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Finishing the job: The Montreal Protocol moves to phase down hydrofluorocarbons

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In October 2016, parties to the Montreal Protocol on Substances that Deplete the Ozone Layer unanimously agreed to amend the Protocol to allow for the phase-down of the super greenhouse gases hydrofluorocarbons (HFCs). The Kigali Amendment is expected to mitigate 70–100 billion tonnes of carbon dioxide equivalents by 2050, and prevent up to 0.5 degrees Celsius increase in the Earth's temperature by 2100. Prioritizing energy-efficient technologies in the refrigeration and air conditioning sector could potentially double these mitigation gains. By phasing down HFCs, the Montreal Protocol will be able to restore the ozone layer without exacerbating global climate change.

1 | INTRODUCTION

After eight years of negotiations, all 197 parties to the Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol)[1] agreed in October 2016 to phase down hydrofluorocarbons (HFCs)[2] and to transition to low-global warming potential (GWP) and energy-efficient substitutes.[3] The phase-down of HFCs through the Kigali Amendment is expected to cost-effectively mitigate greenhouse gas emissions and have near-term impacts due the short atmospheric lives of these gases.[4] By phasing down HFCs, the Montreal Protocol can restore the ozone layer without exacerbating global climate change.[5]

Immediate, ambitious and achievable actions must be taken to reduce the radiative forcing of greenhouse gases being emitted into the atmosphere. The phase-down of HFCs is the fastest and most cost-effective means to mitigate climate change that can be implemented in the near term.[6] The world is rapidly approaching the levels of greenhouse gases that will cause 2°C of global warming, which parties to the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) with scientific support have established as the threshold to avoid the most dangerous impacts of climate change.[7] Disaggregated actions are necessary if we are going to reverse climate change.[8] The procedures and institutions created for the phase-out of ozone-depleting substances (ODS) make the Protocol well-suited to implement the HFC phase-down approved last year in Kigali. By addressing HFCs, the Montreal Protocol helps ensure that the restoration of the ozone layer does not come at the expense of the global climate.

The Montreal Protocol was established to restore the ozone layer, and has been at the forefront of multilateral efforts to address global environmental issues for the past three decades.[9] In the process of phasing out ODS, the Montreal Protocol until recently did

[1]Montreal Protocol on Substances that Deplete the Ozone Layer (adopted 16 September 1987, entered into force 1 January 1989) 1522 UNTS 3.

[2]HFCs are used in 200 industrial sectors, most commonly for refrigerants in refrigeration and air conditioning, as foam-blowing agents, fire suppressants and solvents. See United States (US) Environmental Protection Agency (EPA), 'Questions and Answers about Alternatives in Each Sector' <https://www.epa.gov/snap/questions-and-answers-about-alternatives-each-sector>.

[3]Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer (adopted 15 October 2016, not yet in force) <https://treaties.un.org/doc/Publication/CN/2016/CN.872.2016-Eng.pdf>.

[4]D Kaniaru et al, 'Strengthening the Montreal Protocol: Insurance against Abrupt Change' in D Kaniaru (ed), *Montreal Protocol: Celebrating 20 Years of Environmental Progress* (Cameron May 2007) 165, 165–166.

[5]MW Roberts and PM Gabriel, 'A Window of Opportunity: Combating Climate Change by Amending the Montreal Protocol to Regulate the Production and Consumption of HFCs and ODS Banks' (2009) 22 Georgetown International Environmental Law Review 99.

[6]C Kelly and H Brown, '4 Ways World Leaders Can Win at the Climate Leaders Summit' (Center for American Progress, 8 July 2009) <http://www.americanprogress.org/issues/green/news/2014/07/08/93383/4-ways-world-leaders-can-win-at-the-climate-leaders-summit/>.

[7]Paris Agreement to the United Nations Framework Convention on Climate Change (adopted 22 April 2016, entered into force 4 November 2016) <http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf>.

[8]K Kulovesi and K Keinänen, 'Long-Term Climate Policy: International Legal Aspects of Sector-Based Approaches' (2006) 6 Climate Policy 313.

[9]See '28th Meeting of the Parties to the Montreal Protocol' (2016) <http://conf.montreal-protocol.org/meeting/mop/mop-28/SitePages/Home.aspx>.

not consider the GWP of the substitutes used to transition away from ODS.[10] The parties have steadily protected the ozone layer by facilitating transfers from chlorofluorocarbons (CFCs) (bad for ozone, bad for the climate) to hydrochlorofluorocarbons (HCFCs) (less damaging to the ozone layer and lower GWP, but still bad for the climate), to HFCs (do not affect the ozone layer but mostly still bad for the climate) and now to low-GWP alternatives (safe for both the ozone layer and the climate). Once CFCs were phased out, developed countries started to phase out HCFCs,[11] and by 2009, 77 percent of transitions were from HCFCs to HFCs.[12] However, while HFCs are benign to the ozone layer, most HFCs are 'super' greenhouse gases with extremely high GWP.[13]

The rapid transition to HFCs in developed countries began to be mirrored in developing countries, where increased middle classes and attendant desire for refrigerators, air conditioners and cars created an expediential growth in HFCs.[14] If uncontrolled, this would offset the climate mitigation gains of implementing the pledges (or 'nationally determined contributions') made as part of the 2015 Paris Agreement.[15] Using the methodology developed during the phase-outs of ODS, the HFC phase-down incorporates acknowledgement that developed countries have a historical responsibility for CFCs, HCFCs and HFCs and developing countries need to temper their transitions to promote sustainable growth. As a result, all parties take on commitments to phase down HFCs, but developed countries go first and provide funding for the incremental costs of developing countries to transition out of HFCs. As such, the approach follows the principle of 'common but differentiated responsibilities', recognizing that the phase-down will not be effective if not all countries participate and that developing countries need assistance to meet their obligations.

The HFC phase-down is expected to mitigate 70–100 billion tonnes of carbon dioxide equivalents (Gt CO_2-eq.) by 2050,[16] and prevent up to 0.5°C increase in the Earth's temperature by 2100.[17] Prioritizing energy-efficient technologies in the refrigeration and air conditioning sector could potentially double these mitigation gains.[18]

This article explains the framework and institutions of the Montreal Protocol that will be tasked to phase down HFCs. It first introduces the Montreal Protocol and past phase-outs of ODS. It describes the institutions and framework created to facilitate the restoration of the ozone layer. It further discusses the common but differentiated responsibilities developed by the Montreal Protocol that made passage of the Kigali Amendment possible, providing an example of how developed and developing countries can work together with binding obligations to combat climate change and air pollution. Next, the article examines the serious climate threat posed by expediential growth of high-GWP HFCs. The article then explores the Kigali Amendment and decisions relating to the Amendment in detail, and examines the challenges to implementing the Amendment.

The article concludes that: (i) the phase-down of HFCs will deliver the quickest and most cost-effective means of ensuring the international transition from ODS and HFCs to low-GWP substitutes and the delivery of needed greenhouse gas mitigation to keep global warming below 2°C; (ii) actions on standards, new low-GWP technologies and improving energy efficiency will be needed to implement the HFC phase-down properly and deliver the greatest possible mitigation; and (iii) to curb climate change, cost-effective actions, including phasing down the destruction of ODS and HFCs in banks[19] and other actions on short-lived climate pollutants, are critical.

2 | THE MONTREAL PROTOCOL: USING THE MOST SUCCESSFUL MULTILATERAL ENVIRONMENTAL TREATY TO COMBAT CLIMATE CHANGE

2.1 | Montreal Protocol institutions and operations

The Montreal Protocol initially focused just on CFCs, as they were the chemicals initially identified as ozone-depleting chemicals. Over time, more chemicals were recognized to cause ozone depletion. In the first phase-out the chemicals with high ozone-depleting potential were targeted, and HCFCs, which had low ozone-depleting potential, were allowed as transitional chemicals that would need to be phased out later. The Montreal Protocol has evolved to respond to changes in ozone and climate science, as well as the requirements of the parties and industries that use ODS and their alternatives, including HFCs.

For much of its first 20 years, the Montreal Protocol worked in relative anonymity, methodically phasing out ODS based upon sound science and technological developments. As the Protocol took on the battle to save the ozone layer and thereby prevent millions of

[10]'Decision XXI/9, Hydrochlorofluorocarbons and Environmentally Sound Alternatives' (2009) <http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/210> preamble ('Aware of the increasing availability of low-global warming potential (GWP) alternatives to HCFC, in particular in the refrigeration, air-conditioning and foam sectors').

[11]Developing countries began phasing out HCFCs, with a freeze in 2013 and a complete phase-out by 2040. See A Koszegvary, 'HCFC Phase-Out in Developing Countries' (ATMO Sphere Technology Summit 2013) <http://www.atmo.org/presentations/files/210_0_UNIDO_Koeszegvary.pdf>.

[12]Montreal Protocol (n 1) art 5; GJM Velders et al, 'The Large Contribution of Projected HFC Emissions to Future Climate Forcing' (2009) Proceedings of the National Academy of Sciences of the United States of America 10949, 10952.

[13]HFC-134a has a GWP of 1,340 and HFC-404a has a GWP of approximately 3,900; see The Linde Group, 'Refrigerants Environmental Data: Ozone Depletion and Global Warming Potential' <http://www.linde-gas.com/internet.global.lindegas.global/en/images/Refrigerants%20environmental%20GWPs17_111483.pdf>.

[14]Velders et al (n 12).

[15]Paris Agreement (n 7).

[16]Ministry of Natural Resources, Republic of Rwanda, 'Historic Amendment to the Montreal Protocol adopted in Kigali, giving Renewed Hope in Fight against Climate Change' (17 October 2016) <http://www.minirena.gov.rw/index.php?id=61&tx_ttnews%5Btt_news%5D=451&cHash=d5f244e04d3f9408b021daf6e00d74a5>; L Del Bello, 'UN Agrees Historic Deal to Cut HFC Greenhouse Gases' (Climate Change News, 15 October 2016).

[17]Ministry of Natural Resources, Republic of Rwanda (n 16).

[18]N Shah, 'Benefits of Leapfrogging to Super Efficiency and Low Global Warming Potential Refrigerants in Room Air Conditioning' (Lawrence Berkeley National Laboratory 2015).

[19]'Banks' is the name for the more than 50 years' worth of equipment, foams, chemical stockpiles and other products.

cancers and cases of glaucoma, crop loss and other adverse impacts to the environment,[20] an array of scientific, technical and financial institutions were created to ensure global ratification, as all countries in the world needed to participate if the goal of ridding the world of ODS was to be accomplished. In 1985, the 28 primary countries that produced and consumed CFCs established the Vienna Convention for the Protection of the Ozone Layer as the framework for coordinated international efforts to protect the ozone layer.[21] The Ozone Convention did not include legally binding reduction goals for the main chemicals causing ozone depletion; for this, the Montreal Protocol was adopted in 1987 to implement a freeze and then a 50 percent reduction in both production and consumption.[22]

In the few years after the adoption of the Protocol, a series of scientific expeditions to Antarctica conclusively demonstrated that the ozone hole was caused by CFCs and other man-made chemicals.[23] Based on these findings, the Montreal Protocol was strengthened in 1990 to phase out all of the most powerful ODS by 2000 in developed countries, and by 2010 in developing countries.[24] Parties to the Montreal Protocol entered into successive agreements to eliminate all CFCs and related compounds, and then all HCFCs.[25]

Using this 'start and strengthen' model, the Protocol was able to begin with modest actions and slowly expand until the production and consumption of nearly 100 of the worst ODS were completely phased out by 31 December 2010.[26] The most damaging substances were replaced in large part with HCFCs,[27] as the climate impact was not a consideration for the parties to the Montreal Protocol at the time of that decision.[28] The parties to the Protocol are currently working to phase out HCFCs and the few other remaining ODS.[29]

Parties to the Montreal Protocol make decisions based on sound science and the latest technological information, through the Technology and Economic Assessment Panel (TEAP), Technical Options Committees (TOCs) and the Scientific Assessment Panel (SAP).[30] These mechanisms are perfectly poised to undertake a phase-down of HFCs. The TEAP is the primary scientific and technical panel, made up of experts from both developed and developing countries. The TEAP provides answers to inquiries approved by consensus from the parties.[31] Parties are not allowed to interfere with the work of the TEAP. Politics entered only after the TEAP reports were released.[32] The TOCs have been established to bring specialized expertise to evaluate requests for exemptions and to work with the countries to find ways to meet compliance deadlines and transition away from the banned chemicals as quickly as possible.[33] The SAP continuously assesses the status of the ozone layer and actions taken to restore it, and makes recommendations of next steps; the same can be done for the impacts of the HFC phase-down.[34]

Phase-out schedules for the HFC phase-down are set forth in the Kigali Amendment; however, each party can decide how it will meet these goals given the unique use of HFCs in its country.[35] The Executive Committee of the Multilateral Fund (ExCom) periodically can encourage parties to first phase out chemicals with higher ozone-depleting potential and/or GWP to frontload the benefits of the phase-outs/phase-down.[36] These suggestions from the ExCom are generally followed, but they are not binding if a country wants to phase out other sectors first. The Montreal Protocol allows parties to utilize stockpiles of lawfully produced HFCs and recycled HFCs to minimize the impacts of transitions to new chemicals, by allowing equipment to serve its useful life.[37] There are also provisions to allow countries to continue using a chemical in particular sectors if there are technological barriers preventing the use of alternatives.[38]

2.2 | Common but differentiated responsibilities

As discussed above, during the implementation of the phase-outs of ODS, the Montreal Protocol has developed several techniques to encourage universal participation, notably providing incentives and

[20]See US EPA, 'Health and Environmental Effects of Ozone Layer Depletion' <https://www.epa.gov/ozone-layer-protection/health-and-environmental-effects-ozone-layer-depletion>.

[21]Vienna Convention for the Protection of the Ozone Layer (adopted 22 March 1985, entered into force 22 September 1988) 1513 UNTS 293 art 3(5).

[22]H Ijaiya, 'Ozone Layer Depletion and the Montreal Protocol: An Assessment of Nigeria's Compliance' (2010) 9 International Journal of Environment and Development 9, fn 13; see United Nations Environment Programme (UNEP), *Action on Ozone* (UNEP 2000) <http://ozone.unep.org/pdfs/ozone-action-en.pdf>.

[23]'Ozone depletion' in MK Tolba et al (eds), *The World Environment 1972–1992* (Chapman & Hall 1992) <http://www.ciesin.org/docs/011-466/011-466.html>. The chemicals found to cause ozone depletion included CFCs, halons, carbon tetrachloride and methyl bromide.

[24]'Report of the Eleventh Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer' UN Doc UNEP/OzL.Pro.11/10 (17 December 1999).

[25]These include the London Amendment (1990), the Copenhagen Amendment (1992), the Montreal Amendment (1997) and the Beijing Amendment (1999). See <http://ozone.unep.org/new_site/en/treaty_ratification_status.php>.

[26]See generally Ozone Secretariat, *Handbook for the Montreal Protocol on Substances that Deplete the Ozone Layer* (UNEP 2006).

[27]See World Bank, 'Ozone Depleting Substances: Alternatives' in World Bank (ed), *Pollution Prevention and Abatement Handbook 1998* (World Bank 1999) 250; European Commission, *The Montreal Protocol, Keeping Up the Tempo of Ozone Protection* (European Communities 2007) 5.

[28]GJM Velders et al, 'The Importance of the Montreal Protocol in Protecting the Climate' (2007) 104 Proceedings of the National Academy of Sciences of the United States of America 4814.

[29]UNEP, 'Brief Primer on the Montreal Protocol' <http://ozone.unep.org/Publications/MP_Brief_Primer_on_MP-E.pdf>.

[30]Montreal Protocol (n 1) art 6. Article 6 calls for a review of the best available science, environmental, technical and economic information every four years. See 'Decision I/3, Establishment of Assessment Panels' (1989) <http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/1061>. However, throughout the history of the Montreal Protocol, the parties have requested additional reports from these bodies, often delivered within one year.

[31]See <http://ozone.unep.org/en/assessment-panels/technology-and-economic-assessment-panel>.

[32]ibid.

[33]ibid.

[34]See 'United Nations System-Wide Earthwatch' <http://www.un.org/earthwatch/about/docs/scpozone.htm>.

[35]See, e.g., Montreal Protocol (n 1) art 2A–2I.

[36]Multilateral Fund for the Implementation of the Montreal Protocol, 'Guide for the Preparation of Stage I of HCFC Phase-Out Management Plans (HPMP), (Re-Issued)', MLF/IACM.2016/2/16 (23 August 2016).

[37]'Decision VII/30, Export and Import of Controlled Substances to be Used as Feedstock' (1995) <http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/854>; see also UNEP, 'Backgrounder: Basic Facts and Data on the Science and Politics of Ozone Protection' (UNEP 2008) <http://unep.ch/ozone/pdf/Press-Backgrounder.pdf>.

[38]See, e.g., Multilateral Fund, 'Conditions for Granting and Reporting Critical-Use Exemptions for Methyl Bromide' <http://www.multilateralfund.org/Our%20Work/policy-search-old/index.html?n=534.html>.

financial support to developing countries.[39] These techniques can be seen in the Kigali Amendment as well.[40] The agreed upon phase-down includes schedules for both developed countries and developing countries, with developed countries going first to prove the new alternatives and to give developing countries more time to transition their economies.[41] These differing phase-down schedules form the core of this innovative approach to global environmental action in which all parties accept common but differentiated responsibilities. This includes a grace period for developing countries that allows them to implement mandated phase-out schedules, recognizing the larger historic emissions of ODS and HFCs by developed countries and the need of developing countries to pursue sustainable economic development.[42]

The second pillar of the Montreal Protocol's common but differentiated responsibilities is a commitment by developed countries to facilitate technology transfer, provide financial assistance and create the necessary infrastructure for developing countries to meet their commitments under the Protocol.[43] The Multilateral Fund has been established to pay the incremental costs incurred by developing countries to meet their obligations under the Protocol.[44] The Multilateral Fund Executive Committee has equal numbers of developed countries and developing countries' parties to ensure fair distribution of funding.[45] Approximately 40 developed countries fund the Multilateral Fund's budget in proportion to their United Nations assessment scale.[46] The Multilateral Fund provides incremental financing for transitions in technologies as well as financing in-country infrastructure needed to implement the Protocol obligations.[47] It also facilitates technology transfer, enhances capacity building and development capabilities, and provides funding for demonstration and pilot projects to prove new alternatives.[48]

2.3 | The HFC phase-down amendment

The phase-outs of CFCs and now HCFCs have set the ozone layer to 'heal' by 2050.[49] However, in a majority of the cases, in both developed and developing countries, ODS have been replaced with HFCs, which do not hurt the ozone layer but are hundreds to thousands of times more damaging to the climate than CO_2.[50] The Montreal Protocol is responsible for a significant increase in greenhouse gas emissions due to the commercialization of HCFCs and HFCs that threatened to negate the climate gains being made under the UNFCCC.[51] As HFCs were commercialized as a direct result of the phase-outs of ozone-depleting chemicals,[52] parties to the Montreal Protocol could be said to have a moral duty to phase down HFCs so that the recovery of the ozone layer will not come at the expense of the global climate.

The actions taken to phase out ODS initially did not take into account the global warming impacts of the chosen alternatives. In 2007, the parties decided to accelerate the phase-out of HCFCs to reduce the emission of the strong greenhouse gases. Immediately after this, the attention of the parties turned to the impacts of the major replacements for HCFCs – HFCs – due to their climate impacts.[53] In 2009, and every year since, two proposals to amend the Montreal Protocol to allow for a phase-down of the use and production of HFCs were filed: one by Mexico, Canada and the United States. The other amendment proposal has been filed each year by the Federated States of Micronesia, with various partner countries in different years.[54] Decisions under the Montreal Protocol are made by consensus, meaning that all 197 parties would need to agree for the HFC phase-down to be undertaken.

In 2015, the European Union (EU) filed a discussion paper suggesting a different plan for phasing down HFCs, which dramatically shifted the discussions of the amendment and substantially softened the opposition to the idea of regulating and reducing the consumption and production of HFCs. India was a lead opponent

[39]Montreal Protocol (n 1) art 5, 10, 10A and 13.

[40]UNEP, 'The Kigali Amendment to the Montreal Protocol: HFC Phase-Down' <http://multimedia.3m.com/mws/media/1365924O/unep-fact-sheet-kigali-amendment-to-mp.pdf>.

[41]ibid; see also <https://www.epa.gov/ozone-layer-protection/international-actions-montreal-protocol-substances-deplete-ozone-layer>.

[42]The provision on developing countries, titled 'Special Situation of Developing Countries', was negotiated to establish a grace period for compliance with the control measures to phase out production and consumption of ODS. Classification as a 'developing country party' is dependent on annual per capita consumption of the ODS regulated. See Montreal Protocol (n 1) art 5.

[43]Montreal Protocol (n 1) art 5 conditions developing countries' obligations on financial assistance and technology transfer from non-developing countries. Articles 10 and 10A charge developed countries with the responsibility to provide financial and technological assistance to developing countries to assist them with compliance with their obligations under the Montreal Protocol. Under Article 10A, non-developing countries' parties are required to transfer 'best available, environmentally safe substitutes and related technologies' to developing countries' parties at 'fair and most favorable trade conditions'. ibid art 5(5), 10 and 10A.

[44]ibid art 10. The mechanism also includes other forms of multilateral, bilateral and regional cooperative efforts in compliance with the policies and guidelines of the fund. Incremental costs include costs associated with the supply of substitute chemicals, conversion of existing production facilities, capital costs of equipment, training, premature retirement of equipment, technical assistance, research and development. See 'Report of the Fourth Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer' UN Doc UNEP/OzL.Pro.4/15 (25 November 1992) Annex VIII.

[45]See Multilateral Fund for the Implementation of the Montreal Protocol, 'About the Multilateral Fund: Overview' <http://www.multilateralfund.org/aboutMLF/default.aspx>. The day-to-day operations of the Fund are managed by a secretariat with a small staff located in Montreal, Canada.

[46]Montreal Protocol (n 1) art 10(6–7). The UN Scale of Assessment is established by the General Assembly once every three years, roughly based upon countries' capacity to pay; see United Nations, 'What is the United Nations Scale of Assessment and How is it Determined?' <http://ask.un.org/faq/167379>.

[47]Multilateral Fund for the Implementation of the Montreal Protocol, 'Policies, Procedures, Guidelines and Criteria of the Multilateral Fund' <http://www.multilateralfund.org/Our%20Work/Policy-search72/index.html#!multilateralFund>.

[48]Montreal Protocol (n 1) art 5, 10, 10A and 13; see also the implementing decisions by the Multilateral Fund.

[49]S Solomon et al, 'Emergence of Healing in the Antarctic Ozone Layer' (2016) 353 Science 269.

[50]The Linde Group (n 13).

[51]UNEP, *HFCs: A Critical Link in Protecting Climate and the Ozone Layer* (UNEP 2011). This effect is estimated to offset the climate benefits of the Montreal Protocol to date by up to 10 percent.

[52]See US EPA, 'Reducing Hydrofluorocarbon (HFC) Use and Emissions in the Federal Sector through SNAP' <https://www.epa.gov/snap/reducing-hydrofluorocarbon-hfc-use-and-emissions-federal-sector>.

[53]UNEP, 'Ozone Action: HCFC Phase-Out: Convenient Opportunity to Safeguard the Ozone Layer and Climate' (UNEP 2008).

[54]See, e.g., 'Proposed Amendment to the Montreal Protocol Submitted by Canada, Mexico and the United States of America' UN Doc UNEP/OzL.Pro.WG.1/34/4 (10 May 2014); 'Proposed Amendment to the Montreal Protocol Submitted by the Federated States of Micronesia' UN Doc UNEP/OzL.Pro.WG.1/34/5 (16 May 2014).

of the HFC phase-down for years, but filed its own amendment proposal in April 2016 to push for longer timelines and greater payments to Article 5 countries than had been included in the other amendment proposals.[55] After agreeing that the challenges associated with phasing down HFCs would be addressed before the details of any HFC control measures, negotiations became much more substantive and fast-paced.[56]

3 | HFC EMISSIONS AND CLIMATE CHANGE

HFCs were commercialized in the 1990s as replacements for CFCs and HCFCs because they do not damage the ozone layer.[57] Unfortunately, commonly used HFCs have GWPs of between 150 and 8,000, and thus contribute significantly to global warming.[58] The 2007 Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report[59] documented increases in anthropogenic greenhouse gases, including HFCs, which were contributing to climate change.[60] The HFC consumption rose from almost non-existent in 1990 to more than 1,200 million tonnes of CO_2 equivalents by 2010.[61]

The size of the HFC problem was quantified in 2009, when a variety of scenarios of HFC consumption and emissions for the next four decades were evaluated.[62] It was projected that global emissions of HFCs would be increasing dramatically as a result of their increasing use in developing countries.[63] Total annual HFC emissions were predicted to be between 9 and 19 percent of all predicted CO_2 emissions in 2050.[64] These predicted HFC emissions could substantially offset emissions mitigation actions taken pursuant to the 2015 Paris Agreement.[65]

In 2010, the United States (US) National Research Council evaluated a number of different stabilization targets for greenhouse gas concentrations and determined that emissions of HFCs could reach approximately 6 Gt CO_2-eq. in 2050, the equivalent of up to one-third of the total CO_2 emissions permitted under a stabilization scenario at 450 parts per million of CO_2.[66] The rapid projected increase was confirmed by other modelling and observations of changes in concentrations of HFCs in the atmosphere.[67] During the period from 2004 through 2010, HFC emissions increased between 8 and 15 percent per year, with increases in consumption in developing countries further increasing emissions.[68]

Based on the observed and predicted increases in HFC use, it was predicted that a phase-down of HFCs under the Montreal Protocol would result in a reduction of approximately 70–100 Gt CO_2-eq. in HFC emissions by 2050.[69]

4 | THE KIGALI AMENDMENT ON HFCS

On 15 October 2016, in Kigali, Rwanda, the parties agreed to amend the Montreal Protocol and add HFCs to the list of controlled substances and to phase down HFCs.[70] Under the Amendment, parties are required to reduce HFC consumption and production by 80–85 percent of their baselines[71] by the late 2040s.[72] The first reductions by most of the developed countries will be taken by 2019.[73] Most developing countries will follow with a freeze of HFC consumption levels in 2024 and begin to phase down HFCs by 2029, with a maximum phase-down of 80 percent.[74]

The Kigali Amendment will enter into force on the earlier of 1 January 2019 or the 90th day after 20 countries have ratified it, whichever is later.[75] As an incentive to ratify, the parties agreed to adopt import and export licensing systems for HFCs by 1 January 2019. Given the work involved with obtaining legislative approval, countries are being encouraged to consider implementing the licensing system and ratifying the Kigali Amendment at the same time. As another ratification incentive, after 1 January 2033,

[55]'Proposed Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer Submitted by India' UN Doc UNEP/Ozl.Pro.28/6 (14 April 2016).

[56]'Decision XXVII/1, Dubai Pathway on Hydrofluorocarbons' (2015) <http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/40856>.

[57]AR Ravishankara et al, 'Do Hydrofluorocarbons Destroy Stratospheric Ozone?' (1994) 263 Science 71.

[58]V Ramanathan, 'Greenhouse Effect Due to Chlorofluorocarbons: Climate Implications' (1975) 190 Science 50; World Meteorological Organization (WMO), *Scientific Assessment of Ozone Depletion: 2014* (WMO 2014). HFC-23 has a GWP of 14,800 but is a by-product from the production of the refrigerant HCFC-22 and is not generally a useful product, so is treated separately.

[59]IPCC, *Climate Change 2007: The Physical Science Basis* (Cambridge University Press 2007).

[60]ibid.

[61]UNEP (n 51).

[62]Velders et al (n 12).

[63]ibid.

[64]ibid. Total annual HFC emissions were predicted to be between 5.5 and 8.8 Gt CO_2-eq. per year by 2050.

[65]On 5 October 2016, the threshold for entry into force of the Paris Agreement was achieved, and the treaty entered into force on 4 November 2016.

[66]National Research Council, *Climate Stabilization Targets: Emissions, Concentrations, and Impacts Over Decades to Millennia* (National Academies Press 2011).

[67]B Gschrey, W Schwarz, C Elsner and R Engelhardt, 'High Increase of Global F-Gas Emissions until 2050' (2011) 1 Greenhouse Gas Measurement and Management 85.

[68]UNEP (n 51); see also World Meteorological Organization (WMO), *Scientific Assessment of Ozone Depletion: 2010* (WMO 2011); and GJM Velders et al, 'Preserving Montreal Protocol Climate Benefits by Limiting HFCs' (2012) 335 Science 922.

[69]Proposed Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer Submitted by Canada, Mexico and the United States of America' UN Doc UNEP/Ozl.Pro.28/5 (15 April 2016) 5.

[70]'Decision XXVIII/1, Further Amendment to the Montreal Protocol' (2016) <http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/41471>; and 'Decision XXVIII/2, Decision Relating to the Decision Phasing Down Hydrofluorocarbons' (2016) <http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/41473>.

[71]Different baselines were agreed to by the various blocks of countries: most developed countries have baselines for consumption and production established by the average of the years 2011–2013; most developing countries' baselines are the average of consumption and production in the years 2020–2022; ibid.

[72]ibid.

[73]ibid. A few developed countries need more time to develop alternatives and the infrastructure to implement the phase-down, so their required reductions in the first two phase-down steps are smaller; ibid.

[74]ibid. Some Middle Eastern countries, India and Pakistan opted for a delayed schedule with their freeze date in 2028 and phase-down beginning in 2032, but agreed to an 85 percent phase-down as an accommodation for the slight delay.

[75]ibid.

countries will be prohibited from exporting or importing HFCs to or from countries that have not yet ratified the Kigali Amendment (i.e., 'non-parties').[76]

The decision accompanying the Amendment contains an exemption for parties with high ambient temperature conditions[77] where suitable alternatives do not exist for certain air conditioners, known as the 'high ambient exemption'.[78] This exemption was included in the Amendment to ensure that suitable energy-efficient, low-GWP air conditioners are commercially available before countries are forced to transition to new alternatives.[79] Currently, the proven refrigerants available to use in air conditioners are not energy efficient in high ambient conditions.[80] The parties did not want the HFC phase-down to force countries to transition to technologies that comply with the Amendment but do not result in a net gain for the climate. Countries that opt for the exemption delay have their HFC freeze date and initial control obligations extended by four years.[81] Thereafter, the TEAP periodically evaluates the state of alternative technologies to determine whether suitable alternatives have been commercialized or whether the exemption should be extended further.[82]

5 | IMPLEMENTATION: WHERE MITIGATION PROMISES ARE DELIVERED

5.1 | Where's the money?

The Amendment requests the Multilateral Fund to develop guidelines for financing the phase-down of HFCs within two years of passage.[83] To date, the Multilateral Fund has been focused on how best to phase out ODS, determining the most 'cost-effective' replacements,[84] and then reimbursing only the incremental costs needed to make the selected transition.[85] The Multilateral Fund must now incorporate GWP and energy efficiency[86] into its calculations and address a new array of low-GWP, zero-GWP and not-in-kind alternatives.[87] The Multilateral Fund must review 25 years of decisions and decide whether they need to be rethought to take into the new paradigm of HFCs.[88]

When focusing on ODS, the Multilateral Fund did not pay to maintain or enhance energy efficiency. In fact, in some cases the savings from energy-efficiency gains were deemed to be a windfall and deducted from the incremental costs the Multilateral Fund paid to the party.[89] As the Multilateral Fund evaluates how to address energy efficiency as required by Decision XXVIII/2, the members of the Multilateral Fund will need to decide the extent to which it will pay the incremental costs: to maintain energy efficiency; to improve it slightly; or to maximize it? The answer will have substantial financial and mitigation implications. This is where the membership make-up of the Multilateral Fund and the strength of developing countries' parties will be important.

Traditionally, the Multilateral Fund has paid for the modifications to manufacturing plants to enable them to transition from one fluorinated gas to another, with less harmful effects to the ozone layer. In many instances, the alternatives were 'drop-in solutions' needing little or no modifications.[90] Now, many alternatives to HFCs are not fluorinated gases and use new refrigerants and new technologies. Others are not-in-kind substitutes, such as district cooling, which makes the transition from air conditioning equipment for each house to creating a municipal system to deliver heating and cooling to a community in a manner similar to electricity, water or sewage.[91] The Multilateral Fund will need to figure out how to calculate incremental costs for these new types of equipment.

The Multilateral Fund Secretariat plays a key role as the initial reviewer of phase-down plans and is the initial arbiter of past decisions of the Multilateral Fund Executive Committee.[92] The Multilateral Fund has developed an Evaluation Guide, which contains a multitude of assumptions about how to review projects, in advance of the review by the Executive Committee, and now must be revised to incorporate the HFC phase-down and related decisions.[93] The Secretariat provides

[76]ibid.

[77]The high ambient temperature exemption applies to the following parties: Algeria, Bahrain, Benin, Burkina Faso, Central African Republic, Chad, Côte d'Ivoire, Djibouti, Egypt, Eritrea, Gambia, Ghana, Guinea, Guinea-Bissau, Iran, Iraq, Jordan, Kuwait, Libya, Mali, Mauritania, Niger, Nigeria, Oman, Pakistan, Qatar, Saudi Arabia, Senegal, Sudan, Syria, Togo, Tunisia, Turkmenistan and United Arab Emirates.

[78]Kigali Amendment (n 3).

[79]The most common alternative to the use of HCFC-22 in air conditioners is HFC-410A. Whereas HCFC-22 has a GWP of 1,760, the GWP of HFC-410A is 2,088. The GWP of hydrocarbons, HFC-32 and HFC blends being tested for use in air conditioners are <4, 650 and 650–2,000, respectively. The energy efficiency of HFC-410A drops off dramatically. See N Shah, M Wei, V Letschert and A Phadke, 'Benefits of Leapfrogging to Superefficiency and Low Global Warming Potential Refrigerants in Room Air Conditioning' (Ernest Orlando Lawrence Berkeley National Laboratory 2015).

[80]See <Cooltechnologies.org>.

[81]Kigali Amendment (n 3).

[82]ibid.

[83]ibid.

[84]L Kelly, 'The Multilateral Fund for the Implementation of the Montreal Protocol, Addressing Challenges of Globalization: An Independent Evaluation of the World Bank's Approach to Global Programs' (World Bank 2004) <https://ieg.worldbankgroup.org/Data/reports/gppp_mlf_wp.pdf>.

[85]Multilateral Fund (n 45).

[86]Decision XXVIII/2 (n 70) paras 16 and 22.

[87]Kigali Amendment (n 3); not-in-kind cooling technologies are any alternative cooling systems other than the vapour compression cooling systems that are most commercially dominant today. Such technologies can provide energy savings and other environmental benefits for refrigeration and air conditioning, water heating and refrigeration for domestic, commercial and industrial use. These alternative technologies include: district cooling, thermoacoustic refrigeration, thermoelectric refrigeration, thermotunnelling, magnetic refrigeration, solar cooling, Stirling cycle refrigeration, pulse tube refrigeration, Malone cycle refrigeration, absorption refrigeration, adsorption refrigeration and compressor-driven metal hydride heat pumps. Heat pump water heating and integrated heat pump systems can provide significant energy saving potential for water heating and space conditioning in households. Many of these technologies are already commercially proven, while others are still under development. See S Bansal et al, 'Status of Not-in-kind Refrigeration Technologies for Household Space Conditioning, Water Heating and Food Refrigeration' (2012) 1 International Journal of Sustainable Built Environment 85.

[88]Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol, 'Issues Relevant to the Executive Committee Arising from the Twenty-Eighth Meeting of the Parties to the Montreal Protocol' UN Doc UNEP/OzL.Pro/ExCom/77/70/Rev.1 (24 November 2016).

[89]Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol, 'Relevant Aspects of Component Upgrade in HCFC Conversion Projects (Decisions 59/13(B) and 60/43)' UN Doc UNEP/OzL.Pro/ExCom/61/50 (3 June 2010).

[90]ibid.

[91]ibid.

[92]Multilateral Fund (n 45).

[93]Multilateral Fund, 'Evaluation Guide' <http://www.multilateralfund.org/Our%20Work/Policy-search-for%2066/index.html?n=EvaluationGuide.html>.

a public summary of a country's phase-out plan and its recommendations, but the evaluations, communications with parties and related documents are confidential.[94] Parties' only recourse if they disagree with the Multilateral Fund Secretariat is to bring their proposal for review by the Executive Committee with a negative recommendation from the Multilateral Fund Secretariat.

The Evaluation Guide needs to be scrutinized carefully to ensure that changes are made which properly incorporate climate change and energy-efficiency considerations and fairly evaluate competing alternative technologies. The Evaluation Guide directs the Secretariat on how phase-down plans should be evaluated, how 'cost-effective' alternatives will be determined, how the Secretariat should work with countries and implementing agencies, and what substitutes and technologies will be given priority.[95] It will be critical that all parties be actively engaged in the revision of the Evaluation Guide, that the revision process be transparent and participatory, and that the revisions maximize the climate benefits that can be achieved by the HFC phase-down.

The United States was one of the leading champions of the HFC Amendment since 2009.[96] In the lead-up to the Kigali Amendment, all developed countries made clear that there would be an increase in funding to the Protocol to cover the incremental costs related to the HFC phase-down. The election of Donald Trump has created doubts about the United States' continuing commitment to the Kigali Amendment.[97] While US industry generally has been supportive of the Kigali Amendment, whether the United States will ratify the amendment and provide adequate financial and technical support is yet to be made clear.[98] US ratification is not essential for other countries to proceed with the phase-down, but if the United States and other donor countries do not adequately fund the Multilateral Fund, Article 5 countries could be relieved from implementing their obligations to phase down HFCs, which will have profound climate impacts.[99] Additionally, it is still unknown what impacts the US changes on climate policy will have on other countries' willingness to continuing to combat climate change.[100]

Efforts are underway to ensure that the United States and other countries ratify the Kigali Amendment and provide adequate funding for this decisive climate action, but as of July 2017, the future is still uncertain. Leaders in the United States, the EU and around the world have declared that progress will be made on climate with or without the Trump Administration,[101] and the Kigali Amendment is a great place to start to deliver on these promises.

5.2 | What alternatives will be deemed 'cost-effective'?

As described above, the Montreal Protocol has accomplished the phase-out of ODS by paying the incremental costs of transitions to cost-effective alternatives.[102] Since the phase-down of HFCs began to be discussed, there has been an explosion of new alternatives in almost all industrial sectors.[103] Unlike in previous transitions, there is no one obvious perfect alternative for particular uses; rather, alternatives are being developed which work in specific industrial sectors and in specific types of equipment. In many sectors, multiple alternatives have been developed and are being tested by industry to see which works best given the circumstances of the industry, developed or developing countries' preferences, and characteristics of the alternatives such as flammability, toxicity and costs.[104] In some sectors, the use of particular new alternatives is becoming established. For example, in foam-blowing applications hydrocarbons with GWP of less than 4 are widely used for most foam-blowing operations.[105] However, in cases where the thickness of the foam and insulating characteristics are critical, a new fluorinated gas called HFO (hydrofluorolefins)-1234ez (GWP <1) is widely used.[106] In other sectors, the different alternatives are just being piloted and demonstrated, and in still other sectors, such as unitary air conditioning, energy-efficient, low-GWP alternatives are just being developed.[107]

There are two visions of the path forward for phasing out HFCs. The first vision is to transition to additional classes of fluorinated gases, called HFOs, lower-GWP HFCs and HFC/HFO blends (the GWP of HFOs are generally <4 but the GWP of lower-GWP HFCs and HFC/HFO blends are between 152 and 2,000[108]), which can be

[94]Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol, 'Distribution of Confidential Documents (Decision 66/55)' UN Doc UNEP/OzL.Pro/ExCom/67/36 (2012); personal communications with Multilateral Fund Secretariat.

[95]Evaluation Guide (n 93).

[96]US EPA, 'Recent International Developments under the Montreal Protocol' <https://www.epa.gov/ozone-layer-protection/recent-international-developments-under-montreal-protocol>.

[97]'Statement by President Trump on the Paris Climate Accord' (1 June 2016) <https://www.whitehouse.gov/the-press-office/2017/06/01/statement-president-trump-paris-climate-accord>; Office of Management and Budget, 'A New Foundation for American Greatness, Budget of the U.S. Government, Fiscal Year 2018' (2017) <https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/budget/fy2018/budget.pdf>; Office of Management and Budget, 'America First – A Budget Blueprint to Make America Great Again' <https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/budget/fy2018/2018_blueprint.pdf>.

[98]M Garry, 'Industry, Danfoss Ask for U.S. Approval of Kigali Amendment' (Hydrocarbons21.com, 18 January 2017).

[99]M Garry, 'Trump's Budget Aims to End Greenchill Program' (R744, 6 April 2017).

[100]Initial statements make it appear that other countries are maintaining their commitment to combat climate change, but this does not necessarily mean that they will pick up the US share of costs if they defund these efforts; see 'G20 Leaders' Declaration: Shaping an Interconnected World', Hamburg, 7–8 July 2017 <https://www.g20.org/Content/EN/_Anlagen/G20/G20-leaders-declaration.pdf?__blob=publicationFile&v=11>.

[101]See, e.g., M Bloomberg, 'Climate Progress, with or without Trump' (New York Times, 31 March 2017).

[102]Evaluation Guide (n 93).

[103]See, e.g., Environmental Investigation Agency (EIA), 'Putting the Freeze on HFCs: A Global Digest of Climate-Friendly Refrigeration and Air Conditioning' (EIA 2014), and the 2015 and 2016 updates of this report at <https://eia-global.org/reports/putting-the-freeze-on-hfcs>.

[104]ibid.

[105]See Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol, 'Calculation of the Incremental Capital Costs and Incremental Operating Costs for Foam Sector Alternatives (Decision 75/28)' UN Doc UNEP/OzL.Pro/ExCom/76/58 (2016).

[106]ibid.

[107]US EPA, 'Transitioning to Low-GWP: Alternatives in Unitary Air-Conditioning', <https://www.epa.gov/sites/production/files/2015-07/documents/epa_hfc_uac_0.pdf>.

[108]See, e.g., Chemours, 'New Opteon HFO Refrigerants are Transforming the Industry' <https://www.chemours.com/businesses-and-products/fluoroproducts/opteon-refrigerant>; and 'The Opteon™ Portfolio of Low GWP Refrigerants for Stationary Applications' <https://www.chemours.com/Refrigerants/en_US/products/Opteon/Stationary_Refrigeration/assets/downloads/news/new-generation-hfo-refrigerants.pdf>; and <http://refrigeranthq.com/hfo-refrigerants-need-know/>.

used in existing equipment without major modification.[109] These chemicals are promoted as almost drop-in replacements for HFCs, but they are taking longer than expected to commercialize in part due to poor energy-efficiency ratings, problems with supply and development, and slow market uptake as a result of the costs.[110] In most cases, the HFC/HFO blends are being promoted as transition chemicals, and it is anticipated that they will have to be phased out in 10–20 years in order to meet the Kigali Amendment phase-out targets.[111]

The second vision is for HCFCs and HFCs to be transitioned directly to natural refrigerants (including hydrocarbons, ammonia, CO_2, air and water), and not-in-kind technologies so that this phase-down will be the final transition.[112] New truly low or zero-GWP technologies are being proven and commercialized that ensure natural alternatives are safe for use and protective of human health and the environment.[113] Since natural alternatives have different characteristics than fluorinated gases, they require different equipment, coming with a higher upfront cost but reduced operation and maintenance costs.[114]

Historically, the Multilateral Fund has delivered cost-effective transitions away from ODS by paying the incremental costs of the most 'cost-effective' transition.[115] In the past, the Multilateral Fund only looked at the cost of the then current transition, not total costs of transitions to truly environmentally friendly substitutes. When the Multilateral Fund comes up with guidelines for the incremental costs to be covered in the HFC phase-down, it will have to grapple with the question of whether it will pay slightly more to enable leapfrogging over HFCs and HFC/HFO blends and going directly to natural refrigerants and other final transitions. When considering transitions in sectors where there are proven and commercialized truly low-GWP substitutes, the big question is whether the Multilateral Fund will still fund transitions to the lower-GWP HFCs and HFC/HFO blends, knowing that a second phase-down of these chemicals will still be needed. If all costs are considered, transitions to lower-GWP HFCs and HFC/HFO blends will only be 'cost-effective' when there are no truly low-GWP alternatives in a particular sector, as it will usually be cheaper to transition to zero-GWP or truly low-GWP substitutes that have been proven and commercialized than to pay for two transitions – first to lower-GWP HFCs and HFC/HFO blends, and then to zero- or low-GWP alternatives.

There are proven and commercialized truly low-GWP alternatives for most refrigeration and air conditioning sectors. HFC/HFO blends and lower-GWP HFCs such as HFC-32 can play a role as drop-in replacements for existing equipment using high-GWP HFCs.[116] This will enable the use of equipment using HFCs for their useful lives, while reducing impacts on the climate. However, there is state-of-the-art refrigeration and air conditioning equipment using CO_2, hydrocarbons, ammonia and water and not-in-kind technology, all with GWP of <4, which make it unreasonable to think of using mid- and high-GWP refrigerants in new refrigeration and air conditioning equipment where these low and zero-GWP alternatives have been commercialized. When the Multilateral Fund establishes new guidelines for the HFC phase-down, it will need to incentivize transitions to final low-GWP, energy-efficient natural refrigerants and HFOs if the climate impacts of the HFC phase-down are going to be maximized, while promoting an orderly transition to the next generation of refrigerants.

5.3 | Standards: barriers to the adoption of new low-GWP alternatives

International, regional and national safety standards and building codes are blocking the commercialization and marketing of energy-efficient, low-GWP substitutes to HFCs in refrigeration and air conditioning equipment.[117] 'Standards' are established to ensure that products we buy are safe and do not cause an unreasonable risk to human health or the environment.[118] However, many current standards that apply to low-GWP substitutes to HFCs are more than 15 years old, do not take modern equipment, safety devices or instructions and warnings into account, and act as hidden trade barriers.[119] Smarter standards that allow the safe use of low-GWP alternatives, based on scientifically proven assumptions and backed by rigorous

[109]ClimaLife, 'HFOs Come on the Scene in Refrigeration and Air Conditioning' <http://www.climalife.dehon.com/hfos-come-on-the-scene-in-refrigeration-and-air-conditioning-systems/technical_file/show/id/5>.

[110]A Eltalouny et al, 'Evaluating Low-GWP Refrigerants for Air-Conditioning Industry in High-Ambient Temperature Countries: Key Findings of PRAHA Project and Outline of PRAHA-II', UNEP/UNIDO/US-DOE Side Event 38th OEWG – Vienna, Austria (18 July 2016) <http://conf.montrealprotocol.org/meeting/oewg/oewg-38/eventspublications/Observer%20Publications/PRAHA%20Presentation%20to%20HAT%20Side%20Event%20Vienna%20July%202016pptx.pdf>.

[111]The European Commission has estimated that the average GWP of all refrigerants will need to be reduced to 400 GWP to achieve a 79 percent reduction in HFC use. An even lower average will be needed to achieve the 80–85 percent reductions agreed to under the Kigali Amendment. To meet the phase-down steps set forth for developed countries will require refrigerants used in sectors where low-GWP alternatives have been proven to be phased out in order to allow higher-GWP alternatives to be used in sectors where low-GWP alternatives do not exist, such as unitary air conditioning and flood fire suppression. See Area, 'Area F-Gas Guide: A Practical Guide on the Application of the New F-Gas Regulation to Refrigeration, Air Conditioning and Heat Pump Contractors' (2016) <http://www.refcom.org.uk/media/1183/area-guidelines-fgas-master-3-final-_updated.pdf> 32.

[112]See <cooltechnologies.org> and <http://www.shecco.com>.

[113]ibid.

[114]The Greens/European Free Alliance in the European Parliament and Shecco, 'F-Gas Regulation Shaking Up the HVAC&R Industry' (2016) <http://publication.shecco.com/upload/file/org/57fe03c438c881476264900fdfko.pdf>.

[115]Multilateral Fund for the Implementation of the Montreal Protocol, 'Annex IX.2: Guidelines for Technical Review' <http://www.multilateralfund.org/Our%20Work/Policy-search-for%2066/index.html?n=AnneIX2GuidForTechRevi.html>.

[116]For example, the most common refrigerants for commercial refrigeration are HCFC-22 (GWP 1,810) and HFC-404A (GWP 3,922). Replacing these refrigerants immediately and replacing them with the HFC/HFO blends will mitigate emissions by nearly two-thirds of their climate impacts. See P Forster et al, 'Changed in Atmospheric Constituents and in Radiative Forcing' in S Solomon et al (eds), *Climate Change 2007: The Physical Science Basis: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press 2007) 129, 212.

[117]See P Asinari, M Masoero and M Cali, 'Trends in Commercial Refrigeration' in Italian Ministry of the Environment (ed), *Special International Issue, Refrigeration and Air Conditioning* (2008) <http://www.unep.fr/ozonaction/information/mmcfiles/6241-e-industria_formazione_special_issue_2.pdf> 15, 16.

[118]International Standards Organization (ISO), 'Great Things Happen When the World Agrees' <https://www.iso.org/standards.html>.

[119]GTZ Proklima, 'Natural Refrigerants – Ozone- and Climate-Friendly Alternatives to HCFCs' (2008) <https://www.epa.gov/sites/production/files/documents/en-gtz-proklima-natural-refrigerants.pdf>.

research and data that take into account the full range of modern safety technologies and warning systems, are needed if the HFC phase-down is to succeed.[120]

Unfortunately, the Montreal Protocol parties were not focusing on standards while new ODS and HFC substitutes were being evaluated and promoted.[121] As a result, HCFC phase-out management plans, technology pilot and demonstration projects, and policies on conversion were all developed without any recognition that new refrigeration or air conditioning equipment would have to comply with standards or that existing standards would need to be changed to market this newly developed equipment legally. For example, the German implementing agency GIZ provided financial and technical assistance for Chinese air conditioning companies to develop domestic air conditioners using hydrocarbons as the refrigerant instead of HFCs. These air conditioners have been proven to be safe in risk assessments,[122] but the energy-efficient charge size is bigger than the charge size allowed by international and national standards.[123]

Standard bodies have adopted extremely slow methods for reviewing and changing specific standards.[124] It is not unusual for it to take more than 10 years to review and revise a standard.[125] Actions to modernize standards for flammable refrigerants did not begin in earnest until 2015;[126] revising many of the standards needed for low-GWP substitutes to high-GWP HFCs could easily take until the early or even mid-2020s to be revised. There are international, regional and national standards, many of which apply to the same products.[127] Many countries follow international standards, while larger economies tend to have their own domestic standards governing refrigeration and air conditioning equipment, the main uses of HFCs. All of these need to be reviewed and modernized.

Each equipment-specific standard establishes the design parameters and necessary components that must be met to sufficiently protect human health and the environment if the product subject to that standard is placed on the market.[128] Each standard is based on certain assumptions that establish the parameters and components that must be used. For example, assumptions and safety measures can have a major bearing on the charge size that can be considered safe. These assumptions can be related to: (i) the refrigerant itself; (ii) the frequency, rate and size of refrigerant leaks; and (iii) the design, manufacturing and installation requirements for the piece of equipment. Assumptions and safety measures in standards establish 'safe' charge size thresholds, including, leak rates, airflow, location of components, leak tightness testing and leak detection.[129]

Different underlying assumptions can lead to the commercialization of very different equipment. Under IEC 50335-2-24, up to 150 grams of hydrocarbons can be used as refrigerant charge in domestic refrigerators.[130] This charge size allows hydrocarbon refrigerators to be manufactured that are cheaper, more energy efficient and quieter than traditional HFC refrigerators.[131] There are approximately 1.5 billion domestic refrigerators around the world using hydrocarbons;[132] 100 percent of all refrigerators placed on the European market after 1 January 2017 must use hydrocarbons as the refrigerant.[133] However, the US standard-setting body UL (formerly Underwriting Laboratories), adopted a hydrocarbon charge size of just 57 grams for domestic refrigerators and freezers.[134] It is impossible to make competitively priced and energy-efficient refrigerators using such a small hydrocarbon charge.[135] As a result, nearly 100 percent of the approximately 10 million refrigerators purchased each year in the United States use HFC-134a as the refrigerant, with a GWP of 1,340.[136] Hydrocarbons have dominated the international market for almost 20 years, and the UL standard is finally being changed to harmonize with the 150 gram charge size established by international standards.[137] Hydrocarbon refrigerators could be on the US market by the end of 2017 or early 2018.[138]

[120]Low-GWP alternatives are essential if the average GWP of all HFCs is going to be reduced by between 80 and 85 percent.

[121]For example, China's phase 1 HCFC phase-out management plan included production of 5 million hydrocarbon air conditioners. The new equipment was designed and the manufacturing lines were converted as planned, but while tested and proven safe and more energy efficient than traditional air conditioners, the hydrocarbon air conditioners cannot be sold, as they do not comply with hydrocarbon charge size restrictions in applicable standards. Efforts are now underway to change these standards. Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol, 'Project Proposals: China' UN Doc UNEP/OzL.Pro/ExCom/73/35 (16 October 2014); and Vonsild Consulting, 'IEC/TC61/SC61D/WG16, Working Group to: Address A2 and A3 Refrigerants for IEC 60335-2-40' <http://conf.montreal-protocol.org/meeting/oewg/oewg-38/events-publications/Observer%20Publications/Vonsild_WG16%20purpose%20and%20status%20AVolsid.pptx>.

[122]W Zhang et al, 'Research on the Flammability Hazards of an Air Conditioner Using Refrigerant R-290' (2013) 36 International Journal of Refrigeration 1483.

[123]Vonsild Consulting (n 121).

[124]FIPRA International, 'Standard Setting in a Changing Global Landscape' (2010) <https://www.ert.eu/sites/ert/files/generated/files/document/standard_setting_in_a_changing_global_landscape_final_report.pdf>.

[125]See IEEE Standard Association, 'Revising Standards' <https://standards.ieee.org/develop/revisestds.html>.

[126]See International Electrotechnical Commission (IEC), 'IEC/TC61/SC61D/WG16, Appliances for Air Conditioning for Household and Similar Purposes' <http://www.iec.ch/dyn/www/f?p=103:23:12030341575127::::FSP_ORG_ID,FSP_LANG_ID:1351,25>.

[127]For example, there are the IEC (<http://www.iec.ch>) and the ISO (<https://www.iso.org/about-us.html) international standards, EN standards governing products in the EU (<https://www.en-standard.eu/>), UL standards for products on the US market (<http://ulstandards.ul.com>) and different standards covering the Chinese market (<https://www.standardsportal.org/usa_en/prc_standards_system/standards_used_in_China>).

[128]'Standards: What Are They and Why Are They Important?' <http://www.npes.org/pdf/Standards-WhatAreThey.pdf>.

[129]Vonsild Consulting (n 121).

[130]IEC, 'IEC 60601-2-24, 1998' <https://www.iecee.org/dyn/www/f?p=106:49:0::::FSP_STD_ID:16849>.

[131]J Topley Lira, 'The Wind at our Back' (2015) Accelerate Magazine (North American Edition) 6.

[132]Katom Restaurant Supply, Inc., 'True Begins Rolling out R290 Refrigerant Technology' <https://www.katom.com/vendor/true-refrigeration/true-refrigeration-unveils-new-hc-refrigerant.html#sthash.xYbzyIth.dpuf>.

[133]European Commission, 'F-Gas Emissions to be Cut by Two-Thirds by 2030 in EU' <https://ec.europa.eu/clima/policies/f-gas_en>.

[134]Underwriting Laboratories, 'UL 250, Ed. 10, Household Refrigerators and Freezers' <https://infostore.saiglobal.com/store/details.aspx?ProductID=518702>.

[135]A Maratou, 'Industry Reactions: To U.S. EPA Proposed Approval of 4 HCs in 6 AC&R Applications' <http://www.hydrocarbons21.com/articles/5498/industry_reactions_to_us_epa_proposed_approval_of_4_hcs_in_6_ac_r_applications>.

[136]Statista, 'Total Unit Shipments of Refrigerators in the U.S. from 2005 to 2018 (in Millions)' <https://www.statista.com/statistics/220111/unit-shipments-of-refrigerators-and-freezers-in-the-us/>.

[137]In January 2017, Underwriting Laboratories adopted UL 60335-2-24 Ed. 2, which harmonized the UL standard with IEC 60335-2-24 and increased the allowable charge size in domestic refrigerators to 150 grams. See <https://standardscatalog.ul.com/standards/en/standard_60335-2-24>.

[138]Danfoss, 'Hydrocarbons Charge Up Refrigeration Innovations: Industry Likely to See Propane and Isobutane Products by 2010' <http://www.danfoss.us/technicalarticles/cf/us-article-hydrocarbons-charge-up-innovations/?ref=17179909931#/>.

Experts have started to evaluate and debate new standards for flammable charge sizes.[139] When approving new low-GWP substitute refrigerants, the US Environmental Protection Agency (EPA) frequently references and incorporates UL standards in its risk evaluations on flammability and other safety issues.[140] The EPA Significant New Alternative Policy (SNAP) programme has the responsibility to review and approve all new substitutes for equipment that traditionally used ODS.[141] The SNAP programme recently issued rules that establish deadlines by which high-GWP refrigerants can no longer be used in certain refrigeration and air conditioning equipment.[142] The rules also approved the use of new low-GWP alternative refrigerants in certain sectors.[143] The SNAP programme and the state of California's Air Resources Board are both targeting a 2021 phase-out date for the use of HFC-134a in domestic refrigerators.[144] These actions have prompted UL to begin considering whether standards allowing low-GWP substitutes to HFCs onto the US market are safe.

Chinese, European and Indian companies have hydrocarbon air conditioners that have been proven safe through risk assessments and other evaluations, but these cannot be sold in the United States. The reluctance of UL to permit this equipment to be sold has chilled the international market for these air conditioners.[145] As a result, while the status of hydrocarbon air conditioners is being debated, 40 million HFC-410A air conditioners with a GWP of 2,088[146] are sold in China annually and approximately 4 million HFC-410A air conditioners are sold annually in both the United States and India.[147] Not only are there direct emissions due to the use of high-GWP air conditioners, but HFC-410A has terrible energy efficiency in high ambient temperature regions, which means that the use of this refrigerant causes greater indirect greenhouse gas emissions as well.[148]

Changes to standards take time, as experts must ensure that the standards adopted are safe for human health and the environment. Resources need to be mobilized to expedite the revisions of standards to enable the sale of safe low-GWP substitutes to HFCs to ensure that countries will be able to achieve the phase-down envisioned in the Kigali Amendment.

5.4 | ODS and HFC banks

The Montreal Protocol has focused on eliminating production and consumption of ODS. As the parties historically were unconcerned about climate change, they made no attempt to reduce emissions from the more than 50 years' worth of equipment, foams, chemical stockpiles and other products (collectively referred to as 'banks'), despite the fact that banks are a major source of greenhouse gas emissions. In 2002, the TEAP and the IPCC estimated that banks contained approximately 20 Gt CO_2-eq.[149] They predicted that total direct emissions from banks would reach 2.3 Gt CO_2-eq. per year by 2015. While concerns about banks were raised during the discussions of the HFC phase-down, the final text of the Kigali Amendment and related decisions do not mandate the collection or destruction of banks.[150]

In its assessment, the TEAP evaluated the cost of recovery of different types of banks. The TEAP determined that approximately 85 percent of the total calculated banks would be recoverable. It broke down banks by cost of recovery and determined that easily recoverable banks could be reclaimed for an average cost of US$15 per tonne of CO_2-eq.; and that with medium effort additional banks could be recovered for an average cost of US$35 per tonne of CO_2-eq. Approximately 47.5 percent or 3 million tonnes of the banks fell into the low and medium effort categories. Air conditioning in buildings is responsible for the largest banks in terms of tonnage, with 48 percent of the total banks from commercial refrigeration are almost as important to the climate, since many refrigerants used in commercial refrigeration have extremely high GWP. The TEAP has issued several reports on the size of banks and the related emissions in order to estimate the urgency and cost-effectiveness of mitigation efforts related to banks.[151]

Despite the attention paid to banks by the Montreal Protocol, there was little incentive for countries to pay to control banks while emissions of other greenhouse gases continued to increase due to the failure of the parties to the UNFCCC to reach a meaningful agreement to control other emissions. Now that the world is taking action to control the emission of other greenhouse gases through the Paris Agreement, parties to the Montreal Protocol have started to reconsider this massive climate oversight. During previous inquiries into the feasibility of recovering banks, the Multilateral Fund funded a number of ODS destruction pilot projects to determine whether banks' recovery was truly feasible and to determine

[139]'Decision XXVIII/4, Establishment of Regular Consultations on Safety Standards' (2016) <http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/41479>.

[140]US EPA, 'SNAP Regulations' <https://www.epa.gov/snap/snap-regulations#Rules> Rules 19.

[141]US EPA, 'Significant New Alternatives Policy (SNAP) Program' <https://www.epa.gov/snap>.

[142]SNAP Regulations (n 140) Rules 20 and 21.

[143]ibid.

[144]California Air Resources Board, 'Short-Lived Pollutant Reduction Strategy' <https://www.arb.ca.gov/cc/ejac/meetings/040416/slcp_slides_ejac.pdf>.

[145]Greenpeace and EIA, 'Background' <http://www.cooltechnologies.org/content/background>.

[146]R Rajendran, 'Refrigerants Updates' (19 September 2011) <https://www.epa.gov/sites/production/files/documents/RefrigerantUpdates.pdf>.

[147]Statista (n 136).

[148]O Abdelaziz et al, 'Alternative Refrigerant Evaluation for High-Ambient-Temperature Environments: R-22 and R-410a Alternatives for Mini-Split Air Conditioners' (Oakridge National Laboratory 2015) <https://info.ornl.gov/sites/publications/Files/Pub59157.pdf>.

[149]IPCC and TEAP, *Safeguarding the Ozone Layer and the Global Climate System: Issues Related to Hydrofluorocarbons and Perfluorocarbons* (Cambridge University Press 2005) 9.

[150]'Report of the Twenty-Eighth Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer' UN Doc UNEP/OzL.Pro.28/12 (15 November 2016).

[151]See 'Decision XXV/5, Response to the Report by the Technology and Economic Assessment Panel on Information on Alternatives to Ozone-Depleting Substances (Decision XXIV/7, Paragraph XXVI/9)' (2013) <http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/71>; 'Decision XXVI/9, Response to the Report by the Technology and Economic Assessment Panel on Information on Alternatives to Ozone-Depleting Substances' (2014) <http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/39798>; 'Decision XXVII/4, Response to the Report by the Technology and Economic Assessment Panel on Information on Alternatives to Ozone-Depleting Substances' (2015); and the related Task Force reports.

whether external sources of funding could be enlisted to aid in the destruction of banks.[152] In 2012, ODS banks were estimated to total 21.2 Gt CO_2-eq. Of these, 8.8 Gt were classified as easily recoverable and economically viable banks.[153]

During the discussions leading to the Kigali Amendment, there was substantial interest in having the TEAP prepare a new report on the various scenarios concerning the size of ODS and HFC banks and potential mitigation of banks. A specific Working Group was established that has been tasked to develop models for the banks' destruction scenarios. A detailed explanation of both ODS and HFC banks will be presented to the parties in 2018. The question is whether the parties will maximize the potential climate mitigation from recovering banks, or whether the hissing sound of emissions from the banks of ODS and HFCs will continue to be heard.

6 | CONCLUSION

The phase-down of HFCs under the auspices of the Montreal Protocol will deliver the quickest and most cost-effective means of ensuring a global transition from ODS and HFCs to low-GWP substitutes. This is critical to keep global warming below 2 °C. The Protocol effectively phased out 98 percent of all ODS and now is set to use the same institutions to phase down HFCs. The HFC phase-down was adopted by unanimous consent of all 197 parties to the Protocol who agreed to accept legally binding commitments. These commitments were obtained largely due to the Montreal Protocol's adherence to the principle of common but differentiated responsibilities, requiring developed countries to go faster and to support the incremental costs of developing countries to meet their commitments.

There has been much attention for the phase-down and the claims that it will result in a reduction of between 70 and 105 Gt CO_2-eq. mitigation by 2050. However, the actual amount of mitigation achieved will be determined during the implementation stage. Actions on standards, new low-GWP technologies and improved energy efficiency will be needed to implement the HFC phase-down properly and to deliver the greatest possible mitigation. Standards are a complicated matter requiring more attention by experts, and resources to conduct the research necessary to ensure that people and the environment are not acting as artificial trade barriers that provide an advantage for one technology over another. Likewise, efforts are needed to bring energy-efficient, low-GWP technologies to market. In order to curb climate change, cost-effective actions to control ODS and HFCs in banks are critical. The Montreal Protocol has taken an important first step to mitigate greenhouse gases and provides a great example of how multilateral efforts can enable global actions to combat climate change.

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[152]The 54th meeting of MLF Executive Committee approved a 2008–2010 study of ODS; see <http://www.multilateralfund.org/sites/54th/default.aspx>. See also Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol, 'Desk Study on the Evaluation of the Pilot Demonstration Projects on ODS Disposal and Destruction' UN Doc UNEP/OzL.Pro/ExCom/75/10 (24 October 2015); 'Disposal of ODS Collected from Refrigerators and Air Conditioners under the Mexican Efficient Lighting and Appliances Program, Submitted by the World Bank' UN Doc UNEP/OzL.Pro/ExCom/66/Inf.2 (26 March 2012).

[153]ibid.