

Benefits of Addressing HFCs under the Montreal Protocol

October 2015

Stratospheric Protection Division
Office of Atmospheric Programs
Office of Air and Radiation

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EXECUTIVE SUMMARY

The United States, Canada, and Mexico have proposed an amendment to the Montreal Protocol to phase down production and consumption of hydrofluorocarbons (HFCs) and control byproduct emissions. The proposal includes binding reduction targets for all countries, and provides access to financial support and extended phasedown time to developing countries. The proposal builds on the success of the Montreal Protocol, relies on the strength of its institutions, and realizes climate benefits in both the near and long-term.

HFC use and emissions are rapidly increasing as a result of the phaseout of ozone-depleting substances (ODS) and growing global demand for air conditioning and refrigeration. Although safe for the ozone layer, the continued emissions of HFCs – primarily as alternatives to ODS and also from the byproduct emissions of HFC-23 will have an immediate and significant effect on the Earth’s climate system. Without further controls, it is predicted that HFC emissions could partially negate the climate benefits achieved under the Montreal Protocol. The proposal calls for a gradual phasedown of HFCs which will allow for early transition in sectors where alternatives are widely available while providing more time and incentive for innovation in deploying alternatives in other areas.

This analysis estimates projected climate benefits based on adoption of a freeze in HFC consumption and production (in 2021) for Article 5 parties and on initial reduction steps (in 2019 and 2024) in for non-Article 5 parties. Adopting these provisions would achieve approximately 57–79 gigatons of carbon dioxide equivalent (GtCO₂eq) (or 57,000–79,000 million metric tons of carbon dioxide equivalent (MMTCO₂eq)) cumulatively by 2050, which is about 68% of the consumption reductions from the full North American proposal. In 2016, Parties could return to negotiate the rest of the schedule as well as other provisions. Adoption of the full North American proposal would produce environmental benefits of 90–111 GtCO₂eq cumulatively by 2050. Table ES-1 displays the projected cumulative benefits that could be adopted through 2015 and 2016 negotiations.

TABLE ES-1: ESTIMATED BENEFITS OF THE AMENDMENT PROPOSAL

Cumulative HFC Reductions (GtCO ₂ eq) through 2050			
	A5 Freeze & Non-A5 First Steps	<i>Remaining Provisions</i>	<i>Total</i>
HFC Phasedown – Consumption Reductions	57 – 79	20	78 – 99
Byproduct Controls – Emissions Reductions		12	12
Total*	57 – 79	32	90 – 111

* May not sum due to rounding

1. INTRODUCTION

This paper presents an updated analysis of potential benefits from globally reducing consumption of hydrofluorocarbons (HFCs) and reducing byproduct emissions of HFC-23 to reflect the 2015 proposed amendment to the *Montreal Protocol on Substances that Deplete the Ozone Layer* as submitted by United States, Canada, and Mexico using the same methodology as previous amendment analysis from the U.S. Environmental Protection Agency (U.S. EPA)¹.

2. PROPOSED AMENDMENT TO PHASE DOWN HFC CONSUMPTION AND REDUCE HFC-23 BYPRODUCT EMISSIONS

The governments of the United States of America, Canada, and Mexico proposed an amendment to the Montreal Protocol to phase down the consumption and production of HFCs and reduce HFC-23 byproduct emissions. Key elements of this Amendment proposal:

- Lists 19 HFCs as controlled substances under the Montreal Protocol.
- Recognizes that there may not be alternatives for all HFC applications today and therefore relies on a gradual phase down mechanism with a plateau as opposed to a complete phaseout.
- Establishes commitments for the developed country (non-Article 5) and developing country (Article 5) phasedown of HFC production and consumption while providing additional time for Article 5 countries.
- The amendment uses GWP weighting for HFCs and HCFCs.
- Includes provisions to limit HFC-23 byproduct emissions resulting from the production of HCFCs and HFCs.
- Requires reporting on HFC production, consumption, and byproduct emissions.
- Makes reductions in HFC production and consumption and byproduct emissions eligible for funding under the Multilateral Fund for the Implementation of the Montreal Protocol (MLF).
- Requires licensing of HFC imports and exports, and import and export controls for non-Parties.

After considerable deliberation, these countries have proposed a staged approach that sets a critical goal of adopting a meaningful but less ambitious amendment this year, along with an agreement to take up the remaining elements next year. This approach is intended to address a number of the concerns that have been raised. This revised approach would allow for an achievable first step of an HFC amendment consisting of initial control and other measures to be adopted in 2015; and a complete phasedown schedule and additional aspects to be further negotiated in 2016.

¹ EPA, 2014. Benefits of Addressing HFCs under the Montreal Protocol, July 2014. Accessible at <http://conf.montreal-protocol.org/meeting/mop/cop10-mop26/presession/Information%20Documents%20are%20available%20in%20English%20onl/MOP-26-INF5.pdf>

3. PROPOSED PHASEDOWN OF HFC CONSUMPTION

3.1. ASSUMPTIONS FOR ESTABLISHING THE BASELINE AND PROJECTED CONSUMPTION

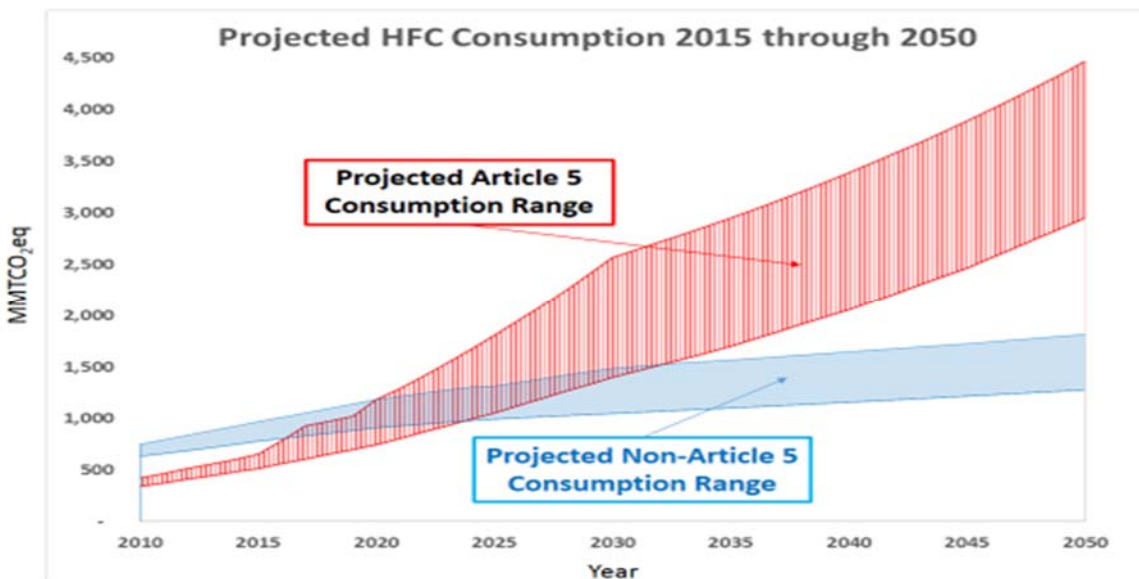
Because HFCs have replaced HCFCs in many applications in some countries, the baseline used in the North American proposal is set using historical information while accounting for this transition. The consumption baseline is depicted in the table below.

TABLE 1: BASELINE EQUATIONS

Party	Method
Equation 1: Non-Article 5 Parties	$100\% \left(\frac{\left(\begin{array}{l} 2011 \text{ HFC Consumption} \\ + 2012 \text{ HFC Consumption} \\ + 2013 \text{ HFC Consumption} \end{array} \right)}{3} \right) + 75\% \left(\frac{\left(\begin{array}{l} 2011 \text{ HCFC Consumption} \\ + 2012 \text{ HCFC Consumption} \\ + 2013 \text{ HCFC Consumption} \end{array} \right)}{3} \right)$
Equation 2: Article 5 Parties	$100\% \left(\frac{\left(\begin{array}{l} 2011 \text{ HFC Consumption} \\ + 2012 \text{ HFC Consumption} \\ + 2013 \text{ HFC Consumption} \end{array} \right)}{3} \right) + 50\% \left(\frac{\left(\begin{array}{l} 2011 \text{ HCFC Consumption} \\ + 2012 \text{ HCFC Consumption} \\ + 2013 \text{ HCFC Consumption} \end{array} \right)}{3} \right)$

Projected consumption estimates for Article 5 and non-Article 5 from 2015 through 2050 are shown in Graph 1.

GRAPH 1. PROJECTED HFC CONSUMPTION 2012 THROUGH 2050



3.2. REDUCTION SCENARIO AND RESULTS

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

GRAPH 2. PROPOSED HFC REDUCTION SCHEDULES

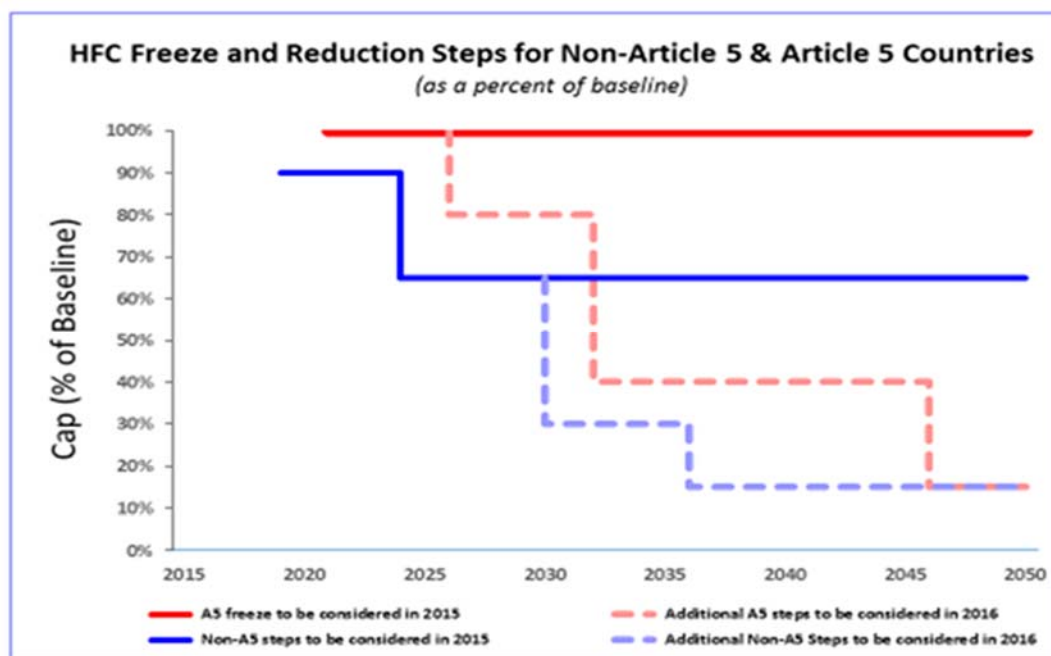


TABLE 2: PROPOSED HFC REDUCTION SCHEDULES

HFC Consumption and Production Reduction Schedule			
Non-Article 5 Parties		Article 5 Parties	
Year	Cap (% of Baseline)	Year	Cap (% of Baseline)
2019	90%	2021	100%
2024	65%	2026	80%
2030	30%	2032	40%
2036	15%	2046	15%

The table above shows freeze and Non-A5 steps through 2025 in bold that represent the first step in our proposed two-step approach for an amendment. The non-bold items are the other steps that were proposed in our original 2015 submission that we now propose be considered in 2016.

Applying the reduction schedule and baselines to the projected consumption developed as described above yields HFC consumption reductions as shown in Table 3. Table 3 estimates the range of cumulative reductions through 2050 of HFC consumption for the A5 freeze and Non-A5 first steps, the remaining reduction schedule, and the total.

TABLE 3: ESTIMATED BENEFITS OF THE HFC PHASEDOWN

Cumulative HFC Phasedown Consumption Reductions (MMTCO ₂ eq) through 2050			
	A5 Freeze & Non-A5 First Steps	Remaining Reduction Schedule	Total*
World	57,000 – 79,000	20,000	78,000 – 99,000

* May not sum due to rounding

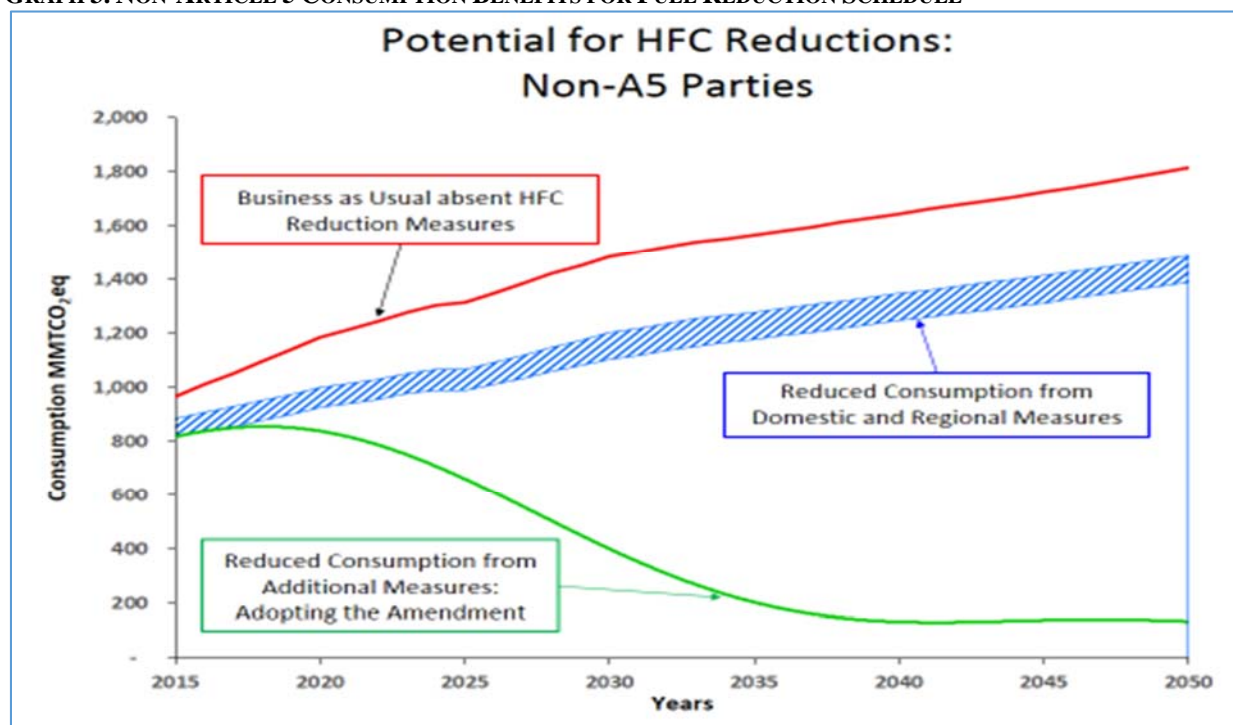
A study by Velders et al.² indicates that if HFC production were phased out in 2020 instead of 2050, for example, up to 146 GtCO₂eq (or 146,000 MMTCO₂eq) of cumulative emissions could be avoided from 2020 – 2050, and an additional bank of up to 64 GtCO₂eq (or 64,000 MMTCO₂eq) could also be avoided in 2050.

3.3. NATIONAL, REGIONAL, AND GLOBAL EFFORTS

Over the past several years, we have seen a number of countries take action to address HFCs and these actions are already resulting in benefits. We can expect additional actions in the absence of an amendment. Graph 3 depicts:

- Business as usual in a world absent HFC reduction measures;
- Reduced consumption from domestic and regional measures
 - Includes measures from the European Union, United States, Japan and assumed measures from Canada
- Reduced consumption from additional measures under the Montreal Protocol (i.e. adopting an HFC phase down).

GRAPH 3. NON-ARTICLE 5 CONSUMPTION BENEFITS FOR FULL REDUCTION SCHEDULE



United States of America

² Velders, G. J. M., S. Solomon, and J. S. Daniel. Growth of climate change commitments from HFC banks and emissions. *Atmos. Chem. Phys.* 14, 4563–4572, 2014.

The President directed the United States to lead through both international diplomacy and domestic action. In particular, he directed the U.S. EPA to use its authority through the Significant New Alternatives Policy (SNAP) Program to encourage private sector investment in low-emissions technology by identifying and approving climate-friendly chemicals while prohibiting certain uses of the most harmful chemical alternatives. In addition, the President directed his Administration to purchase cleaner alternatives to HFCs whenever feasible and to transition over time to equipment that uses safer and more sustainable alternatives.

In the past year, the U.S. EPA issued two new rules and two notices significantly updating the lists of acceptable and unacceptable alternative chemicals under the SNAP Program. In February 2015, several alternatives were added to the acceptability list (subject to use conditions) for use in the refrigeration and air conditioning sectors, including several hydrocarbons. Hydrocarbons are already in use in refrigeration and air conditioning applications in Europe and Asia. In July 2015, the U.S. EPA released a final rule that changed the status of certain high-GWP HFCs used in motor vehicle air conditioning, retail food refrigeration and vending machines, aerosols, and foam blowing to make them unacceptable because safer, more climate-friendly alternatives are available. The expected cumulative emission savings are 1.1 gigatons of CO₂-equivalent by 2030 and 4.5 gigatons by 2050. In October 2014 and July 2015, the U.S. EPA also issued two acceptability notices, adding to the list of alternatives acceptable for use in the refrigeration and air conditioning; aerosols; solvents, coatings and inks; fire suppression and explosion protection; and foam blowing sectors.

European Fluorinated Gas Regulation

The European Commission recently revised and strengthened their requirements on fluorinated gases as part of their policy to combat climate change. The previous F-gas regulation was adopted in 2006 and was aimed at stabilizing European Union (EU) F-gas emissions at 2010 levels. The new regulation went into effect January 1, 2015. The intent is to cut the EU's F-gas emissions by two-thirds compared with 2014 levels. Requirements include a European phasedown and quota system for the supply of HFCs beginning in 2015, along with bans on certain HFC-containing equipment, and a requirement to destroy or recycle HFC-23 (a production byproduct). Existing regulation on labeling, refrigerant management and reporting requirements, and training programs have also been expanded to cover HFCs. The expected cumulative emission savings are 0.9 gigatons of CO₂-equivalent by 2030 and 2.6 gigatons by 2050.

Canada

In March 2015, Environment Canada proposed a permitting and reporting regime for bulk HFCs. The proposal is consistent with the provision for a permitting and reporting regime outlined in the North American Proposal to phase down HFCs under the Montreal Protocol. Additionally, Environment Canada is in the process of developing a proposal for regulatory measures for HFCs, following the publication of a Notice of Intent to Regulate Hydrofluorocarbons on December 6, 2014. Following consultations with industry, Canada is considering an approach that combines two components: 1. a phase-down of HFC consumption (manufacture, imports and exports); and 2. prohibitions on specific HFC-containing products, such as air-conditioning and refrigeration equipment, foam insulation products and aerosol products. This approach is similar to the one used to successfully phase out ozone-depleting substances in Canada. Work on

defining the proposed controls and moving through the regulatory development process is ongoing. Proposed measures for HFCs in line with the above approach could be published in 2016.

Japanese Fluorinated Gas Regulation

In 2013, Japan enacted a law updating and expanding their existing fluorocarbon regulations. The objective of the new legislation, which came into force in April 2015, is to reduce HFC emissions through measures that cover the total life cycle, from manufacture through disposal, of fluorocarbons and equipment using these gases. Under the new law, manufacturers and importers are required to develop HFC phase-down plans that promote non-fluorinated gases or low-GWP fluorocarbons, and meet national GWP targets and timelines for specific end-uses. The government has also created mandatory registration/ permission systems for fluorocarbon process operators (i.e. entities that recover, refill, recycle or destroy fluorocarbons). In addition, end-users of fluorocarbon-containing equipment are responsible for the proper monitoring and management of equipment and leaks.

The Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants

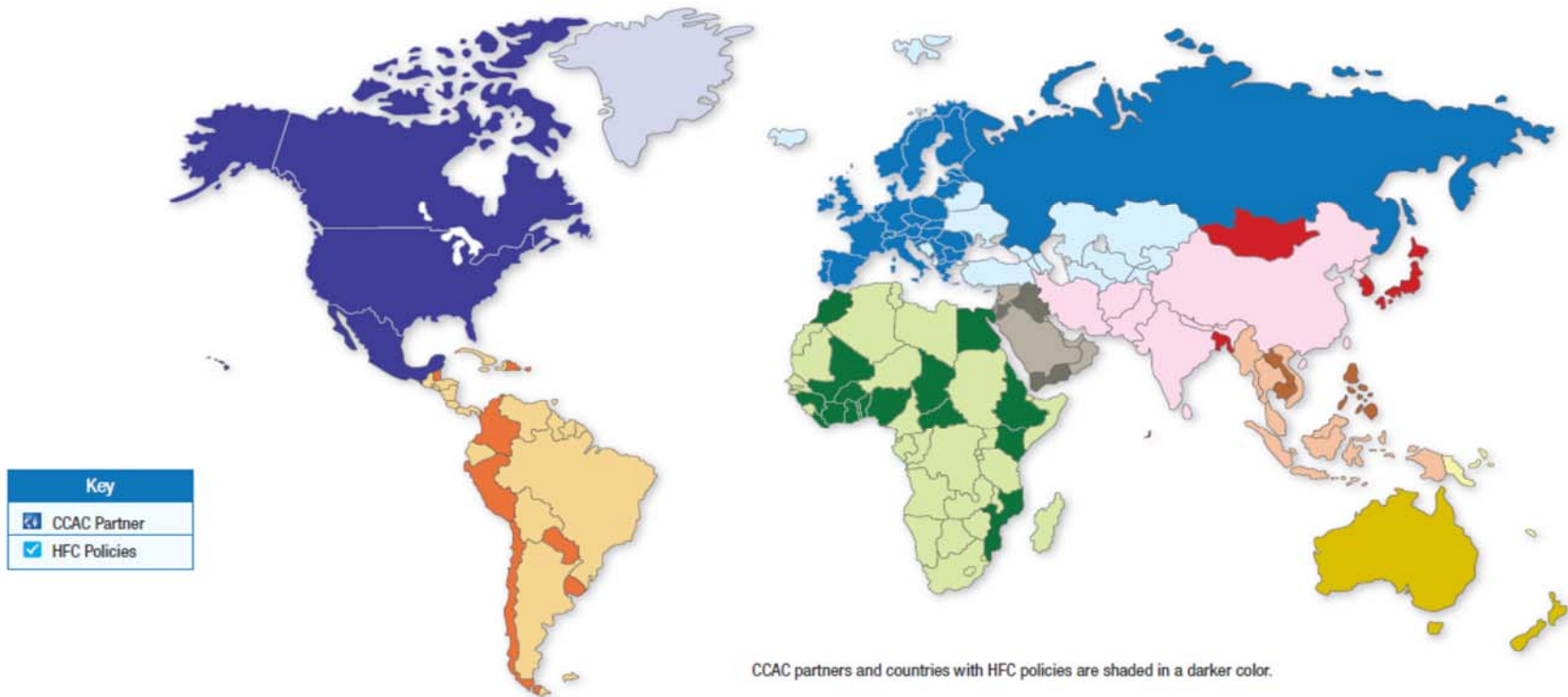
The Climate and Clean Air Coalition (CCAC) to Reduce Short-Lived Climate Pollutants is a voluntary initiative launched in 2012 aimed at achieving progress in addressing near-term contributions to global warming. The CCAC is focusing on HFCs as well as black carbon and methane, and has sponsored several capacity building activities such as workshops and conferences focusing on enabling the use of climate-friendly alternatives to high-GWP HFCs and removing barriers to their adoption. The CCAC is also helping countries inventory their HFC sectors, and has produced case studies to share information about successful transitions to climate-friendly alternatives in commercial refrigeration. In addition, it is sponsoring several technology demonstration projects, HFC inventories in developing countries, and additional capacity building efforts.

Intended Nationally Determined Contributions

Countries committed to develop a new international climate agreement by the conclusion of the U.N. Framework Convention on Climate Change (UNFCCC) twenty first Conference of the Parties (COP21) in Paris in December 2015. Different countries start from different initial situations, development stages, degrees of urbanization, industrial development stages, degrees of technological maturity, degrees of market development, domestic financing capacities etc. Countries thus need to transform their economies under very different conditions and at different phases of growth cycles. Ahead of COP21, countries agreed to publicly outline what post-2020 climate actions they intend to take under a new international agreement, known as their Intended Nationally Determined Contributions (INDCs). The INDCs will include mitigation goals that represent a progress beyond current efforts in the country. INDCs can include a range of efforts including efforts to reduce HFC emissions.

Figure 1 presents a geographic distribution of HFC policies along with countries participating in the Climate and Clean Air Coalition.

FIGURE 1. GEOGRAPHIC DISTRIBUTION OF HFC POLICIES AND CCAC PARTNERS



NORTH AMERICA	LATIN AMERICA AND CARIBBEAN		EUROPE AND CENTRAL ASIA		WEST ASIA	SOUTH ASIA
Canada <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Mexico <input checked="" type="checkbox"/> United States of America <input checked="" type="checkbox"/>	Belize <input checked="" type="checkbox"/> Chile <input checked="" type="checkbox"/> Colombia <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Dominican Republic <input checked="" type="checkbox"/>	Paraguay <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Peru <input checked="" type="checkbox"/> Uruguay <input checked="" type="checkbox"/>	Austria <input checked="" type="checkbox"/> Denmark <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Finland <input checked="" type="checkbox"/> France <input checked="" type="checkbox"/> Germany <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Ireland <input checked="" type="checkbox"/> Italy <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Macedonia <input checked="" type="checkbox"/> Moldova <input checked="" type="checkbox"/> Montenegro <input checked="" type="checkbox"/> Netherlands <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Norway <input checked="" type="checkbox"/> <input checked="" type="checkbox"/>	Poland <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Russian Federation <input checked="" type="checkbox"/> Serbia <input checked="" type="checkbox"/> Slovenia <input checked="" type="checkbox"/> Spain <input checked="" type="checkbox"/> Sweden <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Switzerland <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> United Kingdom <input checked="" type="checkbox"/> <input checked="" type="checkbox"/>	Iraq <input checked="" type="checkbox"/> Israel <input checked="" type="checkbox"/> Jordan <input checked="" type="checkbox"/> Yemen <input checked="" type="checkbox"/>	Bangladesh <input checked="" type="checkbox"/> Japan <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Mongolia <input checked="" type="checkbox"/> Republic of Korea <input checked="" type="checkbox"/> Republic of Maldives <input checked="" type="checkbox"/>
AFRICA						
Benin <input checked="" type="checkbox"/> Burkina Faso <input checked="" type="checkbox"/> Central African Republic <input checked="" type="checkbox"/> Chad <input checked="" type="checkbox"/> Côte d'Ivoire <input checked="" type="checkbox"/> Egypt <input checked="" type="checkbox"/>	Ethiopia <input checked="" type="checkbox"/> Ghana <input checked="" type="checkbox"/> Kenya <input checked="" type="checkbox"/> Kingdom of Morocco <input checked="" type="checkbox"/> Liberia <input checked="" type="checkbox"/> Mali <input checked="" type="checkbox"/>	Mozambique <input checked="" type="checkbox"/> Nigeria <input checked="" type="checkbox"/> Republic of Guinea <input checked="" type="checkbox"/> Togo <input checked="" type="checkbox"/> <input checked="" type="checkbox"/>	European Commission <input checked="" type="checkbox"/> <input checked="" type="checkbox"/>	Pacific Island Countries Australia <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> New Zealand <input checked="" type="checkbox"/> <input checked="" type="checkbox"/>	Southeast Asia Cambodia <input checked="" type="checkbox"/> Laos <input checked="" type="checkbox"/> Philippines <input checked="" type="checkbox"/> <input checked="" type="checkbox"/>	

4. BYPRODUCT EMISSIONS OF HFC-23

PROPOSED AMENDMENT AND CURRENT MITIGATION ACTIVITIES

The North American Amendment proposal includes provisions that limit HFC-23 byproduct emissions (and under our approach these would be taken up in 2016) resulting from the production of HCFCs and HFCs. 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 fluorochemical production. 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. However, given the extensive use of HCFC-22 as a feedstock, its production is projected to continue indefinitely. 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. The capture and destruction technologies for HFC-23 byproduct emissions is proven and readily available. Recent studies³ indicate that HFC-23 emissions continue to increase in developing countries, despite global efforts to curb emissions.

BENEFITS FROM BYPRODUCT CONTROLS

Table 4 estimates the benefits of HFC-23 byproduct emission controls.

TABLE 4: ESTIMATED BENEFITS OF HFC-23 BYPRODUCT EMISSION CONTROLS

Cumulative HFC-23 Byproduct Emission Reductions (MMTCO₂eq)	
through 2050	
World Byproduct Controls	12,000

In April 2013, the Executive Committee of the MLF reached an agreement with China to phase out all HCFC production for consumption by 2030. China is by far the largest Article 5 producer of HCFC-22 and has 34 out of the 43 identified production lines. While the agreement will phase out the HCFC-22 production for consumption, this analysis already accounted for the HCFC-22 phaseout as well as the growth in HCFC-22 for feedstock use; thus, no adjustment is necessary. On September 25, 2015, the United States and China made a joint presidential statement on climate change which states that for China, "Actions on HFCs continue to be supported and accelerated, including effectively controlling HFC-23 emissions by 2020."

³ Montzka, S. A., L. Kuijpers, M. O. Battle, M. Aydin, K. R. Verhulst, E. S. Saltzman, and D. W. Fahey. et al.: Recent increases in global HFC-23 emissions, *Geophysical Research Letters*, 37, L02808, doi:10.1029/2009GL041195, 2010.

5. SUMMARY

This analysis estimates projected climate benefits based on adoption of a freeze in HFC consumption and production (in 2021) for Article 5 parties and on initial reduction steps (in 2019 and 2024) in for non-Article 5 parties. Adopting these provisions would achieve approximately 57,000–79,000 MMTCO₂eq cumulatively by 2050, which is about 68% of the consumption reductions from the full North American proposal. In 2016, Parties could return to negotiate the rest of the schedule as well as other provisions. Adoption of the remaining provisions would add an additional 32,000 MMTCO₂eq of environmental benefits for a total of 90,000–111,000 MMTCO₂eq cumulatively by 2050. Table 5 displays the projected cumulative benefits that could be adopted through 2015 and 2016 negotiations.

TABLE 5: ESTIMATED BENEFITS OF THE AMENDMENT PROPOSAL

Cumulative HFC Reductions (MMTCO₂eq) through 2050			
	A5 Freeze & Non-A5 First Steps	<i>Remaining Provisions</i>	<i>Total</i>
HFC Phasedown – Consumption Reductions	57,000 – 79,000	<i>20,000</i>	<i>78,000 – 99,000</i>
Byproduct Controls – Emissions Reductions		<i>12,000</i>	<i>12,000</i>
Total*	57,000 – 79,000	<i>32,000</i>	<i>90,000 – 111,000</i>

* May not sum due to rounding

The analysis assumes the HFC reduction obligations in the proposal by the United States, Canada, and Mexico are met, and that all Parties (developed and developing countries) continue to comply with current HCFC phaseout obligations. Although both the HFC proposal and the HCFC controls would be effective simultaneously, individual countries would still have the ability to examine their specific conditions and obligations, and determine how to meet the obligations. Transitions from HCFCs could include interim steps using a range of HFCs in various end uses, transitioning to low-GWP HFCs and non-fluorinated alternatives (e.g., ammonia, hydrocarbons) and continuing to use some amount of HFCs for the foreseeable future for certain end-uses (e.g., metered dose inhalers for asthmatics).