Benefits of Phasing Down HFCs under the Montreal Protocol May 2011

This paper presents preliminary analysis of potential benefits from globally reducing consumption of hydrofluorocarbons (HFCs). HFCs are a subset of fluorinated greenhouse gases intentionally-made and used in various applications. HFCs are predominantly alternatives to ozone-depleting substances (ODS) being phased out under the *Montreal Protocol on Substances that Deplete the Ozone Layer* (Montreal Protocol). Recent scientific papers, including a 2009 paper by Velders et al.[1], suggest that HFC use will grow substantially over the next several decades, driven both by increased demand for refrigeration and air-conditioning (in particular but not exclusively in developing countries), and because these substances were developed as alternatives to ODS. The governments of Mexico, Canada, and the United States of America proposed an Amendment to the Montreal Protocol to phase down the consumption and production of HFCs. The preliminary benefits analysis of the amendment proposal suggests it would reduce greenhouse gas (GHG) emissions by more than 98,000 million metric tonnes of carbon dioxide equivalent (MMTCO_2eq).

In 1995, HFC emissions constituted approximately 1% of the existing basket of covered UNFCCC greenhouse gases for the U.S. (weighted by Global Warming Potential (GWP)).[2] By 2009, HFC emissions had grown to nearly 2% of the basket. If left unaddressed, consumption of HFCs is projected to roughly double by 2020 relative to today, which, if emissions of other greenhouse gases remain about constant, could result in HFCs constituting 3-4% of the basket by 2020. Growth of HFCs is anticipated to continue well beyond 2020 if left unconstrained or weakly regulated. An important study[3] projects that if left unchecked, HFC global emissions could rise to a significant fraction of CO_2eq emissions by 2050. U.S. Environmental Protection Agency's (USEPA's) analysis estimates somewhat lower levels of HFC growth as compared to the Velders model, but nonetheless indicates substantial increases in HFC use and emissions.

The assumptions used in USEPA' analysis are based on the proposed Amendment and assume a global phase-down of HFC consumption. The analysis assumes the HFC reduction obligations in the proposal by the Mexico, Canada and the United States are met while all Parties (developed and developing countries) continue to comply with current hydrochlorofluorocarbon (HCFC) phaseout obligations. Although both the HFC proposal and the HCFC controls would be effective simultaneously, individual country conditions and obligations would determine whether transitions in HCFC sectors include an interim step (i.e., HCFC to HFC to low-GWP), occur directly (HCFC to low-GWP), or continue to use fluorocarbons (HCFC to HFC) for the foreseeable future. The estimated cumulative HFC reductions are 2,700 MMTCO_2eq [4] through

[1] Velders, G. J. M., Fahey, D. W., Daniel, J. S., McFarland, M., and Andersen, S. O. : The large contribution of projected HFC emissions to future climate forcing, P. Natl. Acad. Sci. USA, 106, 10949–10954, doi:10.1073/pnas.0902817106, 2009. 2091, 2092, 2098, 2108 Accessible at: http://www.pnas.org/content/early/2009/06/19/0902817106.full.pdf+html
[2] *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009,* April 15, 2011, EPA Report #430-R-011-005, www.epa.gov/climatechange/emissions/usinventoryreport.html
[3] See footnote 1: Velders et al., PNAS, 106, June 2009
[4] The benefit calculations assume participation from all parties to the Montreal Protocol (i.e., global participation), with consumption at the maximum level allowed under the proposed amendment. Other modeling techniques could calculate different benefits. For instance, a different method could be used to analyze what reduction options are available, what benefits they would achieve, and, assuming options are undertaken based solely on cost, the reductions that would be achieved.

2020, and 87,200 $MMTCO_2eq$ through 2050, assuming annual global compliance with the HFC phasedown requirements.[5]

Assumptions for Establishing the Baseline and Projected Consumption

Baseline

Because HFCs have replaced HCFCs in many applications in some countries, the baseline used by Mexico, Canada and the United States is set using historical information while accounting for this transition. Because HCFC controls for developing countries (hereafter referred to as Article 5 or A5) do not start until 2013, only historical HCFC consumption is used to set the baseline. The baseline for all Parties uses data from the years 2005 through 2008. The baseline for Article 5 countries is calculated as 100% of the average 2005-2008 HCFC consumption. The baseline for industrialized countries (hereafter referred to as non-Article 5 or non-A5) is calculated as 100% of the average 2005-2008 HFC consumption plus 85% of the average 2005-2008 HCFC consumption. In addition to estimating historical HCFC and HFC consumption, USEPA estimated business-as-usual (BAU) HFC consumption through 2050 to determine the benefits of the proposed phase-down. Such estimates are prepared regionally and aggregated below to reflect Article 5, non-Article 5, and world totals.

Projected Consumption in the U.S.: HCFCs and HFCs

For estimates of U.S. consumption, USEPA used its Vintaging Model,[6] which tracks and projects past and future use and emissions of chemicals (including HFCs) in products that previously relied on ODS. Although each type of product is modeled separately at its respective growth rates as determined through information relevant to the product type, USEPA projected the U.S. growth of all products at an equal and steady amount beginning in 2030, the date at which ODS consumption in the U.S. will cease. For this period 2030-2050, USEPA assumed an annual growth rate for each HFC-using product of 0.8%, which equals the approximate population growth rate expected in the U.S. at that time. Previous sensitivity studies using a 1.8% annual growth rate for 2030-2050 show an approximate 10% increase in cumulative benefits through 2050.

Projected Consumption in Other Countries: HCFCs

HCFC consumption data as reported under Article 7 of the Montreal Protocol are used to determine total GWP-weighted HCFC consumption. Because reports from United Nations Environment Programme (UNEP) and the Ozone Secretariat are in Ozone Depletion Potential (ODP)-tonnes, assumptions regarding the mix of HCFCs constituting such ODP-tonne consumption are made for Article 5 countries based on UNEP (2007)[7] and for non-Article 5 countries are based on U.S. consumption patterns. Once this breakdown (i.e., HCFC-22, HCFC-

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[5] The adoption of binding targets for HFCs (separately or in a basket of gases) under the UNFCCC could also accrue significant benefits relative to this baseline. The magnitude of such benefits would depend upon the nature of commitments, how individual countries choose to meet such commitments, and the range of countries with substantive commitments in an agreement (e.g. whether it includes obligations for all developing countries).

[6] Vintaging Model, 12/16/2009. (This version is used to maintain consistency with past analyses presented to the Montreal Protocol Parties.)

[7] UNEP (2007) "Status/Prospects of Article 5 Countries in Achieving Compliance with the Initial and Intermediate Control Measures of the Montreal Protocol." UNEP/OzL.Pro/ExCom/52/7/Rev.1 9 July 2007.

141b, HCFC-142b, etc.) is estimated, GWPs from the Intergovernmental Panel on Climate Change's Fourth Assessment Report (IPCC AR4) are used to develop total HCFC consumption in terms of MMTCO_2eq.

Projected Consumption in Other Countries: HFCs

HFC consumption was estimated on a country-by-country basis and then aggregated to Article 5 and non-Article 5 regions. To develop the global HFC consumption baseline through 2050, USEPA relied on the approach used to develop two peer-reviewed reports released in 2006: *Global Anthropogenic Emissions of Non-CO_2 Greenhouse Gases 1990-2020* (USEPA Report #430-R-06-003)[8] and *Global Mitigation of Non-CO_2 Greenhouse Gases* (USEPA Report #430-R-06-005).[9] This process, as outlined in those reports, generally follows these steps:

1. Gather ozone-depleting substance (i.e., CFC, HCFC, Halon, Carbon Tetrachloride, and Methyl Chloroform) consumption data as reported under the Montreal Protocol. Data from 1986, 1989 or 1990 are chosen because they pre-date most of the ODS phaseout.[10]
2. Split ODS consumption by ODS type into end-use sectors (i.e., refrigeration/air conditioning, aerosols, foams, solvents, and sterilization).
3. Use ODS consumption to estimate HFC consumption by multiplying by the ratio of U.S. HFC consumption for the relevant year to U.S. 1990 ODS consumption. U.S. HFC consumption estimates are generated from USEPA's Vintaging Model as described above.
4. Scale HFC consumption by the region's Gross Domestic Product (GDP) growth relative to the U.S. Historical and projected GDP by region were obtained from the U.S. Energy Information Administration (2008).[11]
5. Apply several adjustment factors to account for country-specific differences in transition pathways:
    a. Apply the later phaseout of ODS for Article 5 countries.
    b. Account for a proportion of natural refrigerants (such as hydrocarbons) in lieu of HFCs in the baseline for all regions except North America.
    c. Account for lower levels of recovery and recycling of refrigerants from small equipment in Countries with Economies in Transition (CEITs) and Article 5 countries.
    d. Account for regional transitions in the foams and fire protection sectors by using results from regional Vintaging Model runs that modeled sector-specific data from both the fire protection industry[12] and the foams industry.[13]
6. Multiply the consumption (i.e., tonnes) by an average GWP to derive GWP-weighted consumption (i.e., MMTCO_2eq). The average GWP, which varies by sector, is determined by examining the estimated baseline HFC consumption in the U.S. in 2012. This year is chosen because the U.S. HFC market is assumed to be relatively mature by this date and, under a BAU scenario, the mix of HFCs, and hence the average GWP, is

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[8] http://www.epa.gov/climatechange/economics/international.html#global_anthropogenic
[9] http://www.epa.gov/climatechange/economics/international.html#global_mitigation
[10] If available, 1989 data is used; where 1989 data is not available, the next closest available year's data is used.
[11] EIA (2008) *International Energy Outlook 2008*. Washington, D.C. Release date: June 2008. Department of Energy/Energy Information Administration-084(2008). At: http://www.eia.doe.gov/oiaf/archive/ieo08/index.html
[12] 2001 Hughes Associates - International Market Share Data
[13] Data provided by Paul Ashford in personal communications with ICF in 2004.

not expected to change significantly thereafter. For instance, this year is beyond the recent (January 1, 2010) U.S. and Montreal Protocol HCFC phaseout step.

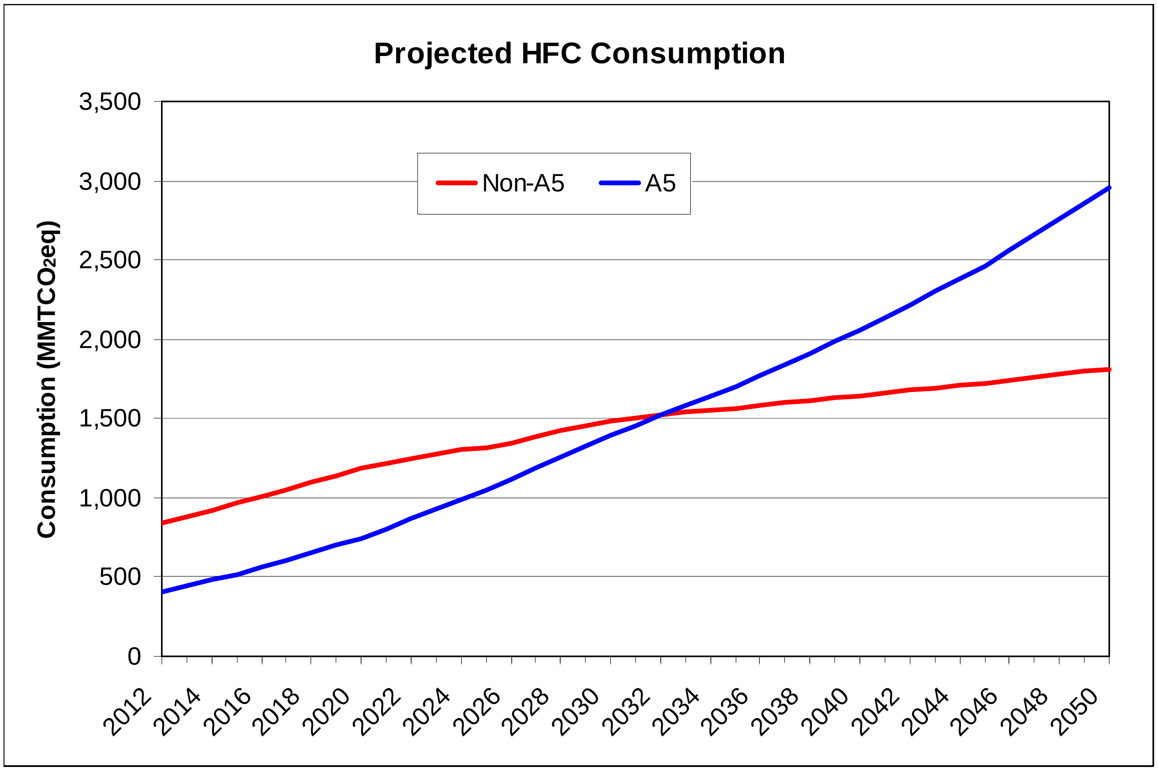
The procedure outlined above is summarized in Equation 1:

Equation 1: Estimating HFC consumption from ODS consumption data

$$\text{ODS consumption (1989 or as available)} \times \text{End Use Percentage} \times \frac{\text{HFC consumption (U.S., year)}}{\text{ODS consumption (U.S., 1990)}} \times \text{Growth and other adjustments} \times \text{Average GWP of HFC consumption (U.S., 2012)} = \text{GWP-weighted HFC consumption (year)}$$

Projected consumption estimates for Article 5 and non-Article 5 are shown in Graph 1 below.

Graph 1. Projected HFC Consumption 2012 Through 2050



Benefits from Byproduct Controls

The Mexico, Canada, and U.S. Amendment proposal includes provisions that limit HFC-23 byproduct emissions resulting from the production of HCFCs and HFCs beginning in 2014. HFC-23 is a potent greenhouse gas that is 14,800 times more damaging to the Earth's climate system than carbon dioxide. HFC-23 is a known byproduct from the production of HCFC-22. HCFC-22 is used primarily as a refrigerant and as a feedstock for manufacturing synthetic polymers. HCFC-22 is an ODS; non-feedstock production of it is scheduled for phaseout by

2040 under the Montreal Protocol. While a small amount of HFC-23 is used predominantly in plasma-etching processes in semiconductor manufacturing, as a fire suppressant, and either neat or as a blend component in cryogenic refrigeration, the vast majority of HFC-23 produced is not used and is either emitted, captured or destroyed. Recent studies (e.g., Montzka, et al., 2009)[14] indicate that HFC-23 emissions continue to increase in developing countries despite international efforts to curb emissions.

Currently, some HFC-23 emissions are mitigated through Clean Development Mechanism (CDM) projects employing destruction technologies, namely thermal oxidation or plasma arc. The CDM allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one ton of CO_2. However, not all HCFC-22 facilities are eligible to earn credits under CDM; therefore a number of facilities may not have emission reduction technology installed. Given the HFC-23/HCFC-22 relationship and the Montreal Protocol's role in phasing out production and consumption of HCFC-22 (with exceptions for feedstock and transformation), the provisions are intended for production lines that do not have an approved project under the CDM to control emissions of HFC-23.

Benefits were calculated with UNEP reported and projected data for HCFC consumption and feedstock production estimates (Montzka, 2009) and with publicly available data on individual CDM Projects (accessible at: http://cdm.unfccc.int/), and data from the MLF Secretariat.[15] Using the data from the CDM, the annual amount of CERs for each project is transformed from SAR to AR4 to reflect the updated GWP. As CDM projects come offline, the benefits are included in the cumulative total. A number of assumptions were made to estimate the benefits: feedstock is projected to increase at a rate of 5% per year through 2050 (Montzka, 2009), HCFC-22 production is derived from HCFC consumption data for 2009 through 2012[16], and the fraction of HFC-23 produced per tonne of HCFC-22 is 3% in A5 countries[17] based on CDM methodologies. Once the total HCFC-22 production is estimated from adding together the adjusted consumption plus projected feedstock, the total is multiplied by the estimated fraction of HFC-23 produced per tonne of HCFC-22. That number is then multiplied by the GWP of HFC-23 and finally divided by 1,000,000 to yield the benefits for that year in $MMTCO_2eq$. Results are shown in Table 3 below.

Reduction Scenario and Results

The reduction schedule used for this analysis appears in Table 1 and Graph 2 below. Targets were set by considering the need to achieve real and significant reductions, the likely availability of alternatives, and other obligations under the Montreal Protocol (e.g., HCFC phaseout).

[14] *Montzka et al., "Recent increases in global HFC-23 emissions". Geophysical Research Letters, December 2009*
[15] "Summary of Information Publicly Available on Relative Elements of the Operation of Clean Development Mechanisms and the Amounts of HCFC-22 Production Available for Credits" by Executive Committee of the Multilateral Fund for the Implementation of the Montréal Protocol, Fifty-seventh Meeting, Montreal, 30 March – 3 April 2009. Available at: http://www.multilateralfund.org/files/57/5762.pdf
[16] "Updated Model Rolling Three-Year Phase-Out Plan: 2011-2013 (Decision 59/5), Table 7." Document 62/7 by Executive Committee of the Multilateral Fund for the Implementation of the Montréal Protocol, Sixty-second Meeting, Montreal, 29 November – 3 December 2010. Available at: http://www.multilateralfund.org/files/62/6207.pdf
[17] A 1% factor is used for baseline non-A5 production.

Applying the reduction schedule to the projected consumption and baselines developed as described above (and shown in Table 2) yields HFC consumption reductions as shown in Table 3. Table 3 estimates the cumulative reductions of HFC consumption for four different time intervals: 2014 to 2020, 2014 to 2030, 2014 to 2040, and 2014 to 2050.

Table 1: Proposed HFC Reduction Schedules

HFC Consumption Reduction Schedule			
Non-Article 5 Parties		Article 5 Parties	
Year	**Cap (% of Baseline)**	**Year**	**Cap (% of Baseline)**
2015	90%	2017	100%
2017	80%	2021	80%
2020	70%	2025	70%
2025	50%	2029	50%
2029	30%	2035	30%
2033	15%	2043	15%

Graph 2. Proposed HFC Reduction Schedule

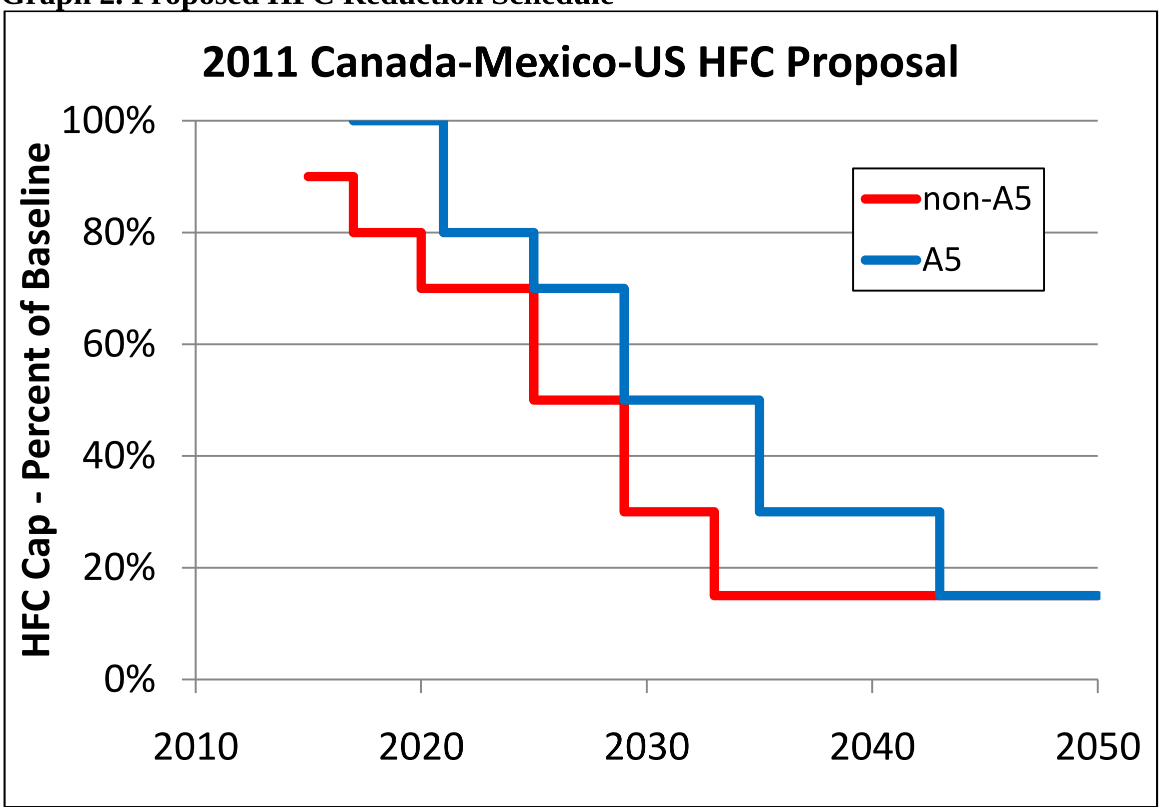


Table 2: Estimated Baselines

Party	Method	Baseline (MMTCO$_2$eq)
Non-Article 5 Parties	100% HFC + 85% HCFC Consumption, Average 2005-2008	760
Article 5 Parties	100% HCFC Consumption, Average 2005-2008	729
World		**1,489**

Table 3: Estimated Benefits of the Amendment Proposal, at Various Intervals

Cumulative HFC Reductions (MMTCO$_2$eq)				
Party	**2014 to 2020**	**2014 to 2030**	**2014 to 2040**	**2014 to 2050**
Non-Article 5 Parties	2,700	12,100	26,400	42,600
Article 5 Parties	14	5,900	20,500	44,500
World*	**2,700**	**17,900**	**47,000**	**87,200**
Byproduct Controls	**1,300**	**3,400**	**6,600**	**11,600**
World Total *	**4,100**	**21,300**	**53,500**	**98,800**

* World total may not sum due to rounding.

Availability of Alternatives for Meeting the Reduction Schedule

In many ways, the current availability of substitutes (in this case for HFCs) is similar to the availability of CFC substitutes at the 1987 signing of the Montreal Protocol, and similar to when the Parties agreed to phase out HCFCs – in all cases, some alternatives were known but not for all applications.

As part of the U.S. ozone layer protection program, the USEPA established the regulatory Significant New Alternatives Policy (SNAP) program in 1994. The SNAP program ensures a smooth and timely transition from ODS to a variety of alternatives across major industrial, commercial, and military sectors. The SNAP program's findings are relevant globally and can be used by countries as they consider transitioning to alternatives. The SNAP program provides a broad menu of options that includes HFCs with a range of GWPs as well as non-HFC options. As the SNAP menu continues to expand, more low-GWP and no-GWP alternatives have been added.

USEPA has analyzed certain sector-specific, technically- and economically-viable mitigation options for HFCs. The most promising options to reduce HFC consumption include:

- Substituting HFCs with low-GWP or no-GWP substances in a variety of applications (where safety and performance requirements can be met);
- Implementing new technologies that use significantly lower amounts of HFCs; and,
- Various process and handling options that reduce consumption during the manufacture, use, and disposal of products that contain or use HFCs.

Information on existing and potential options to reduce HFCs can be found in Tables 4 through 6. For some subsectors additional information also is available on USEPA's website, as discussed below.

It is clear that many options exist across all major sectors to reduce, or even eliminate, the use of HFCs. Some of these options are available today, meaning they could be used to meet HCFC phaseout obligations while at the same time contributing to the proposed HFC reductions. While low-GWP alternatives already exist for many end-use applications, additional research may be required to find alternatives for some important applications, such as residential and light-commercial air conditioning (i.e., unitary air conditioners, mini-splits and multi-splits).
SNAP continues to identify substitutes – for ODS as well as HFCs – that offer lower overall risks to human health and the environment. The environmental risk factors considered include:

- ozone depletion potential (ODP);
- global warming potential (GWP);
- flammability;
- toxicity;
- contributions to smog;
- aquatic and ecosystem effects; and,
- occupational health and safety.

To date, USEPA has reviewed approximately 400 substitutes in the refrigeration and air conditioning; fire suppression; foam blowing; solvent cleaning; aerosols; adhesives, coatings, and inks; sterilants; and tobacco expansion sectors. Most substitutes have been found acceptable, although in some cases restrictions are applied to protect the environment and human health. Across all sectors, roughly one-third of the substitutes reviewed contain HFCs. For the refrigeration and air conditioning sector, HFCs now dominate. However, the SNAP program has issued several proposed or final rulemakings, and is currently considering a number of other such rulemakings and projects that have and will continue to provide additional low-GWP or no-GWP options including hydrocarbons and low-GWP hydrofluoro-olefins (HFOs).

A detailed analysis of *how* Parties might meet the proposed reduction schedule has not been performed, as that would depend on national circumstances and preferences. However, many types of transitions can be foreseen. For example, the mobile air conditioning industry is poised to introduce HFO-1234yf or CO_2 in new vehicles to meet regulations in Europe; these same technologies could be used elsewhere. In May, 2010, USEPA issued standards for GHG emissions from passenger cars and other light-duty vehicles for model years 2012 through 2016. That regulation included an option for car manufacturers to earn credit toward their company's GHG emission standards by switching from the current automotive refrigerant, HFC-134a, to a refrigerant with a lower GWP. Some car manufacturers may find a switch to HFO-1234yf to be a reasonable and cost-effective part of a compliance strategy to meet their company's emission standards. For example, General Motors has announced they intend to start manufacturing some models using HFO-1234yf in their 2013 model year, to be built in 2012 in the U.S.

Several options in foam-blowing, including hydrocarbons and HFOs, also offer an opportunity for non-A5 countries to reduce HFC consumption, and for A5 countries to move directly from HCFCs in certain applications. Many types of hermetic air-conditioning and refrigeration equipment—including domestic refrigerators, vending machines, and bottle coolers—are becoming available worldwide with low-GWP alternatives in lieu of HCFC-22, HFC-134a and other high-GWP chemicals.

USEPA is developing a series of sector-specific fact sheets to provide more current information on low-GWP or no-GWP alternatives. Five fact sheets covering commercial refrigeration, domestic refrigeration, motor vehicle air conditioning, unitary air-conditioning, and construction foam are currently available on our website at: www.epa.gov/ozone/intpol/mpagreement.html. Additional fact sheets for other sectors will be available later this year.

Taken together, the suite of known alternative chemicals, new technologies, and better process and handling practices can significantly reduce HFC consumption in both the near and long term, while simultaneously completing the HCFC phaseout. Although there is much work to do to fully implement these chemicals, technologies and practices, and some unknowns still remain, the industries currently using HCFCs and HFCs have proven through the ODS phaseout that they can move quickly to protect the environment.

Table 4. HFC Substitutes by Sector: Aerosols, Foams, Fire Suppression & Solvents

End-Use		Substitute or Mitigation Strategy	Change in CO_2e Where Adopted*	Years Until Available**
Aerosols	Non-Medical	Replace HFC-134a with HFC-152a	91%	Available Now
		Hydrocarbons	100%	Available Now
		Not-in-Kind (pumps, roll-ons, etc.)	100%	Available Now
		HFO-1234ze(E)	95.2 to 99.6%	<5
	Medical	Dry Powder Inhalers	100%	Available Now
		Injections / Tablets	100%	10+
Fire Suppression	Total Flooding	Inert Gases	100%	Available Now
		Water Mist	100%	Available Now
		Fluorinated Ketone	99.97%	Available Now
	All	Other Low-GWP Substances	~90%	10+
Foam Blowing	Various	Hydrocarbons	100%	Available Now
	XPS	CO_2	99.9%	<5
	Spray	H_2O	100%	<5
	Appliance, XPS, Spray	HFO-1234ze(E)	99.4 to 99.6%	<5
		HFO-1336mzz(Z)	99.0 to 99.3%	<5
	Appliance Foam	Capture / Destruction at End-of-Life (EOL)	~90%	Available Now
	Construction Foam	Capture / Destruction at EOL	~90%	10+
Solvents	Electronics & Precision Cleaning	Aqueous & Semi-Aqueous	100%	Available Now
		Hydrofluoroethers (HFEs)	82 to 96%	Available Now

* Indicates the reduction achieved where applied. For example, replacing HFC-134a with HFC-152a yields a 91% reduction in consumption (in CO_2-equivalent terms). However, the substitute or mitigation strategy may not be applicable across the entire end-use.
** Key to time-frames
Available Now: option applied in significant amounts; regional and product type variations may exist
<5 Years: option in the early deployment stage and/or SNAP acceptability determination made or proposed
<10 Years: option known to be under development and/or logical extension of other known options
10+ Years: option not known to be under development; more intense research and testing required

Table 5. HFC Substitutes by Sector: Air Conditioning

End-Use	Substitute or Mitigation Strategy	Change in CO_2e Where Adopted	Years Until Available
All End Uses	Recovery/ Reclamation/ Destruction	10 to 100%*	Available Now
	Leak Repair	10 to 100%*	Available Now
Auto A/C	Enhanced HFC-134a Systems	50%	Available Now
	HFO-1234yf, CO_2, HFC-152a	91.3 to 99.9%	<5
Bus, Train A/C	HFO-1234yf, CO_2	99.7 to 99.9%	<5
Residential & Commercial A/C, Chillers	Microchannel Heat Exchangers	35 to 50%	Available Now
	Low-GWP Blends	50 to 90%	<10
Window A/C units	Hydrocarbons, CO_2, HFO-1234yf	99.7 to 100%	<5
Dehumidifiers			

* Wide range indicates the wide range of practices across different end-uses and institutional behaviors.

Table 6. HFC Substitutes by Sector: Refrigeration

End-Use	Substitute or Mitigation Strategy	Change in CO_2e Where Adopted	Years Until Available
All End Uses	Recovery/ Reclamation/ Destruction	10 to 100%*	Available Now
	Leak Repair	10 to 100%*	Available Now
Supermarkets	Low Charge / Low Leak Technologies (e.g., Cascade or Secondary Systems)	90 to 100%	Available Now
	Low-GWP Blends	50 to 90%	Available Now to <10
Chillers, Cold Storage	Ammonia	100%	Available Now
	Low-GWP Blends	50 to 90%	Available Now to <10
Home Refrigerators/ Freezers	Hydrocarbons, CO_2, HFOs	99.7 to 100%	Available Now
Stand-Alone Commercial Refrigerators/ Freezers			Available Now
Beverage Coolers			Available Now
Vending Machines			<5
Ice Makers			<10
Transport Refrigeration	Hydrocarbons, Ammonia, Low GWP Blends	50 to 100%	<10

* Wide range indicates the wide range of practices across different end-uses and institutional behaviors.