# Benefits of Addressing HFCs under the Montreal Protocol

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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.[1] Our goal is to adopt an ambitious HFC phasedown amendment in 2016 that includes HFC control commitments from both Article 5 (developing) and non-Article 5 (developed) countries. The agreement should produce significant climate mitigation benefits, and also include increased financial support that the United States and other countries can provide for the Protocol's Multilateral Fund (MLF) to enable compliance. 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. The continued emissions of HFCs – primarily as alternatives to ODS and as byproduct emissions of HFC-23 – are having an immediate and significant effect on the Earth's climate system. Without further controls, HFC emissions could largely negate the climate benefits achieved under the Montreal Protocol. The proposed amendment calls for a gradual phasedown of HFCs, which will allow for an early transition in sectors where alternatives are widely available while providing more time and incentive for innovation in deploying alternatives in other areas.

Phasing down HFCs through the Montreal Protocol has a large potential for slowing climate change by avoiding up to one-half degree Celsius of warming by the end of the century.[2] At the November 2015 27th Meeting of the Parties (MOP-27) in Dubai, the Parties adopted the Dubai Pathway. The Dubai Pathway commits Parties to "work within the Montreal Protocol to an HFC amendment in 2016." Adoption of the North American proposal would produce cumulative HFC consumption reductions of 90–111 $GtCO_2eq$ (or 90,000–111,000 million metric tons of carbon dioxide equivalent ($MMTC0_2eq$)) by 2050. Table ES-1 displays the projected cumulative benefits of adoption of the North American proposal as submitted in 2015 and forwarded by the Parties for continued consideration in 2016.

**TABLE ES-1: ESTIMATED BENEFITS OF THE AMENDMENT PROPOSAL**

| **Cumulative HFC Reductions ($GtCO_2eq$) through 2050** | |
|---|---|
| | **A5 & Non-A5 Parties** |
| **HFC Phasedown** – Consumption Reductions | **78 – 99** |
| **Byproduct Controls** – Emissions Reductions | **13** |
| **Total** | **90 – 111** |

* Totals may not sum due to independent rounding.

[1] This paper only analyzes the amendment proposed by Canada, Mexico and the United States (the "North American proposal"). Three other proposed amendments have been submitted to the Ozone Secretariat, with different proposed control measures and dates. They are summarized in section three of this paper.

[2] Y. Xu, D. Zaelke, G. J. M. Velders and V. Ramanathan. "The role of HFCs in mitigating 21st century climate change," *Atmospheric Chemistry and Physics* 13 (2013): 6083-6089. *Accessible from* http://www.atmos-chem-phys.net/13/6083/2013/acp-13-6083-2013.pdf.

# 1. INTRODUCTION

A phasedown of HFCs under the Montreal Protocol is the best way to reduce the rapidly growing climate effect of these gases. This paper presents an analysis of potential benefits from globally reducing consumption of hydrofluorocarbons (HFCs) and reducing byproduct emissions of HFC-23 in accordance with the North American proposed amendment to the *Montreal Protocol on Substances that Deplete the Ozone Layer* as submitted by the United States, Canada, and Mexico using the same methodology as previous amendment analyses from the U.S. Environmental Protection Agency (U.S. EPA).[3]

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

The governments of the United States of America, Canada, and Mexico are proposing 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 phasedown mechanism with a plateau as opposed to a complete phaseout;
- Establishes commitments for the phasedown of HFC production and consumption by developed countries (non-Article 5) and by developing countries (Article 5) with additional time for Article 5 countries;
- 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, import, export, and byproduct emissions of HFC-23;
- 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); and
- Requires licensing of HFC imports and exports, and import and export controls from/to non-Parties.

# 3. PROPOSED PHASEDOWN OF HFC CONSUMPTION

## 3.1. ASSUMPTIONS FOR ESTABLISHING THE BASELINE AND PROJECTED CONSUMPTION

Because HFCs have replaced HCFCs in many applications already, particularly in non-Article 5 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.

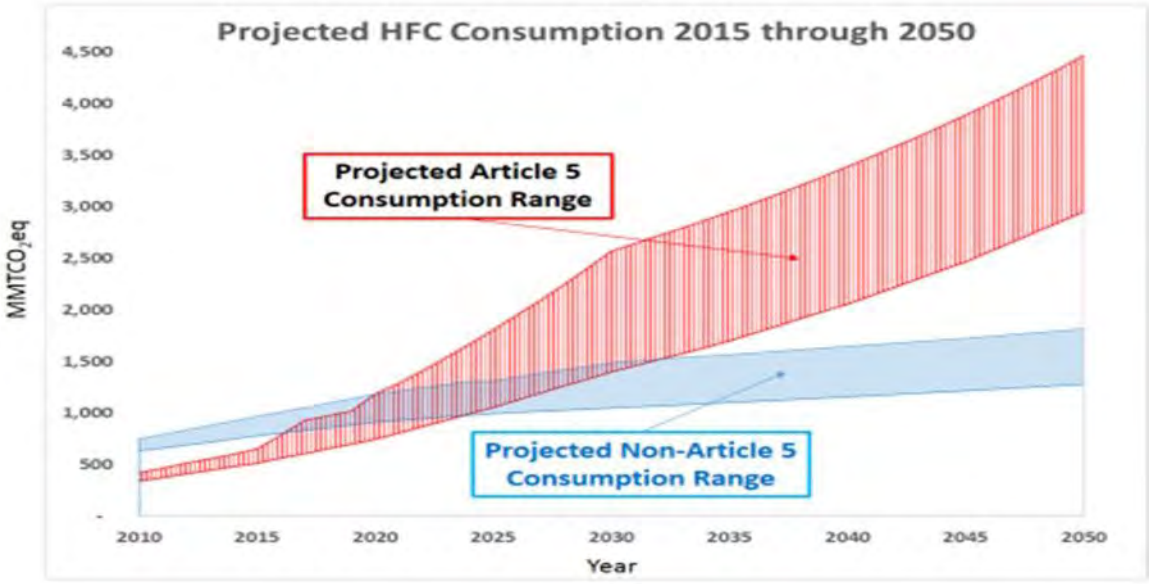
[3] EPA, 2015 Benefits of Addressing HFC under the Montreal Protocol, October 2015. *Accessible at https://www.epa.gov/sites/production/files/2016-03/documents/2015_benefits_of_addressing_hfcs_under_the_montreal_protocol_-_final_clean.pdf*.

**TABLE 1: BASELINE EQUATION**

| Party | Method |
|---|---|
| Equation 1: Non-Article 5 parties | $100\% \left( \frac{\left( \begin{matrix} 2011\ HFC\ consumption \\ +2012\ HFC\ consumption \\ +2013\ HFC\ consumption \end{matrix} \right)}{3} \right) + 75\% \left( \frac{\left( \begin{matrix} 2011\ HCFC\ consumption \\ +2012\ HCFC\ consumption \\ +2013\ HCFC\ consumption \end{matrix} \right)}{3} \right)$ |
| Equation 2: Article 5 parties | $100\% \left( \frac{\left( \begin{matrix} 2011\ HFC\ consumption \\ +2012\ HFC\ consumption \\ +2013\ HFC\ consumption \end{matrix} \right)}{3} \right) + 50\% \left( \frac{\left( \begin{matrix} 2011\ HCFC\ consumption \\ +2012\ HCFC\ consumption \\ +2013\ HCFC\ consumption \end{matrix} \right)}{3} \right)$ |

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

While the Parties to the Montreal Protocol are considering four different amendment proposals, as noted above, this paper only analyzes the North American proposal. Therefore, the reduction schedule used for this analysis appears in Graph 2 and Table 2 below. Phasedown steps were set by considering the need to achieve significant reductions to protect the global climate, the known and likely availability of alternatives, and other obligations under the Montreal Protocol (e.g., HCFC phaseout).

**GRAPH 2. PROPOSED HFC REDUCTION SCHEDULES**

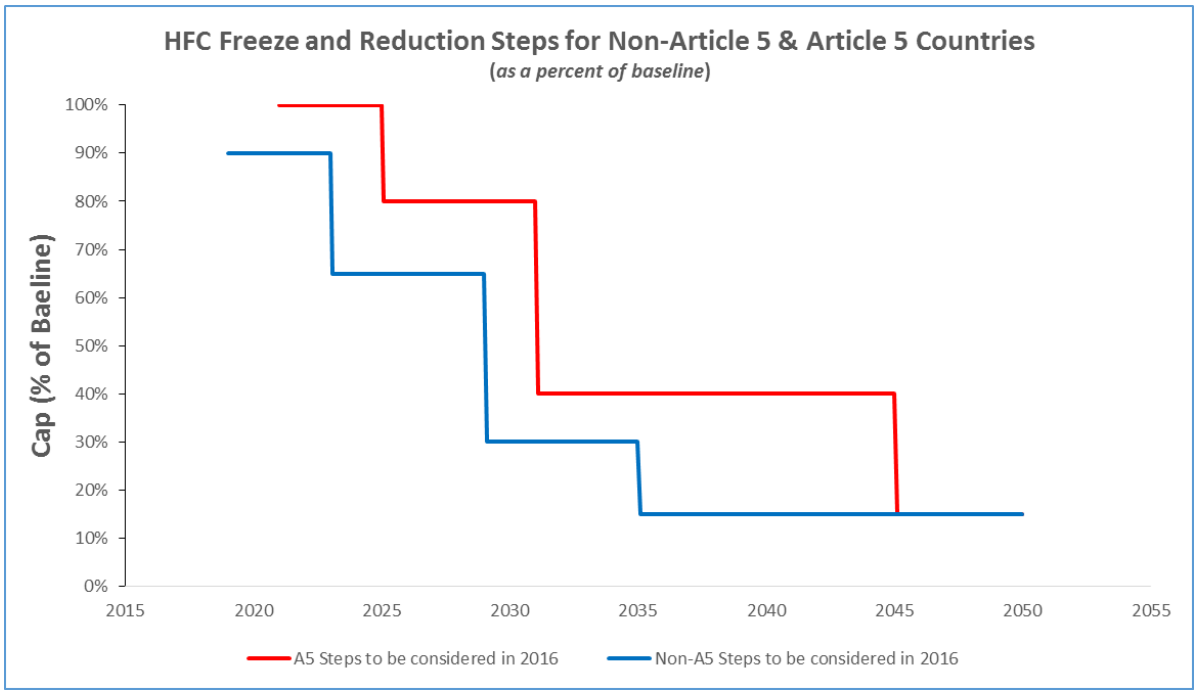



**TABLE 2: PROPOSED HFC REDUCTION SCHEDULES**

| 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%** |

Applying the reduction schedule and baselines to the projected consumption for Article 5 and non-Article 5 parties yields HFC consumption reductions as shown in Table 3. Table 3 estimates the range of cumulative reductions through 2050.

**TABLE 3: ESTIMATED BENEFITS OF THE HFC PHASEDOWN**

| Cumulative HFC Phasedown Consumption Reductions ($MMTCO_2eq$) through 2050 | |
|---|---|
| **Non-Article 5 Parties** | *25,000 – 37,000* |
| **Article 5 Parties** | *40,000 – 73,000* |
| **World*** | *78,000 – 99,000* |

* Totals may not sum due to independent rounding.
* Totals do not include benefits from controlling HFC-23 byproduct emissions.

A study by Velders et al.[4] indicates that phasing out HFC production in 2020, for example, prevents up to 146 $GtCO_2eq$ (or 146,000 $MMTCO_2eq$) of cumulative emissions from 2020 – 2050, and an additional bank of up to 64 $GtCO_2eq$ (or 64,000 $MMTCO_2eq$) could also be avoided in 2050.

## 3.3. OTHER AMENDMENT PROPOSALS

The European Union (EU), India, and a coalition of Pacific Island States submitted proposals in

[4] G. J. M. Velders, S. Solomon and J. S. Daniel. "Growth of climate change commitments from HFC banks an emissions," *Atmospheric Chemistry and Physics* 14 (2014): 4563–4572. *Accessible from* http://www.atmos-chem-phys.net/14/4563/2014/acp-14-4563-2014.html.

2015 along with the North American proposal. Each proposal recognizes the differing transition capabilities of Non-Article 5 and Article 5 countries, as evidenced in Tables 4 and 5 below. The four proposals suggest a first step or freeze by 2019, with at least two additional steps occurring by 2030 for Non-Article 5 countries. For Article 5 countries, the four proposals call for a freeze date ranging from 2019 to 2031, with varying numbers of steps.

**TABLE 4: COMPARISON OF HFC AMENDMENT PROPOSALS' KEY ELEMENTS FOR NON-ARTICLE 5 PARTIES**

| KEY ELEMENTS | NORTH AMERICAN PROPOSAL | INDIA PROPOSAL | EUROPEAN UNION PROPOSAL | ISLAND STATES PROPOSAL* |
|---|---|---|---|---|
| **Party's Baseline (GWP-weighted)** | Average of HFC production and consumption in 2011-2013 + 75% of average HCFC production and consumption in 2011-2013 | Average of HFC production and consumption in 2013-2015 + 25% of HCFC baseline (excludes HFC-23) | Average of HFC production and consumption in 2009-2012 + 45% of average HCFC production and consumption in 2009-2012. | Average of HFC production and consumption in 2009-2012 + 45% of average HCFC production and consumption in 2009-2012 |
| **Control Measures for HFC Production and Consumption (percent of baseline)** | 2019 – 90%<br>2024 – 65%<br>2030 – 30%<br>2036 – 15% | 2016 – 100%<br>2018 – 90%<br>2023 – 65%<br>2029 – 30%<br>2035 – 15% | 2019 – 85%<br>2023 – 60%<br>2028 – 30%<br>2034 – 15% | 2017 – 85%<br>2021 – 65%<br>2025 – 45%<br>2029 – 25%<br>2033 – 10% |

* Kiribati, Marshall Islands, Mauritius, Federated States of Micronesia, Palau, Philippines, Samoa and Solomon Islands.

**TABLE 5: COMPARISON OF HFC AMENDMENT PROPOSALS' KEY ELEMENTS FOR ARTICLE 5 PARTIES**

| KEY ELEMENTS | NORTH AMERICAN PROPOSAL | INDIAN PROPOSAL | EUROPEAN UNION PROPOSAL | ISLAND STATES PROPOSAL |
|---|---|---|---|---|
| **Party's Baseline (GWP-weighted)** | Average of HFC production and consumption in 2011-2013 + 50% HCFC production and consumption in 2011-2013 | Average of HFC production and consumption in 2028-2030 + 32.5% of HCFC baseline (excludes HFC-23) | *Consumption*: average of HFC and HCFC consumption in 2015-2016<br><br>*Production*: average of HFC production in 2009-2012 + 70% of HCFC production in 2009-2012 | Average of HFC consumption in 2015-2017 + 65% of HCFC baseline |
| **Control Measures for HFC Production and Consumption (percent of baseline)** | 2021 – 100%<br>2026 – 80%<br>2032 – 40%<br>2046 – 15% | 2031 – 100%<br>2050 – 15%<br>Phasedown steps are to be nationally determined 5 years in advance for the next 5-year period | *Consumption:* 2019 – 100% combined HCFC/HFC consumption; further reduction steps and timing to be agreed by 2020<br><br>*Production*<br>2019 – 100% HFC production<br>2040 – 15% HFC production | 2020 – 85%<br>2025 – 65%<br>2030 – 45%<br>2035 – 25%<br>2040 – 10% |

A key takeaway from comparing these proposals is that, with the exception of the Indian

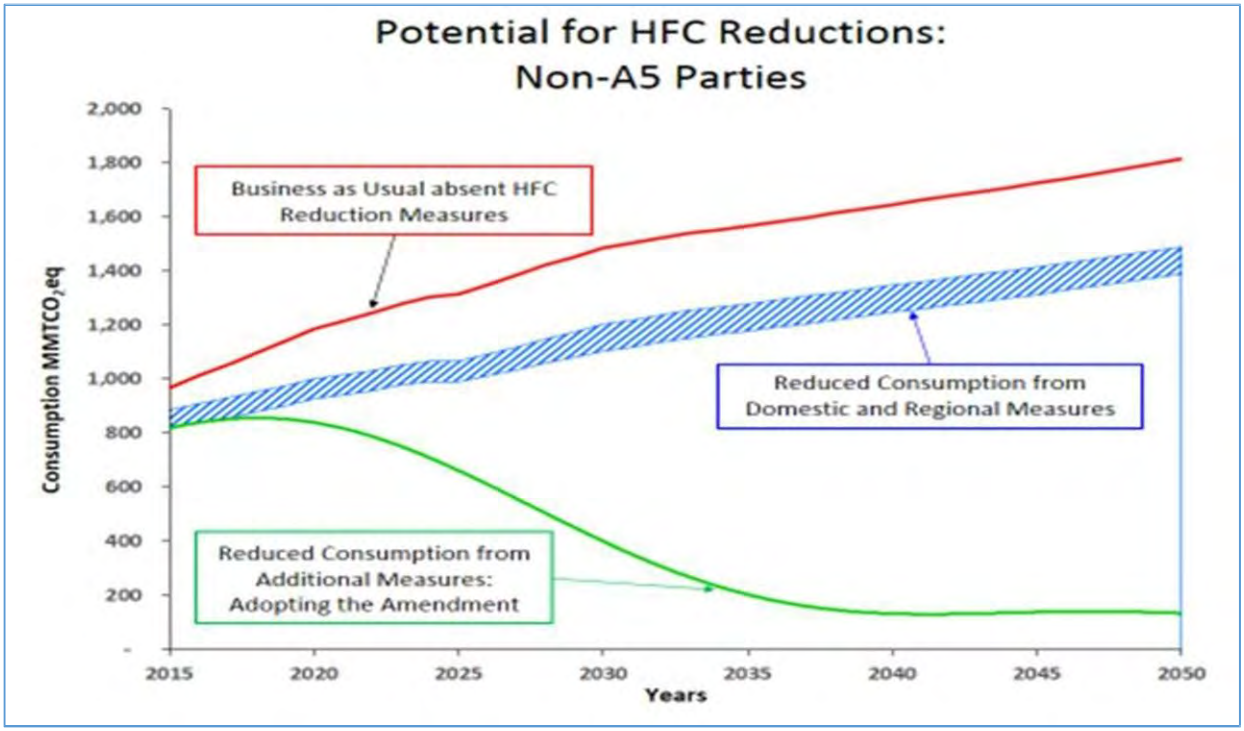
amendment proposal, they all call for an early freeze on HFC consumption and production for Article 5 countries. This early action is vital, as the majority of the benefits will be realized by 2030, and a freeze well before that year is an essential first step to realizing these benefits.

## 3.4. NATIONAL, REGIONAL, AND GLOBAL EFFORTS

Over the past several years, we have seen a number of countries take actions to address HFCs. Even in the absence of an amendment, we can expect additional actions at the national and regional levels. While these actions have already changed the trajectory of global HFC emissions, these actions alone are not enough. Graph 3 depicts:

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

**GRAPH 3. NON-ARTICLE 5 CONSUMPTION BENEFITS**




### United States of America

In June 2013, 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 also 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.

Since the President's direction, the U.S. EPA issued two rules, three notices, and one proposed rule significantly updating the lists of acceptable and unacceptable alternative chemicals under the SNAP Program. In February 2015, several alternatives were added to the acceptable 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 and are now entering the U.S. market. 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 alternatives that are more climate-friendly and pose less overall risk are available. The expected cumulative emission savings are 1.1 gigatons of $CO_2$-equivalent by 2030 and 4.5 gigatons by 2050. In October 2014, July 2015, and May 2016, the U.S. EPA also issued three acceptability notices, adding to the list of alternatives acceptable for use in the refrigeration and air conditioning; solvents, coatings and inks; fire suppression and explosion protection; and foam blowing sectors. In April 2016, the U.S. EPA issued a proposed rulemaking to change the status of certain high-GWP HFCs used in chillers, household refrigerator-freezers, foam blowing, cold storage warehouses, and additional uses in retail food refrigeration.

The U.S. also recognizes that refrigerant management is an important way to reduce climate-damaging emissions from equipment used for air-conditioning and refrigeration. In November 2015, the U.S. EPA proposed a regulation that would strengthen the existing refrigerant management requirements and then extend those requirements to HFCs. This rule would further reduce HFC emissions by an estimated 7 million metric tons of CO2 equivalent in 2025. The U.S. EPA intends to finalize this rule in 2016.

The U.S. government is a large purchaser of goods and services. To meet the President's goals for federal leadership to reduce HFC emissions, new executive actions were announced in September 2014 to begin the process to update procurement regulations for federal agencies in order to promote the use of safer chemical alternatives to HFCs by service and vendor contractors. The Department of Defense (DoD), General Services Administration, and the National Aeronautics and Space Administration (NASA) jointly issue the Federal Acquisition Regulation (FAR) for use by executive agencies in acquiring goods and services. In May 2016, DoD, GSA, and NASA sponsored a final rule to amend the FAR to address HFCs. The final rule directs government agencies to procure other alternatives in lieu of high-GWP HFCs, where feasible, and refers to EPA's SNAP Program for the current list of acceptable alternatives; refers to EPA's pending regulation to extend refrigerant management requirements to reduce HFC emissions; requires vendor reporting on use of HFCs (i.e., refrigerants); and supports using reclaimed HFCs where feasible.

**European Fluorinated Gas Regulation**

The European Commission revised and strengthened its requirements on fluorinated gases as part of its policy to combat climate change. The previous F-gas regulation (including the mobile air conditioning (MAC) Directive) was adopted in 2006 and was aimed at stabilizing EU F-gas emissions at 2010 levels. The regulation went into effect January 1, 2015, and aims 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 that began in 2015, 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 $CO_2$-equivalent by 2030 and 2.6 gigatons by 2050.

**Canada**

Canada is in the process of developing a licensing and reporting regime consistent with how the North American Proposal would phase down HFCs under the Montreal Protocol. Most recently,

they published a notice that requires information to be provided on HFCs manufactured, imported or exported in bulk during the 2015 calendar year. Following consultations with industry, Canada is considering three approaches: 1) a phasedown of HFC consumption (manufacture, imports and exports); 2) prohibitions on specific HFC-containing products, such as air-conditioning and refrigeration equipment, foam insulation products and aerosol products; and 3) a hybrid approach that combines elements of the first two. The hybrid 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. The target date for publication is late 2016.[5]

**Japanese Fluorinated Gas Regulation**

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 phasedown 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 and additional capacity-building efforts.

# 4. BYPRODUCT EMISSIONS OF HFC-23

## PROPOSED AMENDMENT AND CURRENT MITIGATION ACTIVITIES

HFC-23 is a potent greenhouse gas that is 14,800 times more damaging to the Earth's climate system than carbon dioxide. The North American Amendment proposal, as well as two other proposals, includes provisions that limit HFC-23 byproduct emissions resulting from the production of HFCs and HCFCs, particularly HCFC-22. HCFC-22 is an ODS used primarily as a refrigerant and as a feedstock for manufacturing synthetic polymers. Non-feedstock production of HCFC-22 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 in plasma-etching processes in semiconductor manufacturing, as a fire suppressant, and either neat or as a blend component in cryogenic

[5] The reporting requirement can be found in *Canada Gazette*, Part I: Vol. 150, No. 24, available at http://gazette.gc.ca/rp-pr/p1/2016/2016-06-11/html/notice-avis-eng.php#nl4. For the proposed measures see *Amendments to the Ozone-depleting Substances and Halocarbon Alternatives Regulations*, available at https://www.ec.gc.ca/ozone/default.asp?lang=En&n=77A94123-1&offset=1&toc=show.

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 are proven and readily available. Yet, recent studies[6] indicate that HFC-23 emissions continue to increase in developing countries, despite global efforts to curb emissions.

### BENEFITS FROM BYPRODUCT CONTROLS

**TABLE 6: ESTIMATED BENEFITS OF HFC-23 BYPRODUCT EMISSION CONTROLS**

| Cumulative HFC-23 Byproduct Emission Reductions through 2050 ($MMTCO_2eq$) | |
|---|---|
| **World Byproduct Controls** | **13,000** |

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 of the 43 identified production lines. While the agreement will phase out HCFC-22 production for consumption, this analysis accounts for the HCFC-22 phaseout as well as the growth in HCFC-22 production for feedstock use. On September 25, 2015, the United States and China made a joint presidential statement on climate change that states that, for China, "Actions on HFCs continue to be supported and accelerated, including effectively controlling HFC-23 emissions by 2020."

## 5. SUMMARY

One of the world's most significant climate mitigation opportunities of 2016 is the adoption of an ambitious amendment to the Montreal Protocol to phase down production and consumption of HFCs. This analysis estimates the projected climate benefits of phasing down HFCs in accordance with the proposed North American Amendment to the Montreal Protocol. Adoption of its provisions would produce cumulative climate benefits of 90,000–111,000 $MMTCO_2eq$ through 2050. Table 7 displays the projected cumulative benefits of adoption of the proposal as submitted in 2015.

**TABLE 7: ESTIMATED BENEFITS OF THE AMENDMENT PROPOSAL**

| Cumulative HFC Reductions ($GtCO_2eq$) through 2050 | |
|---|---|
| | **A5 & Non-A5 Parties** |
| **HFC Phasedown** – Consumption Reductions | **78 – 99** |
| **Byproduct Controls** – Emissions Reductions | **13** |
| **Total** | **90 – 111** |

* Totals may not sum due to independent rounding.

Although both the HFC proposal and the HCFC controls would be effective concurrently, individual countries would still have the ability to examine their specific conditions and obligations, and to determine how best to meet their obligations under the two regimes. 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).

[6] S. A. Montzka, 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 (2010): L02808. *Accessible from* http://onlinelibrary.wiley.com/doi/10.1029/2009GL041195/full.