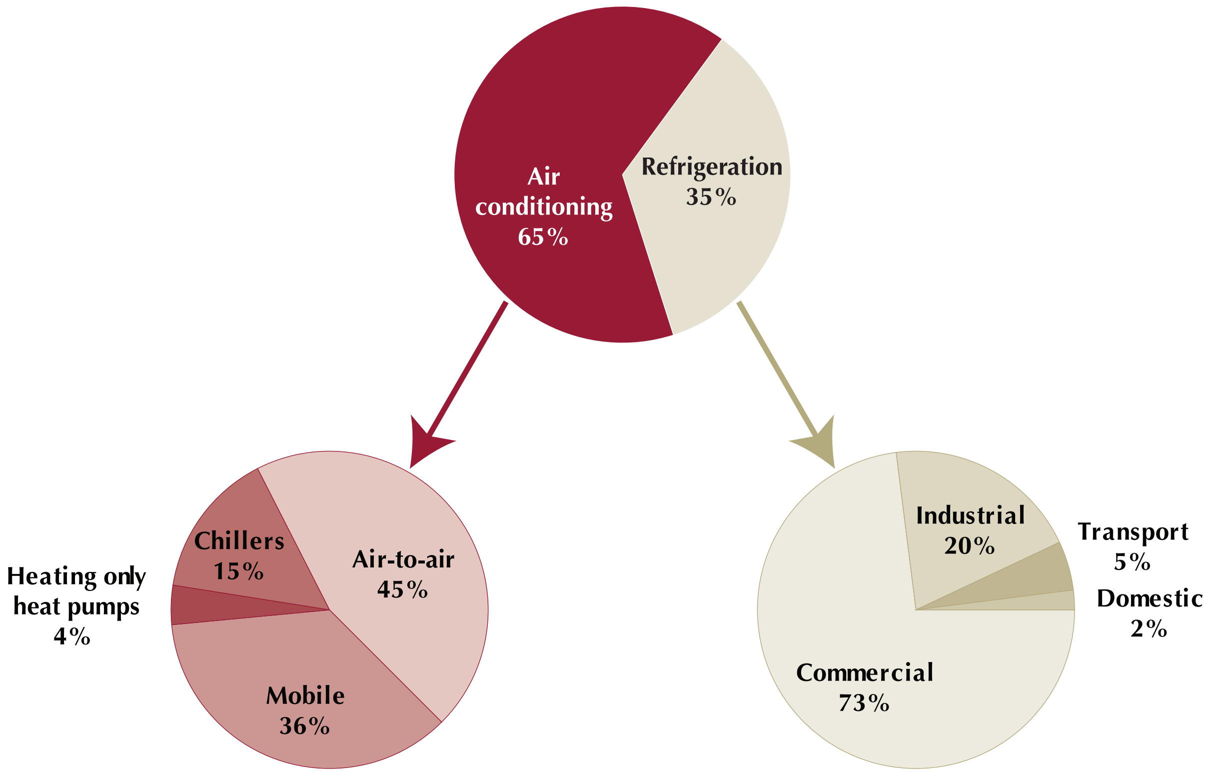
This review of different ways the protocol has structured past exemptions highlights two basic approaches. In the case of process agents, feedstocks, and quarantine and pre-shipment applications, these exemptions occur upfront by exempting these uses from the definition of a controlled substance. These exemptions have been applied to categories of uses and were permitted either where the uses were considered important and emissions were deemed minimal or where uses were necessitated because of mandated requirements (e.g., quarantine and pre-shipment). In contrast, the laboratory and analytical uses, critical and essential use exemptions, and emergency exemptions have been applied at the tail end of phase outs and are reviewed by the parties on an annual basis. In all cases, efforts have been made by the parties to limit emissions even where exclusions or exemptions have been allowed.

STRUCTURING AN EXEMPTION FOR HIGH AMBIENT TEMPERATURE APPLICATIONS

The potential need for an exemption for certain equipment when used in high ambient temperatures rests primarily on the importance to society of cooling technologies, particularly in the warmest climates. Under high ambient temperature conditions, the system load for cooling technologies increases and the cooling capacity and energy efficiency decreases. Concerns also exist that under extreme temperature conditions, condensing pressure and compressor discharge temperatures also increase, thus leading to possible reliability issues. While system designs with alternative refrigerants are being developed to address these issues, the need for an exemption exists because there is not yet an adequate demonstration of viable alternative technologies suitable and effective under these conditions for all air-conditioning applications.

Given the importance of cooling technologies to the quality of life in areas that experience high ambient temperatures, it would seem prudent to allow exemptions from controls on HFCs where cooling capacity, energy efficiency, or reliability is not proven under high ambient temperatures.

FIGURE 1: Breakout of HFC Use in the Refrigeration, Air-Conditioning and Heat Pump Sectors: 2012



Source: http://conf.montreal-protocol.org/meeting/workshops/hfc_management-02/presession/English/FS%202%20Overview%20of%20HFC%20Markets%20final.pdf.

Because the ultimate goal of an HFC amendment is to limit production and consumption of these compounds, any exemption should be narrowly defined to only those applications where no suitable alternatives have been demonstrated. The exemption also should be structured in a way that encourages research and demonstration projects on alternatives and should be periodically reviewed (e.g., on the order of every 2-5 years) and lifted when there is agreement by the parties that alternatives with comparable or superior cooling capacity, energy efficiency, and reliability are available. The exemption should be limited to those parties that apply for it and that satisfy any qualifying conditions (e.g., temperatures exceed agreed upon thresholds) adopted by the parties.

USE SECTORS COVERED BY EXEMPTION

Refrigeration, air-conditioning and heat pump applications accounted for almost 80 percent of the global use of HFCs in 2012,[12] and that number is likely to be even higher today. Foams, fire protection, solvents, and technical and medical aerosol applications make up the majority of the remaining 20 percent of HFC use, but are likely not adversely impacted by high ambient temperatures.

Figure 1 shows the breakout of global use within the refrigeration, air-conditioning and heat pump sectors. It shows that 65 percent of use is for air conditioning, with

TABLE 2: Projects Testing Performance of Alternative Refrigerants under High Ambient Conditions

	U.S. DEPARTMENT OF ENERGY		EGYPRA (UNEP, UNIDO) EGYPT					PRAHA (UNEP, UNIDO) HIGH-AMBIENT COUNTRIES			
Types of test	Soft optimization tests, comparing with base units: HCFC-22 and R-410A		Individual test prototypes, comparing with base units: HCFC-22 and R-410A					Individual test prototypes, comparing with base units: HCFC-22 and R-410A			
No. of categories	60 Hz		50 Hz					60 Hz		50Hz	
	Split unit	Split unit	Split	Split	Split	Central	Micro channel	Window	Mini split	Ducted	Packaged
	18 MBH* R22 eq.	18 MBH R-410A eq.	12 MBH	18 MBH	24 MBH	120 MBH	120 MBH	18 MBH	24 MBH	36 MBH	90 MBH
Testing conditions	ANSI/AHRI Standard 210/240 and ISO 5151 T3 (2010) condition		EOS 4814 and 3795 (ISO 5151), T1 conditions plus one point in T3 conditions					ISO 5151 at T1, T2 and T3+ (50°C) and a continuity test for 2 hours at 52°C.			

* MBH is the equivalent of 1,000 BTU/hour.

Source: UNEP Ozone Secretariat, Decision XXVI/9 Task Force Report Additional Information on Alternatives to Ozone-Depleting Substances, June 2015 Report of the Technology and Economic Assessment Panel Volume 3 (United Nations Environment Programme 2015), http://conf.montreal-protocol.org/meeting/oewg/oewg-36/presession/Background%20Documents%20are%20available%20in%20English%20only/TEAP_Task-Force-XXVI-9_Report-June-2015.pdf.

air-to-air stationary systems constituting almost half of that amount, followed by mobile air conditioning and chillers. Within refrigeration, commercial systems account for almost three-quarters of all use.

A key question is whether some or all of these end-use sectors should be covered by the exemption. For some of these uses, viable low-GWP alternatives exist and have been proven with performance equal to or better than HFCs including under high ambient conditions. For example, for domestic refrigerators, HC-600a is widely used to replace HFC-134a and performs better under high ambient conditions. For chillers, HFO-1234ze, -1233zd, and -1336mzz are being made commercially available and based on extensive testing perform well at high ambient temperatures. For large supermarket systems, subcritical carbon dioxide systems can be used efficiently at high ambient temperatures.[13] For motor vehicle air conditioning, HFO-1234yf systems have been redesigned to provide comparable cooling capacity and energy efficiency at high ambient temperatures.

Much of the research has focused on air-to-air stationary air-conditioning systems as the key application where questions exist about the performance of alternatives under high ambient conditions. Table 1 summarizes the equipment tested in three recent projects aimed at examining alternative refrigerants under high ambient conditions. For example, the recent US Department of Energy (US DOE) Oak Ridge National Laboratory (ORNL) project tested a number of alternatives used in mini-split air-to-air systems under high ambient conditions.[14]

Given that suitable substitutes appear to exist for other refrigeration and air-conditioning applications and that research and demonstration projects have focused on the air-to-air stationary air-conditioning sector, this would appear to be the most important application to include in a high ambient temperature exemption. Parties will want to consider whether other specific sectors within the broader category of refrigeration and air conditioning should also be included in the exemption with the goal of including only those where suitable alternatives under high ambient temperatures have not yet been demonstrated.

DEFINING WHAT CONSTITUTES HIGH AMBIENT TEMPERATURE CONDITIONS

To achieve its objective, any exemption should apply only to those parties that experience high ambient temperature conditions. A clear and objective basis must be established for defining what constitutes temperature conditions of concern and which parties would meet those conditions and qualify to apply for an exemption. This section outlines several possible approaches for defining conditions for a high ambient temperature exemption.

IDENTIFY PARTIES THAT QUALIFY TO BE EXEMPT BASED ON EXCEEDING A SPECIFIED NUMBER OF COOLING DEGREE DAYS

Cooling-degree days are a standard measure of temperature related demands placed on energy consumption and cooling equipment. It is calculated by comparing the daily average outdoor temperature with a defined baseline temperature for indoor comfort. The resulting cooling degree days are the number of degrees by which the baseline has been exceeded by the average temperature for the day. For example, if the average temperature on a particular day is 26 C, and the baseline for measuring cooling degree days was set at 18 C, then that day counts as 8 cooling degree days. A building's interior would need to be cooled by 8 C to reach to baseline temperature of 18 C. The total cooling degree days for a location is the cumulative total over the course of a year of the daily amounts by which the average daily outdoor temperatures exceed the designated indoor baseline temperature.

Data on cooling degree days is available for major cities throughout the world. See for example: http://www.degreedays.net. This tool allows users to set their own base level temperature and calculates the number of cooling degree days for that location. Instead of comparing outdoor temperatures with optimum indoor temperatures, this tool could be used to calculate the cumulative number of degree days above a threshold temperature defined as a high ambient condition. For example, the tool could be used to identify those countries with major cities experiencing conditions that exceed daily average temperatures of 46 C (or some other temperature). In this case, an exemption could be defined for those locations where the average daily temperatures exceeded the baseline of 46 C by some cumulative amount (e.g., if cumulative cooling degree days above 46 degrees exceeded some specified number such as 50 or 100 cooling degree days for a year).

This approach allows for estimating the cumulative burden on the equipment from average daily temperatures above some designated threshold, but because it is based on daily average temperatures, it only indirectly reflects extreme temperatures.

EXEMPTION BASED ON ASHRAE STANDARDS FOR CLIMATE ZONES

The May 2015 TEAP report includes an example of how the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) standards could be used with cooling degree days to define different climate zones. ASHRAE develops standards for refrigeration equipment and the design and maintenance of indoor environments that rely on such equipment. ASHRAE Standard 162 defines climate zones ranging from "Extremely Hot and Humid"[15] to "Sub-Arctic/Arctic."[16]

Figure 2 from the TEAP report shows different climate zones as defined in ASHRAE Standard 162-2013. Note that this definition includes combinations of temperature and humidity. A world map of these zones is shown below.

IDENTIFY EXEMPTIONS BASED ON EXCEEDING TEMPERATURE THRESHOLDS

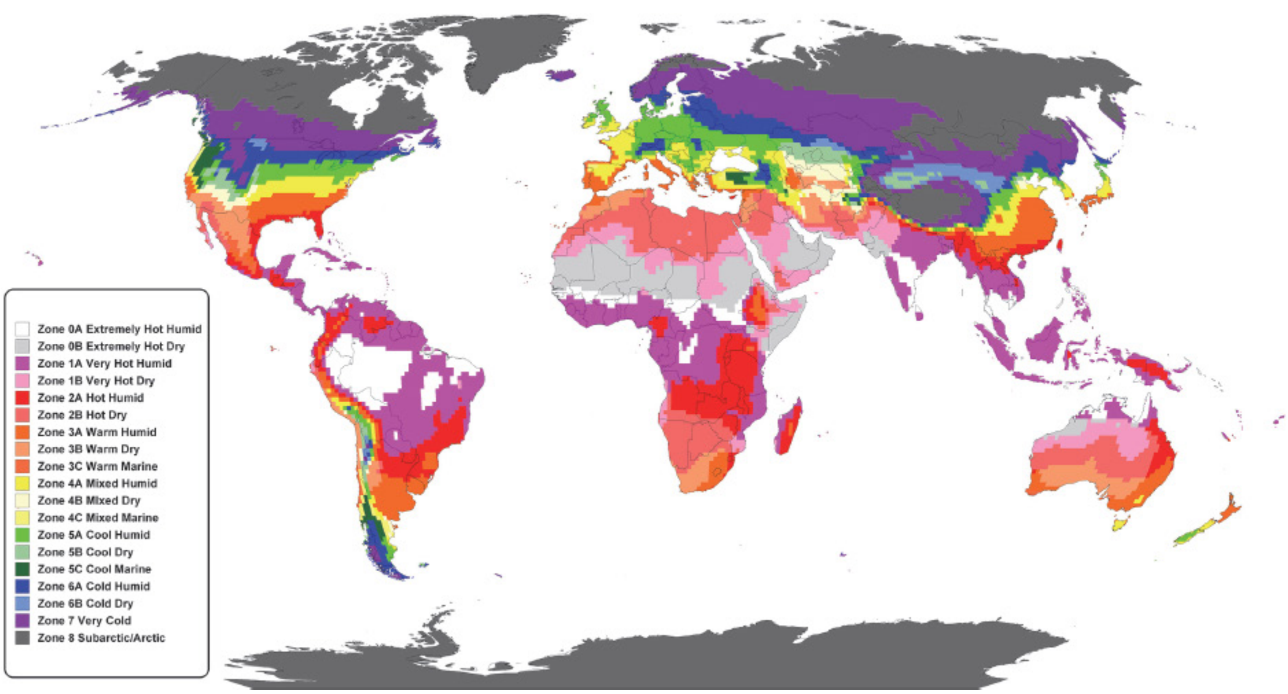
This approach involves directly defining a threshold for high temperatures and a length of time or total number of days that the threshold is exceeded. Temperature thresholds used in this approach could focus on those established for high ambient conditions by the International Organization for Standardization (ISO) which is often used in the design and performance testing of equipment. For example, in countries with high ambient temperatures, the ISO standard requires testing to determine performance at 46°C (115 degrees F) (T3 in ISO 5151:2010) with appropriate operation up to 52°C. Equipment being sold into these geographic regions may often be designed and tested to this standard.

Under this approach, the parties could assess the number of days within a country that maximum daily high temperatures exceeded the temperature thresholds used by ISO (or some other temperature threshold deemed appropriate by the parties). Information on

FIGURE 2: An Example of Zone Definitions

ZONE REFERENCE	DESCRIPTION		ZONE REFERENCE	DESCRIPTION
0A	Extremely Hot Humid		4A	Mixed Humid
0B	Extremely Hot Dry		4B	Mixed Dry
1A	Very Hot Humid		4C	Mixed Marine
1B	Very Hot Dry		5A	Cool Humid
2A	Hot Humid		5B	Cool Dry
2B	Hot Dry		5C	Cool Marine
3A	Warm Humid		6A	Cold Humid
3B	Warm Dry		6B	Cold Dry
3C	Warm Marine		7	Very Cold
			8	Sub-Artic/Arctic

ASHRAE World climate zones map



Source: UNEP Ozone Secretariat, TEAP September 2015 - Decision XXVI/9 Task Force Report - Additional Information on Alternatives to Ozone-Depleting Substance, September 2015 Report of the Technology and Economic Assessment Panel, (Nairobi, Kenya: United Nations Environment Programme, 2015), http://conf.montreal-protocol.org/meeting/mop/mop-27/presession/Background%20Documents%20are%20available%20in%20English%20only/TEAP_Task-Force-XXVI-9_Update-Report_September-2015.pdf.

maximum daily temperatures for major cities throughout the world is available from official government sources.[17] Parties that exceeded that threshold temperature above a specified number of days annually would qualify to be exempt.

PARTIES COVERED BY THE EXEMPTION

A final design question is whether an exemption for certain applications subject to high ambient temperatures should include all parties meeting those temperature conditions or be limited to Article 5 Parties. Given that an increasing number of non-Article 5 Parties have their own domestic rules limiting HFC use and that none of these include an exemption for high ambient temperatures, it would seem appropriate to limit any such exemption to Article 5 Parties. This approach has the added advantage of providing an incentive for manufacturers to continue to develop and test equipment suitable to a wide range of conditions including those locations within developed countries that may be subject to high ambient temperatures.

Finally, Article 5 Parties that meet the requirements for high ambient temperatures should be able to qualify for the exemption through a simple, straightforward process. In addition, parties will also have to decide whether and under what conditions the Multilateral Fund would provide funding for projects in those cases where a Party has opted to be covered under the exemption for one or more particular end use sectors. For example, the Multilateral Fund might reasonably first finance the costs of removing barriers to the safe use of substitute technology suitable for high ambient temperatures, and only after the exemption has ended finance the costs of transitioning the sector.

CONCLUSIONS

This paper looked at different approaches used by the Montreal Protocol where there was a need to exempt specific sources of emissions. It then described the key elements of a high ambient temperature exemption and lays out three approaches for the parties to consider for setting temperature conditions and thresholds in structuring such an exemption. Table 2 summaries those approaches.

TABLE 2: Summary of Approaches to Defining Temperature Thresholds

APPROACH	DESCRIPTION	KEY ELEMENTS
Cooling degree days (CDD)	Compares daily average outdoor temperature with defined baseline temperature. Could define baseline temperature at level equivalent to extreme temperatures.	Standard measure of temperature-related demands on cooling equipment. Tool using CDD data available for major cities globally. Based on daily average, not maximum temperatures.
ASHRAE climate zones	Established by international standard-setting organization.	Based on cooling degree days and daily average temperatures.
Temperature thresholds	Could be based on temperature thresholds linked to equipment design parameters. Need to set amount by which thresholds exceeded as basis for exemption.	Thresholds could be based on extreme temperature conditions (46 C) for standard cooling capacity rating (T3 in ISO 5151:2010) Database for daily maximum and average daily temperature for major cities widely available.

ENDNOTES

1 The Fourth Meeting of the Parties decided to exclude feedstocks from the calculation of production and consumption, but also urged parties to minimize emissions from this use. "Decision IV/12: Clarification of the definition of controlled substances," United Nations Environment Programme (UNEP) Ozone Secretariat, accessed February 19, 2016.

2 Ibid.

3 See for example, "Decision XVII/6: Process agents," United Nations Environment Program (UNEP) Ozone Secretariat, accessed February 19, 2016, http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/1132.

4 Similar language is used to allow for approval of exemptions for CFCs, halons, CTC, and methyl chloroform.

5 The 4th Meeting of the Parties by decision laid out specific criteria to define what would qualify as an essential use: it must be necessary for health safety or functioning of society, no technically or economically feasible alternatives that were acceptable from an environmental and human health perspective and all economically feasible steps had been taken to minimize emissions and supplies are not available from existing stock or recycled materials. "Decision IV/25: Essential uses," United Nations Environment Program (UNEP) Ozone Secretariat, accessed February 19, 2016, http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/1166.

6 Decision IX/6 establishes the detailed criteria for qualifying for a critical use exemption for methyl bromide. "Decision IX/6: Critical-use exemptions for methyl bromide," United Nations Environment Program (UNEP) Ozone Secretariat, accessed February 19, 2016, http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/738.

7 "Decision XV/12: Use of Methyl Bromide for the Treatment of High-Moisture Dates" United Nations Environment Program (UNEP) Ozone Secretariat, accessed March 17, 2016, http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/488.

8 "Decision VIII/9: Essential use Nominations for Parties Not Operating under Article 5 for Controlled Substances for 1997 through 2002" United Nations Environment Program Ozone Secretariat, accessed March 17, 2016, http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/794.

9 "Decision IX/7: Emergency Methyl Bromide Use" United Nations Environment Program Ozone Secretariat, accessed March 17, 2016, http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/739.

10 See for example, "Decision XXI/6: Global laboratory use exemption," United Nations Environment Program (UNEP) Ozone Secretariat, accessed February 19, 2016, http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/1212.

11 "Decision VI/11: Clarification of "quarantine" and "pre-shipment" applications for control of methyl bromide," United Nations Environment Program (UNEP) Ozone Secretariat, accessed February 19, http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/1276; "Decision VII/5: Definition of "quarantine" and "pre-shipment applications," United Nations Environment Program (UNEP) Ozone Secretariat, accessed February 19, http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/1277.

12 UNEP Ozone Secretariat, *Overview of HFC Market Segments*, April 2015 Fact Sheet 2 (Bangkok, Thailand, United Nations Environment Program 2015), http://conf.montreal-protocol.org/meeting/workshops/hfc_management-02/presession/English/FS%202%20Overview%20of%20HFC%20Markets%20final.pdf.

13 See, UNEP Ozone Secretariat, *Technical Issues on the feasibility of managing HFCs*, June 2015 Report of the Inter-sessional Informal Meeting (United Nations Environment Program 2015), http://conf.montreal-protocol.org/meeting/workshops/hfcs-intersessional-informal-consultation/Information%20Documents%20are%20available%20in%20English%20onl/informal%20brief_technical%20issues_intersessional_June%202015_final.docx.

14 A significant finding of the ORNL report is that HFC-410A (the business-as-usual replacement for HCFC-22 in room air-conditioning units) has ***inferior*** cooling capacity and energy efficiency compared to some of the lower GWP alternatives already commercialized for high ambient temperature uses.

15 This zone is defined by the ASHRAE standards as 5,000 < Cooling degree days at 10 C.

16 This zone is defined by the ASHRAE standards as 7,000 < Heating degree days 18 C.

17 "Global Temperature Time Series," National Weather Service Climate Prediction Center, accessed February 19, 2016, http://www.cpc.ncep.noaa.gov/products/global_monitoring/temperature/global_temp_accum.shtml.

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