Primer on HFCs

Fast action under the Montreal Protocol can limit growth of hydrofluorocarbons (HFCs), prevent 100 to 200 billion tonnes of CO_2-eq by 2050, and avoid up to 0.5°C of warming by 2100

Institute for Governance & Sustainable Development

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About the Institute for Governance & Sustainable Development (IGSD)

IGSD's mission is to promote just and sustainable societies and to protect the environment by advancing the understanding, development, and implementation of effective and accountable systems of governance for sustainable development.

Beginning in 2005, IGSD embarked on a "fast-action" climate mitigation campaign that will result in significant reductions of greenhouse gas emissions and will limit temperature increase and other climate impacts in the near term. The focus is primarily on strategies to reduce non-CO_2 climate pollutants as a complement to cuts in CO_2, which is responsible for more than half of all warming. It is essential to reduce both non-CO_2 pollutants and CO_2. Neither alone is sufficient to limit the increase in global temperature to a safe level.

IGSD's fast-action strategies include reducing emissions of short-lived climate pollutants—black carbon, methane, tropospheric ozone, and hydrofluorocarbons. They also include measures to promote energy efficiency of air conditioners and other appliances, and measures to capture, reuse, and store CO_2 after it is emitted, including biosequestration and mineralization strategies that turn carbon dioxide into stable forms for long-term storage without competing with food supply.

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This *HFC Primer* also is available on IGSD's web site (http://www.igsd.org) with active links to the references and periodic updates. IGSD's *Primer on Short-Lived Climate Pollutants* also is available on IGSD's web site.

Table of Contents

Figures and Tables

Fast action under the Montreal Protocol can limit growth of HFCs, prevent 100 to 200 billion tonnes of CO_2-eq emissions by 2050, and avoid up to 0.5°C of warming by 2100, with additional climate benefits from parallel improvements in energy efficiency of air conditioners and other appliances.

1. Summary

The IPCC's *Fifth Assessment Report* concludes that climate change is unequivocal, significantly caused by human activities, occurring faster than anticipated, with impacts that are more severe than predicted, and that urgent action is required to reduce climate pollutants.[1] This *Primer* describes how the Montreal Protocol can be used to quickly reduce one category of climate pollutants, hydrofluorocarbons (HFC),[2] with further support from national and regional laws and institutions.

HFCs are the fastest growing greenhouse gases in much of the world, increasing at a rate of 10-15% per year.[3] They are factory-made gases that were once thought necessary to replace ozone-depleting substances, but today are no longer needed in most sectors, including air conditioning, refrigeration, and foam insulation. In November 2015, the Parties to the Montreal Protocol, recognizing the threat posed by the growth of HFCs, agreed on the *Dubai Pathway on Hydrofluorocarbons* to "*work within the Montreal Protocol to an HFC amendment in 2016.*"[4] Ninety-five countries have submitted formal proposals to amend the Montreal Protocol to phase down HFCs, including a coalition of island States, India, the EU, the US, Canada, and Mexico, and the 54 members of the Africa Group.

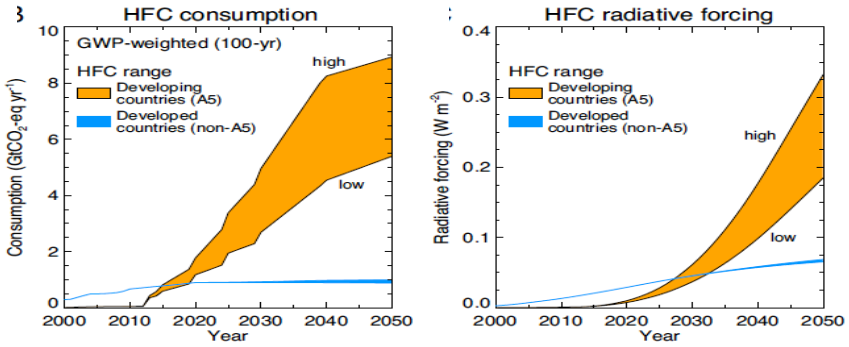
A fast phaseout of high-GWP HFCs under the Montreal Protocol by 2020 would prevent up to 200 billion tonnes (Gt) of CO_2-equivalent (CO_2-eq) emissions by 2050,[5] and avoid up to 0.5°C warming by 2100,[6] using a treaty that requires developed countries to act first, provides implementation assistance to developing countries,[7] and has the experience and expertise to ensure that reductions are fast, effective, and efficient. In addition, an HFC phasedown under the Montreal Protocol would, as it has always been the case in the past, catalyze significant energy efficiency gains in air conditioning and refrigeration systems, in the range of 30 to 60%, and significantly reduce CO_2 emissions.[8] In the room air conditioning sector alone, improving energy efficiency could provide additional climate mitigation of nearly 100 Gt CO_2-eq by 2050, and save an amount of electricity equivalent to up to 2,500 medium-sized power plants.[9]

An amendment to phase down HFCs under the Montreal Protocol in 2016 will provide a level playing field for producers and consumers in lieu of a patchwork of regional and national regulations. The agreement to work to amend the Montreal Protocol in 2016 also builds momentum for a successful climate agreement under the UNFCCC in December 2015 to go into effect in 2020.

2. HFC are used primarily as refrigerants and to make insulating foams

HFCs are a group of factory made chemicals primarily produced for use in refrigeration, air-conditioning, insulating foams, and aerosol propellants, with minor uses as solvents and for fire protection. HFCs were developed in order to replace chlorofluorocarbons (CFCs) that have already been phased out and hydrochlorofluorocarbons (HCFCs) that are currently being phased out under the Montreal Protocol in order to put the stratospheric ozone layer on a path to recovery. HFCs are now being used as substitutes for HCFCs. HFCs are very powerful greenhouse gases, trapping thousands of times more heat in the atmosphere per unit of mass than CO_2.[10] HFC-134a is the most abundant and fastest growing HFC; it has an atmospheric lifetime of 13.4 years and a GWP of 1,300.[11] According to new research by NASA, HFCs are also weak ozone-depleting substances and cutting them would "reduce the HFC impacts on the stratosphere, lessen the temperature and circulation responses and resulting ozone depletion."[12]

Fig. 1: Projected growth in HFCs and climate forcing from emissions



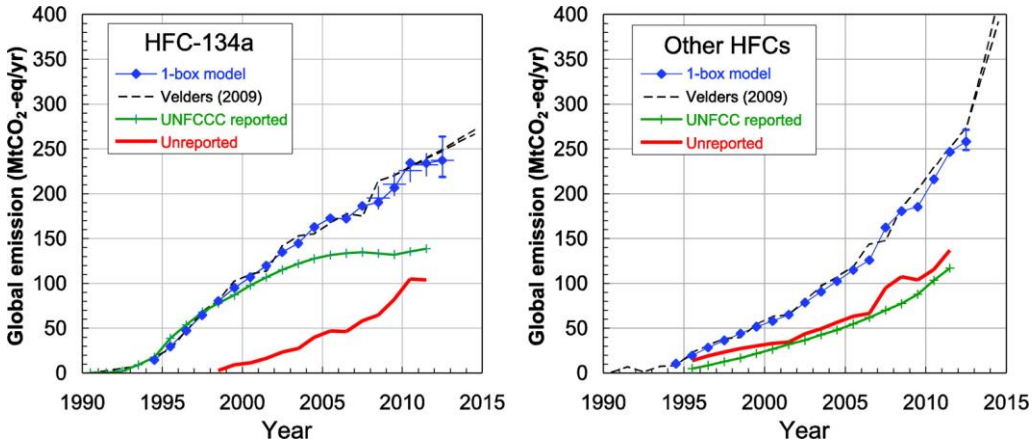
Guus J.M. Velders, David W. Fahey, John S. Daniel, Mack McFarland, & Stephen O. Andersen (2009) *The large contribution of projected HFC emissions to future climate forcing*, PROC. NAT'L. ACAD. SCI. U.S.A. 106:10949-10954.

HFCs were only commercialized in the early 1990s, and so while HFCs have caused only 1% of total global warming to date, production, consumption, and emissions of these factory-made gases are growing at a rate of 10-15% per year,[13] which will cause a doubling every five to seven years. HFC growth is accelerating as HFCs are used as substitutes to replace ozone depleting substances (ODSs) and as the demand grows for the appliances that use these refrigerants.[14] *See* Figure 1. HFCs and other fluorinated greenhouse gases are the fastest growing climate pollutants in many countries, including the U.S., E.U., Australia, China, and India.[15]

3. High growth rates for HFCs will cause significant global warming

Atmospheric measurements confirm the high growth rates of HFCs used as substitutes for ODSs.[16] According to the measurements, emissions of these HFC substitutes are now twice as high as those reported to the UNFCCC, implying that developing countries (which are not required to report emissions to the UNFCCC) now account for nearly 50% of global HFC emissions. [17] *See* Figure 2.

Fig. 2: High HFC emissions confirmed by global measurements



"Figure [2]. HFC emissions derived from NOAA global observations (blue ◆ connected by solid lines; 1-box result) are compared to the projections of Velders et al.(2009) (black dashed lines; 1-box result), and those reported to the UNFCCC (green lines and plus symbols; data from http://unfccc.int/ghg_data/ghg_data_unfccc/items/4146.php) for HFC-134a alone (left) and for the aggregate sum of other HFCs used as substitutes for ozone-depleting substances (right panel, HFC-125, −143a, −32, −152a, −227ea, and −365mfc [i.e., not HFC-134a or HFC-23]). The difference between global emissions derived from NOAA atmospheric measurements (3-box result) and those reported to the UNFCCC are shown as "unreported" emissions (red lines)." Stephen A. Montzka, Mack McFarland, Stephen O. Andersen, Benjamin R. Miller, David W. Fahey, Benjamin D. Hall, Linhua Hu, Carolina Siso, & James W. Elkins (2014) *Recent Trends in Global Emissions of Hydrochlorofluorocarbons and Hydrofluorocarbons: Reflecting on the 2007 Adjustments to the Montreal Protocol*, J. PHYS. CHEM.

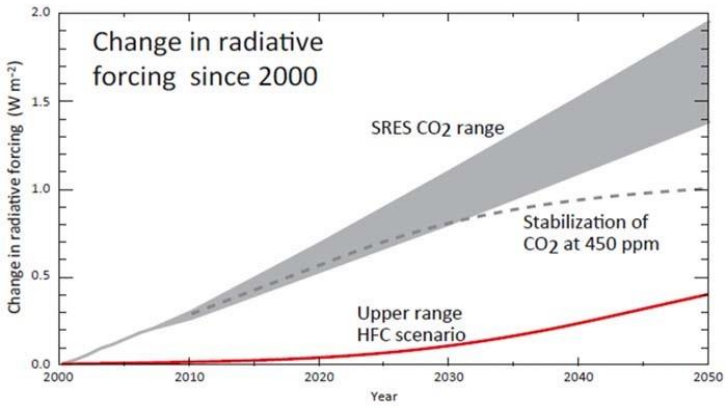
Without fast action, HFC forcing will increase as much as thirty-fold by 2050, from a forcing of 0.012 W/m^2 to as

much as 0.40 W/m^2.[18] Continued growth in HFCs will add up to 0.1°C of global average temperature rise by mid-century, which will increase up to five-fold to 0.5°C by 2100.[19]

If left unchecked, by 2050, annual HFC emissions could be equivalent to 12% of annual CO_2 emissions under a business-as-usual (BAU) scenario, and up to 71% of annual CO_2 emissions under the IPCC's strongest mitigation scenario.[20] Such uncontrolled growth in HFCs would cancel much of the climate benefit achievable under an aggressive CO_2 450 ppm mitigation scenario. (In Figure 3, compare radiative forcing reduced from CO_2 mitigation to radiative forcing increased from HFC growth.).

In addition to direct emissions, by 2050, the unchecked growth of HFC production and use will also produce between 39-64 GtCO_2-eq of HFCs trapped in millions of refrigerators, air conditioners, and other cooling equipment, as well as in chemical stockpiles and foams, collectively known as "HFC banks."[21] These HFCs banks will slowly emit their stored HFCs over a few decades, further contributing to global warming.[22]

Fig. 3: By 2050 forcing from HFCs could equal 20-25% of the growth of CO_2 forcing since 2000



"Clearly, the contribution of HFCs to radiative forcing could be very significant in the future; by 2050, it could be as much as a quarter of that due to CO_2 increases since 2000 if the upper range HFC scenario is compared to the median of the SRES scenario [Special Report on Emissions Scenarios, establishing a baseline scenario]. Alternatively, the contribution of HFCs to radiative forcing could be one-fifth the radiative forcing due to CO_2 increases since 2000 if the upper range HFC scenario is compared to the upper range of the SRES scenario." UNEP (2011) HFCs: A Critical Link in Protecting Climate and the Ozone Layer – A UNEP Synthesis Report.

4. Phasing down HFCs will prevent significant warming and climate impacts

A fast phasedown of high-GWP HFCs, has the potential to prevent the equivalent of up to 8.8 Gt CO_2 *per year* in emissions by 2050.[23] The proposed phasedown will avoid up to 0.5°C of warming by 2100 under the high HFC growth scenario, and up to 0.35°C under the low HFC growth scenario.[24] A more ambitious strategy of completely eliminating the use of high-GWP HFCs by 2020, would avoid emissions equivalent to between 91-146 Gt CO_2 by 2050,[25] plus an additional amount equivalent to 50 Gt CO_2 (39–64 Gt) trapped in HFCs banks, for a combined total of up to 200 or more Gt CO_2-eq.[26] *See* Figure 4, far right bar. These avoided emissions from HFCs are equal to two-thirds of the projected 307 (192–439) Gt CO_2 of future emissions from the lifetime operation of existing power plants constructed as of 2012.[27] Avoiding this warming is essential for staying within the long-term international goal of stabilizing global temperature rise to below 2°C above pre-industrial temperatures by the end-of-century. *See* Figure 5.

Fig. 4: Climate protection from the Montreal Protocol and Kyoto Protocol[28]

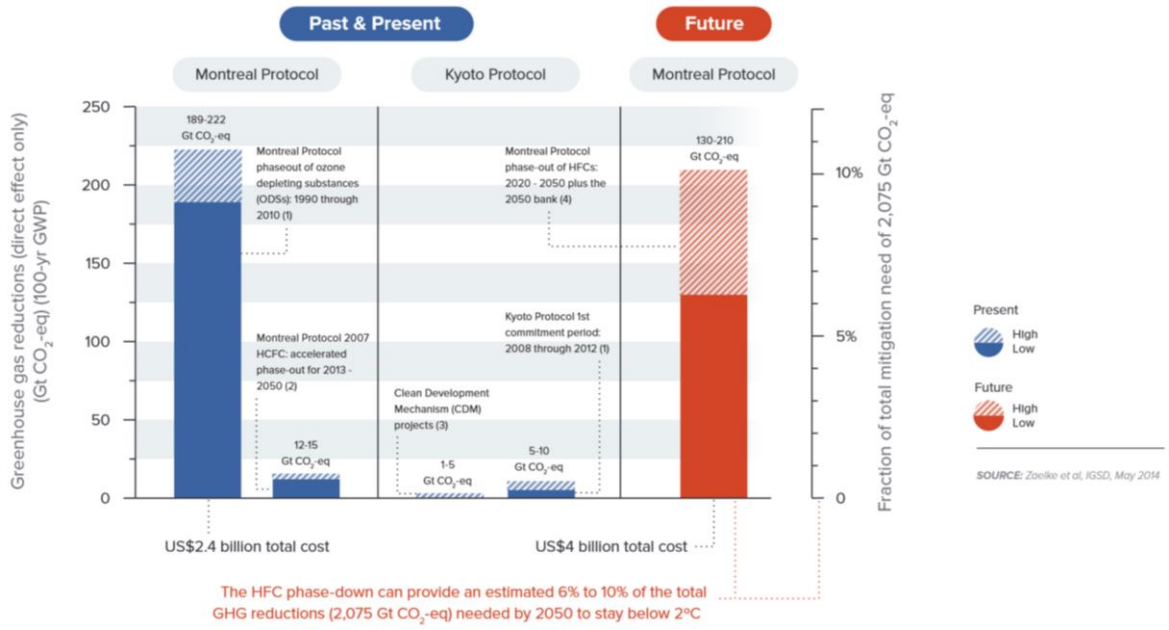


Fig. 5: 21st Century warming that can be prevented by mitigating Short-Lived Climate Pollutants and CO_2

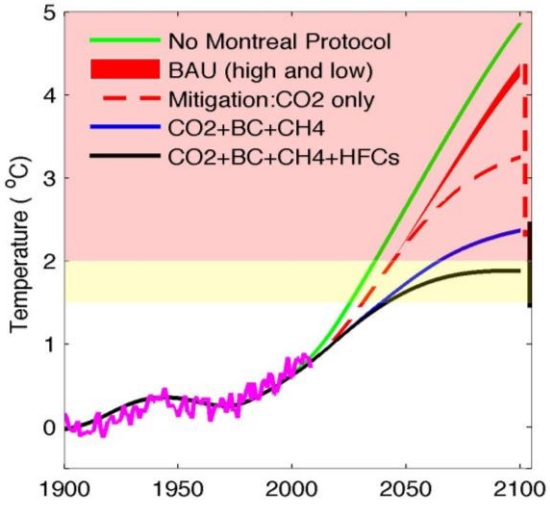


Figure [5] *"[D]epicts model simulated temperature change under various mitigation scenarios that include CO_2 and SLCPs (BC, CH_4, HFCs). BAU case (red solid line with spread) considers both high and low estimates of future HFC growth. Note this uncertainty of temperature projection related to HFC scenarios is around 0.15°C at 2100. The vertical bars next to the curve show the uncertainty of temperature projection at 2100 due to climate sensitivity uncertainty."* Yangyang Xu, Durwood Zaelke, Guus J.M. Velders, & Veerabhadran Ramanathan (2013) *The role of HFCs in mitigating 21st century climate change*, ATMOS. CHEM. PHYS. 13:6083-6089.

Fast mitigation of HFCs combined with mitigation of the other short-lived climate pollutants (SLCPs) — black carbon, methane, and tropospheric ozone — can avoid 0.6°C of future warming by 2050, and up to 1.5°C by end-of-century, with HFC mitigation contributing one-third of the avoided warming by end-of-century.[29] *See* Figure 5.

Fast action to phase down all four SLCPs "would cut the cumulative warming since 2005 by 50% at 2050 and by 60% at 2100…. Based on our high HFC growth scenarios, the contribution to the avoided warming at 2100 due to HFC emission control is about 40% of that due to CO_2 emission control."[30]

Reducing HFCs and the other SLCPs can significantly reduce future climate impacts, including slowing sea-level rise. Research led by Professor Veerabhadran Ramanathan at Scripps Institution of Oceanography, University of

California, San Diego, calculates that cutting SLCPs can reduce the rate of sea-level rise by almost 20% by 2050 and nearly 25% by 2100; adding immediate and aggressive CO_2 mitigation can double the end-of-century reductions.[31] Combined SLCP and CO_2 mitigation can reduce cumulative sea-level rise by 31% in 2100.[32] Individual contributions to avoided sea-level rise by 2100 from different mitigation actions are: 29% from CO_2 mitigation and 71% from SLCP mitigation (13% from HFC mitigation, 17% from black carbon mitigation, and 41% from methane mitigation).[33] *See* Figure 6.

Fig. 6: Avoided sea-level rise at 2100 due to aggressive CO_2 and SLCP mitigation

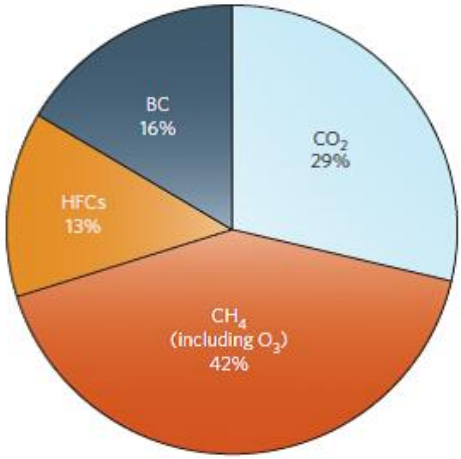


Figure [6] *"Avoided sea-level rise at 2100 due to aggressive mitigation of long-lived CO2 and SLCPs. Such aggressive actions can reduce the rise in sea levels by 35 cm (uncertainty range is 17–70 cm) from the projected sea-level rise of 112 cm (49–210 cm) under a business-as-usual scenario for emissions (Representative Concentration Pathway (RCP) 6.0). The pie chart shows percentage contribution of each pollutant. Mitigation of the SLCP methane would lead to reductions in tropospheric ozone, another SLCP, and hence the pie chart includes both. As a long-lived pollutant, CO2 plays a substantial role (blue section), but reduction in SLCPs (shown in darker colours) would lead to a larger degree of avoided sea level. (Under a more intensive business-as-usual RCP8.5 level, reductions in CO2 would increase the share of CO2 mitigation to 50%)." From* David G. Victor, Durwood Zaelke, & Veerabhadran Ramanathan (July 2015) *Soot and short-lived pollutants provide political opportunity*, NATURE CLIMATE CHANGE (based on Hu, A., Y. Xu, C. Tebaldi, W. M. Washington, and V. Ramanathan (2013), *Mitigation of short-lived climate pollutants slows sea-level rise*, NATURE CLIMATE CHANGE, 3, 1–5.)

5. Phasing down HFCs will catalyze energy efficiency and significant CO_2 reductions

In addition to the direct climate benefits from HFC mitigation, a global HFC phasedown will catalyze additional climate benefits through improvements in the energy efficiency of the refrigerators, air conditioners, and other products and equipment that use HFC refrigerants. (Complementary measures to encourage consumers to choose energy efficient appliances can speed the gains.) These efficiency gains will significantly reduce CO_2 emissions. Depending on the application, generation mix, and fuel type, emissions from generating electricity account for between 70-95% of total climate emissions attributable to products using refrigerants.[34]

The phaseout of CFCs under the Montreal Protocol, which began in the mid-1980s, catalyzed substantial improvements in air conditioning and refrigerant energy efficiency—up to 60% in some subsectors.[35] These efficiency improvements were the result of replacing old products and equipment with a new generation of higher efficiency machines.[36] When refrigeration and air conditioning manufacturers redesigned their systems to be CFC-free, many took the opportunity to improve the efficiency of their designs.[37] For example, the U.S. EPA estimated that CFC-free chillers were up to 50% more energy efficient in the U.S.[38] and the Global Environment Facility estimated the chillers were over 30% more efficient in India than the CFC-based machines they replaced.[39]

Similar energy efficiency improvements are expected with an HFC phasedown. Case studies of recent demonstration projects presented by the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC) calculated energy savings of 15% to 30%, and carbon footprint reductions of 60% to 85% for refrigeration in commercial food stores.[40]

A number of global companies that are already making the transition away from HFCs report significant gains in energy efficiency. For example, the Coca-Cola Company and PepsiCo have reported energy efficiency gains of up to

47% in their new CO_2 and hydrocarbon-based refrigeration equipment over baseline HFC-based models.[41] Global supermarket chains Tesco and Unilever both report a 10% gain from new hydrocarbon-based commercial refrigeration equipment and freezer cabinets over HFC-models.[42]

Recent calculations by scientists at Lawrence Berkeley National Laboratory confirm that, in the room air conditioning sector, improving efficiency could avoid ~25 Gt of CO_2 emissions in 2030, 33 Gt in 2040, and ~40 Gt in 2050, for cumulative mitigation up to 98 Gt.[43] Room air conditioning is an important target for efficiency programs due to rapidly expanding consumer cooling markets in emerging economies; an additional 700 million units will be added to the global stock of air conditioners by 2030.[44] The market for room air conditioning is growing 10-15% per year in many emerging economies, including India, China, and Brazil, and straining often weak grids.[45] Ownership of room air conditioners in India, for example, is projected to increase to 73% in 2030 from 30% in 2020.[46] Air conditioning accounts for a significant percentage of peak energy load in hot climates, such a Dehli in India, where it represents 40-60% of peak electricity demand.[47]

According to Lawrence Berkeley National Laboratory, a combined transition to low-GWP refrigerants and higher efficiency A/C could produce energy savings in peak demand equal to 544-1,270 gigawatts (GW) of electricity.[48] This would avoid (or free up for other uses) an amount of electricity equal to the production of between 680 and 1,587 medium-sized peak-load coal power plants by 2030, and between 1,090 and 2,540 by 2050.[49] Over the next 15 years, the potential energy savings in India alone from improving the energy efficiency of room air conditioning is the equivalent of up to 142 new medium-sized (500 MW) coal power plants.[50] Other countries would also see significant energy savings. *See* Table 1. These efficiency gains also would lower the cost of operating the air conditioning, ease pressure on overloaded electricity grids, and save consumers money.[51]

Table 1: 500-megawatt power plants avoided by 2030 and 2050 from combined transition for split room air conditioners[52]

COUNTRY	NUMBER OF AVOIDED 500 MW PEAK-LOAD POWER PLANTS	
	2030	**2050**
Brazil	31-72	92-216
Chile	1-2	2-4
China	265-619	310-720
Colombia	4-10	10-24
Egypt	6-14	20-46
India	61-142	219-511
Indonesia	40-93	60-140
Mexico	4-9	11-26
Pakistan	3-6	18-42
Saudi Arabia	4-9	5-12
Thailand	12-27	14-30
United Arab Emirates	2-4	2-6
Vietnam	13-30	15-36
Global	**680-1587**	**1090-2540**

6. Energy efficient alternatives to HFCs exist in almost every sector

Low-GWP alternatives to high-GWP HFCs are widely and increasingly available (*see* Table 2).[53] Alternatives to existing high-GWP HFCs fall into two basic categories: non-fluorinated substances with low-GWP, and fluorinated substances with low- to mid-range GWPs. The Montreal Protocol's Technology and Economic Assessment Panel (TEAP) uses the term "low-GWP' to refer to refrigerants with GWPs of 300 or lower while "moderate-GWP" refers to refrigerants with GWPs of 1,000 or lower.[54] For comparison, the $GWP_{100\text{-}yr}$ of HFC-134a, one of the most commonly used high-GWP HFC refrigerants today, is 1,300.[55]

In sectors where an alternative has been identified, the next steps will be to develop equipment, gain regulatory approval, address any servicing needs, and determine if a drop-in solution is available.[56] TEAP cautions that differences in energy efficiency could determine which "low-GWP" or "moderate-GWP" alternatives would have the

lowest overall impact on global warming.[57] The most comprehensive way to evaluate the climate impact of any proposed refrigerant is to use Life Cycle Climate Performance (LCCP) methodology to calculate "cradle-to-grave" climate emissions for a particular refrigerant and application. LCCP was developed by TEAP and U.S. EPA and includes direct and indirect climate emissions, energy embodied in product materials, climate emissions during chemical manufacturing, and end-of-life loss (typically refrigerant leakage).[58] *See* Section 5 for a discussion of the energy efficiency gains that will be catalyzed by an HFC phasedown.

Commercially available non-fluorinated or "natural refrigerants" primarily include ammonia with a GWP of near zero, hydrocarbons (e.g., propane and isobutene) with GWPs of less than four, and CO_2 with a GWP of one. Alternative fluorinated substances include primarily the low-GWP HFCs, also known as "HFOs", including HFC-1234yf and HFC1234ze[59] with IPCC Firth Assessment Report (AR5) calculating a $GWP_{100\text{-}yr}$ of less than one.[60] Another alternative is HFC-32, with a $GWP_{100\text{-}yr}$ of 677 according to the AR5.[61] There are other alternative methods and processes that do not involving chemical refrigerants. These are termed "not-in-kind" alternatives.

In the mobile air conditioning sector, which represents up to half of HFC emissions on a CO_2-eq basis[62], available low-GWP alternatives include HFC-1234yf, CO_2, and HFC-152a (AR5 $GWP_{100\text{-}yr}$ = <1, 1, and 138, respectively).[63] Currently, more than a dozen vehicle manufacturers in Europe, Japan, and North America have vehicles with the low-GWP refrigerant HFC-1234yf in the global market.[64] Daimler, with support from other German car manufacturers, announced in March 2013 that they are developing CO_2 as a low-GWP alternative for vehicle air-conditioning.[65] In Norway, approximately 16% of new refrigerated truck and trailer systems were equipped with CO_2 cryogenic refrigeration systems in 2011; use of these systems is expected to expand further in the future.[66]

In commercial refrigeration, globally, up to 65% of new installations are using low-GWP HFC alternatives, including CO_2, ammonia, and hydrocarbons, while in the domestic refrigeration sector, low-GWP hydrocarbon technology is expected to reach about 75% of global production by 2020.[67] *See* Table 3 for examples of companies that have already made the switch to low-GWP alternatives in the refrigeration sector.

In the room air conditioning sector, thousands of hydrocarbon units have been sold and new production lines are coming on line each year.[68] The Indian manufacturer, Godrej, and the Chinese manufacturer, Gree, have developed models of propane (HC-290) room air conditioners.[69] The Godrej models are up to 11% more efficient than the minimum requirements for the 5-Star energy efficiency rating set by the Indian Bureau of Energy Efficiency.[70] China, Japan, India, Indonesia, and other countries have projects underway using moderate-GWP HFC-32 with high levels of operating efficiency.[71] CO_2 air conditioning prototypes are also available.[72]

In the foam sector, low-GWP alternatives include hydrocarbons, CO_2/water, and fibrous materials.[73] Hydrocarbons and CO_2/water make up 28% to 76% of the global market for new polyurethane foam products, while fibrous materials comprise 59% of the new market for insulation in Western Europe.[74] HFC-1233zd(E) is a liquid blowing agent that has a GWP of about one,[75] and is up to 12% more energy efficient than leading hydrocarbon alternatives, according to the companies making it.[76] Companies are developing additional low-GWP HFC alternatives and a number of developing country Parties intend to adopt low-GWP alternatives for foam products as part of their HCFC phaseout plans.[77]

In all major sectors, the best available low-GWP alternatives to high-GWP HFCs demonstrate at least equal, and often greater, energy efficiency than the HFCs they replace — up to 30% greater.[78] A 2011 study for the European Commission concluded that technically feasible and cost-effective low-GWP alternatives exist for all major HFC subsectors.[79] This analysis, which was prepared in association with industry, research institutes, and other technical experts, analyzed HFC alternatives available in 26 subsectors; all alternatives identified achieved at least equal energy efficiency and more often resulted in energy savings compared to commercially available HFC-based equipment.[80]

The TEAP also concluded that low-GWP alternatives are available that achieve equal or superior energy efficiency in a number of sectors stating, "hydrocarbon and ammonia systems are typically 10-30% more energy efficient than conventional high-GWP HFC systems."[81] Tests of room air conditioning utilizing hydrocarbon refrigerants showed energy improvements of up to 20% over HFC models.[82] Fluorinated refrigerant producers also report high levels of energy efficiency with use of their air conditioning products, particularly in hot climates.[83] In Japan, an HFC-32 room air conditioner was awarded the 2012 Grand Prize for Excellence in Energy Efficiency and Conservation and the prestigious "Top Runner" designation as the most energy efficient room air conditioning available.[84] In the commercial refrigeration sector, supermarkets are improving energy efficiency by 15-30% when they switch to low-GWP alternatives.[85] For example, Sobeys, Canada's second largest food retailer found that the new CO_2 transcritical system used 18% to 21% less energy than the high-GWP HFC equipment it replaced.[86]

Other not-in-kind alternatives are available for some applications, such as district cooling, which relies on water chilled in high efficiency central plants to cool a large number of buildings.[87] If powered by renewable sources of energy, such as hydroelectric, wind, or solar, this type of cooling system can have virtually no climate impact.[88]

Table 2: Indicative list of low-GWP alternatives to high-GWP HFCs[89]

APPLICATION	CURRENT HIGH GWP REFRIGERANT[90]	GWP[91]	ALTERNATIVE	GWP[92]
Refrigeration (Domestic)	HFC-134a HFC-152a	1,300 138	HC-600 (isobutene) HC-290 (propane) HFO-1234yf	~3 <5 <1
Refrigeration (Commercial & Industrial)	HCFC-22 HFC-407C HFC-134a HFC-404a	1,760 1,774 1,300 3,943	HC-600 (isobutene) R-744 (CO_2) R-717 (ammonia) HFCs and HFC blends	~3 1 0 <1-1,600
Air Conditioners (Room)	HFC-410A HCFC-22 HFC-407C	1923 1,760 1,774	HC-290 (propane) HFC-32 HFC/HFC blends emerging	<5 677 ~350
Air Conditioners (Commercial)	HFC-134a HCFC-22 HCFC-123	1,300 1,760 79	HFC-1233zd HFC-1234ze HFC/HFC blends emerging HFC-1234yf	<1 <1 400-500 <1
Mobile Air Conditioners	HFC-134a	1,300	HFC-1234yf HFC-152a R-744 (CO_2)	<1 138 1
Foams	HFC-227ea HCFC-142b HFC-245fa HCFC-22 HFC-134a	3,220 1,9800 1,030 1,810 1,300	HCs CO_2/water HFC-1234ze Methyl formate HFC-1336mzz-Z	<5 1 <1 <25 2

HFC alternatives are further elaborated in Suely Carvalho, Stephen O. Andersen, Duncan Brack, & Nancy J. Sherman (2014) Alternatives to High-GWP Hydrofluorocarbons, IGSD WORKING PAPER. (November 2014).

Energy efficient alternatives are important in countries with high ambient air temperatures with long and often humid seasons, including in countries currently choosing replacements for HCFCs, which are being phased out under the Montreal Protocol.[93] LBNL highlighted that energy efficiency can have an even greater impact than refrigerant transition alone for some countries, particularly those in high-ambient temperature locations and countries with increasing demand for air conditioning.[94] A study for the European Commission shows that, in countries with high ambient air temperatures, almost 70% of sectors currently using HCFCs can leapfrog past high-GWP HFCs refrigerants directly to low-GWP alternatives with equal or better energy efficiency.[95] The same study notes that other low-GWP alternatives are in development and expected to be ready to replace the remaining uses by 2025.[96] Recent tests by the US Oak Ridge National Laboratory demonstrated that many low-GWP alternatives perform with similar cooling capacity and efficiency in high-ambient temperature conditions.[97] An agreement to phase down HFCs under the Montreal Protocol will accelerate development and deployment of additional climate-friendly alternatives.

7. Companies are taking action ahead of an amendment to phase down HFCs

Business support is growing for phasing down HFCs.[98] The *Consumer Goods Forum*, a global network of over 400 retailers, manufacturers, and service providers from over 70 countries, has pledged that its members will begin phasing out HFCs by 2015.[99] Other industry groups support reducing HFCs under the Montreal Protocol, including the Air-Conditioning, Heating and Refrigeration Institute,[100] the European Fluorocarbon Technical Committee,[101] and Refrigerants, Naturally![102] The Alliance for Responsible Atmospheric Policy, whose 48 members include Trane, Whirlpool, Sub-Zero, and Mitsubishi, also supports a global phasedown of high-GWP refrigerants.[103] On 15 October 2015, 16 U.S. and multinational companies made a variety of pledges to phase down and replace HFCs and to commercialize alternatives.[104]

Individual companies across the value chain are developing and implementing alternative refrigerants. DuPont endorses the HFC phasedown under the Montreal Protocol,[105] and DuPont and Honeywell, both manufacturers of HFCs, are actively developing lower GWP alternative refrigerants and have several currently being commercialized, [106] as discussed in Section 5 above. The Climate and Clean Air Coalition has produced a series of case studies demonstrating HFC alternatives developed and utilized by supermarket industry leaders, including Carrefour, H-E-B, and Supermercado.[107]

On the retailer and point-of-sale side, the companies in Refrigerants, Naturally!, including Coca-Cola, PepsiCo, Red Bull, and Unilever, are taking action to eliminate the use of HFCs within their respective companies.[108] Coca-Cola began using HFC-free insulation for new beverage vending equipment, which reduced direct HFC emissions by 75%, identified a feasible natural refrigerant, and pledged to eliminate HFCs in all new equipment by 2015.[109] PepsiCo, Red Bull, Unilever, and Carrefour started installing a substantial amount of natural refrigerant point-of-sale equipment.[110] Individual companies in the *Consumer Goods Forum*, including Wal-Mart, Nestlé, Sobeys, Supervalu, and Tesco are purchasing alternative refrigerant equipment, converting existing equipment, and improving efficiency while reducing leakage.[111] Whirlpool announced that it will convert all foam blowing agents in from the current HFC-245fa (AR5 $GWP_{100\text{-}yr} = 858$)[112] to HFC-123zd(E) ($GWP_{100\text{-}yr} = \sim 1$)[113] in the manufacture of refrigerators and freezers sold in North America, a reported reduction in GWP of 99.9%, by the end of 2014.[114] Table 3 summarizes several of these measures.

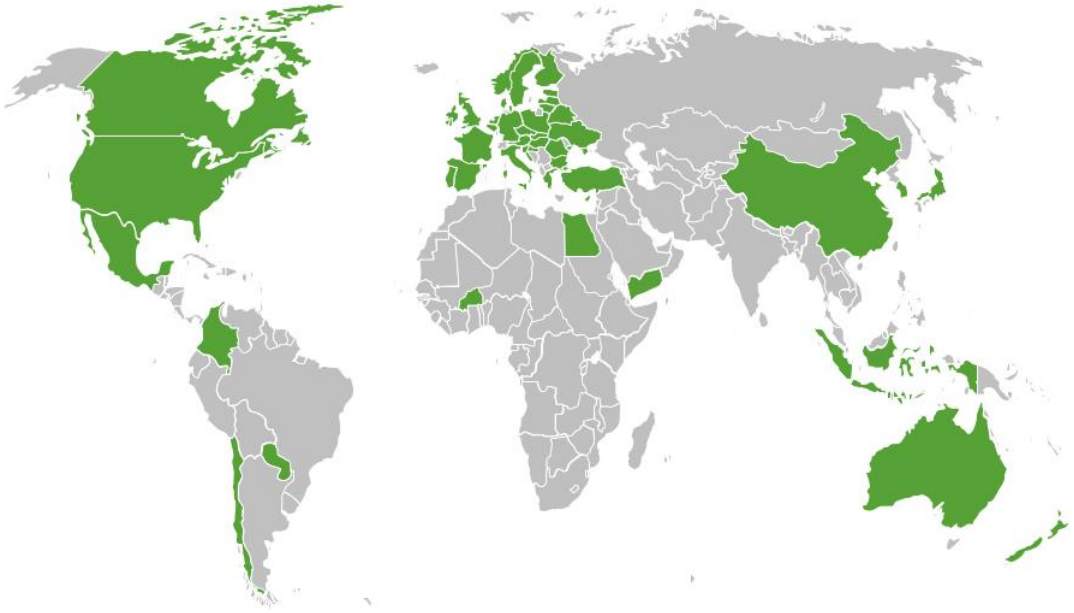
Table 3: Examples of corporate reductions of high-GWP HFCs

COMPANIES	ACHIEVEMENTS & GOALS
PepsiCo[115]	240,000 HFC-free units HFC-free equipment in 30 countries with 100% natural refrigerants in Turkey since 2009 and Russia since 2011
The Coca-Cola Company[116]	1,000,000 HFC-free units as of January 2014 100% HFC-free insulating foam for new refrigeration equipment 100% HFC-free new cold drink equipment purchases by 2015
Red Bull[117]	457,000 ECO-Coolers (more than 50% of all units) as of the end of 2013 Procurement 100% hydrocarbon since 2010
Unilever[118]	800,000 HFC-free freezers in 2012 Working with their subsidiary Ben & Jerry's to roll out hydrocarbon ice cream freezers in U.S.
McDonalds[119]	3,300 HFC-free meat freezers, frozen food storage, reach-ins & salad refrigerated display cases 2012. Investing in ammonia industrial refrigeration in U.S.
Nestlé[120]	11,000 hydrocarbon ice cream freezers in Europe, Australia, Spain, Malaysia, Chile, and the U.S. Nestlé uses natural refrigerants in 90% of its industrial food processing refrigeration
Heineken[121]	130,000 hydrocarbon refrigerated beverage displays Aiming for 50% reduction in carbon footprint of installed refrigerators by 2020
Sobeys[122]	"Natural Refrigerant Commitment" requires that CO_2 refrigeration systems are installed in all new full-service stores
Whirlpool[123]	HFC-1233zd(E) in all U.S. refrigerator and freezer manufacturing facilities by end of 2014 Equivalent to removing more than 400,000 cars from the road

8. A growing number of nations and regions are phasing down HFCs ahead of an amendment

Support to phase down HFCs is also growing at the national and regional levels. *See* Figure 7 and Table 4. China, the U.S., and the E.U., the top three global consumers of HFCs, have all announced new policies and regulations to control and reduce HFC emissions.[124] In May 2014, the State Council of China announced that they would strengthen their management of HFC emissions and accelerate the destruction and replacement of HFCs, as part of the action plan to implement the energy conservation and emission reduction targets of the 12th five-year plan.[125] China's action plan is expected to reduce HFC emissions by 0.28 Gt CO_2-eq by 2015.[126] The E.U. HFC regulations ("F-Gas Directive"), which received final approval on 14 April 2014 and went into effect on 1 January 2015, will phase down HFCs by 79%, from the baseline 2009-12 levels, by 2030.[127] In addition, as part of its regulatory regime to control HFCs, the European Directive on mobile air conditioning systems requires the use of refrigerants with GWPs less than 150; new type vehicles sold in the E.U. are covered as of 1 January 2013, and all vehicles sold in the E.U. will be covered by 2017.[128]

Fig. 7: Map of countries with existing HFC regulations (dark green)



The U.S. is addressing HFCs at national and state levels. In June 2013, President Obama announced domestic action on HFCs as part of his *Climate Action Plan*.[129] Both the U.S. House and Senate have introduced bills that would require the establishment of a U.S. task force to reduce HFCs and other super climate pollutants using existing authorities.[130] In July 2015, the U.S. EPA issued a final rule banning and otherwise restricting various high GWP HFCs in specific uses under the "Significant New Alternatives Policy Program" (SNAP) of the Clean Air Act.[131] In March 2015, the President issued Executive Order 13693, which requires federal agencies to reduce direct GHG emissions by 40% by 2025 including through purchasing sustainable products identified by SNAP.[132] In May 2015, the U.S. Department of Defense, NASA, and the General Services Administration proposed a rule that would direct the U.S. government to procure alternatives to high-GWP HFCs.[133] Finally, the U.S. currently provides manufacturers of cars and light trucks the opportunity to earn credits toward their compliance with CO_2 emission standards and corporate average fuel economy (CAFE) standards by employing HFC alternative refrigerants in mobile air conditioning systems for model year 2012-2016 vehicles.[134]

In 2009 California passed refrigerant regulations expected to reduce F-gas emissions by 25% 2020.[135] In 2014 California passed a law that requires the California Air Resources Board (CARB) to develop a comprehensive strategy to reduce emissions of HFCs and other SLCPs by 1 January 2016.[136] CARB released its draft *SLCP Reduction Strategy* for public comment September 2015, calling for more than 40% reduction in HFC emissions by 2030.[137] Beginning in 2018, HFCs will also be regulated according to a statewide cap-and-trade system.[138] California has also forged intrastate and international agreements concerning HFCs. In October 2013 California and India formed the India-California Air Pollution Mitigation Program (ICAMP)[139] that includes future HFC mitigation.[140]

The CCAC is also targeting HFCs as part of its global effort to scale-up action to reduce SLCPs.[141] Many CCAC state partners already have existing HFC policies, and six are developing national-level inventories of HFCs and identifying policies and measures to avoid the growth of high-GWP HFCs (Bangladesh, Chile, Colombia, Ghana, Indonesia, and Nigeria).[142]

Table 4: Select national and sub-national HFC regulations[143]

Country/Region	Taxes, Levies, Fees	Economic and Market-Based Incentives	Prohibition/Authorization	Required Practices	Voluntary Initiatives /Education Programs	Import/Export Licensing	Reporting/Recordkeeping Requirements	Prioritization of Climate-Friendly Alternatives
Africa								
Burkina Faso	X					X		
Egypt							X	
Europe and Central Asia								
Austria			X		X			
Belgium[144]					X			
Denmark	X		X					
Estonia							X	
France[145]	X*			X			X*	
Germany			X	X				
Italy				X			X	
Macedonia	X		X			X		
Montenegro	X		X	X		X	X	
Netherlands		X	X	X				
Norway	X	X						
Poland	X						X	
Serbia[146]			X	X		X		
Slovenia	X							
Spain[147]	X							
Sweden	X		X	X				
Switzerland			X	X			X	
Turkey[148]	X		X	X	X	X	X	
United Kingdom				X				
Latin America and the Caribbean								
Belize				X		X	X	
Chile[149]			X	X		X		
Colombia			X	X		X		
Paraguay[150]		X						
North America								
Canada			X	X		X	X	
United States	X	X	X	X	X		X	X
California		X		X	X		X	
Mexico					X			
Island Countries								
Australia	X	X	X	X		X	X	
New Zealand	X	X	X	X			X	
Seychelles[151]		X	X					
East Asia								
China[152]		X*		X				X
Indonesia[153]								X
Japan				X	X		X	
South Korea[154]		X						
West Asia								
Yemen				X			X	

* Proposed legislation.

9. The Montreal Protocol has the experience and expertise to phase down HFCs

At the international level, there is now a consensus that HFCs can be most effectively controlled through the phasedown of their *production and consumption* under the Montreal Protocol as a complement to controls on *emissions* under the Kyoto Protocol. The Montreal Protocol has the experience and expertise to ensure a fast, effective, and efficient phasedown of HFCs, which are in the same family of gases, have similar chemical properties, and are used in the same sectors as the CFCs already phased out and the HCFCs currently being phased out.[155] Because all CFCs and HCFCs are also greenhouse gases, between 1990 and 2010 the Montreal Protocol reduced CO_2-eq emissions nearly twenty times more than the 5 to 10 Gt CO_2-eq reduction goal of the first commitment period of the Kyoto Protocol. *See* Figure 4.[156] Sophisticated statistical analysis confirms that the successful phaseout of CFCs and related chemicals by the Montreal Protocol, along with reductions of methane, slowed climate change and contributed to a lower rate of global warming since the early 1990s.[157]

The Montreal Protocol has universal membership and provides robust implementation of the principle of "common but differentiated responsibilities."[158] This includes having developed country Parties undertake control measures first, followed by typical grace periods of 10 to 19 years before developing country Parties are subject to control measures, with funding for the agreed incremental cost of the developing country phaseout provided by the developed country Parties through the Multilateral Fund (MLF).[159] The MLF has played a key role in achieving cost-effective emissions reductions. Between 1990 and 2010, the phaseout of CFCs and other fluorinated gases cost US$2.4 billion and achieved an estimated 188–222 Gt CO_2e in emissions reductions, equivalent to less than US$0.01 per tonne of CO_2 reduced.[160] Since it was established in 1991, the MLF has provided more than U.S. $3 billion in funding.[161] At the 26th Meeting of the Parties of the Montreal Protocol, in 2014, the Parties agreed to a MLF replenishment of just over US$500 million for 2015–2017.[162]

The Montreal Protocol has an in-depth understanding of all sectors it finances, including detailed knowledge of technical options.[163] The Montreal Protocol also supports institutional strengthening for all 147 developing country Parties.[164] The combination of these features has allowed all Parties to comply with the control measures; to date, the Parties have phased out 98% of nearly 100 damaging chemicals.[165]

The orderly and transparent schedule for phasing out chemicals under the Montreal Protocol allows time for markets to innovate and adjust, often resulting in significant cost and technical efficiencies.[166] The Montreal Protocol also provides "essential use" and "critical use" exemptions that allow continued use of a chemical when environmentally acceptable alternatives are not yet available.[167]

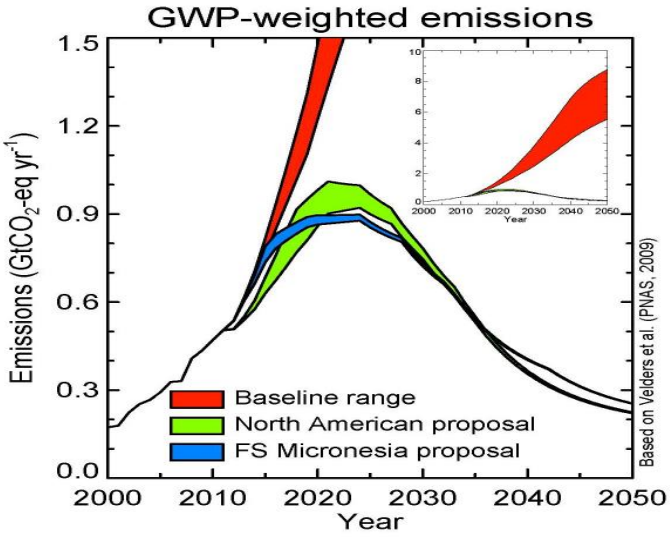
In sum, the Montreal Protocol can provide fast, effective, and efficient reductions of upstream production and consumption of HFCs, while downstream emissions would remain with the Kyoto Protocol, as would measurement and reporting.[168]

10. 95 Parties have submitted proposals to amend the Montreal Protocol to phase down HFCs

Recognizing the opportunity presented for fast and effective phasing down of HFCs through the Montreal Protocol, starting in 2009 the Federated States of Micronesia proposed an amendment to phase down high-GWP HFCs, with the U.S., Canada, and Mexico following with a similar amendment. Both proposals would reduce 85-90% of HFC production and consumption and provide climate mitigation equivalent to more than 100 Gt CO_2 emissions by 2050.[169] By one calculation, the total incremental cost through 2050 would be € 5–11 billion, less than € 1 per CO_2e tonne, or "ten [MLF] replenishing periods with funding in the range of [€] 500 to 1000 million from freeze to 2050."[170] Preliminary analysis by the TEAP calculates that converting manufacturing in A/C and refrigeration sectors to low GWP-HFCs by 2020 could cost $2.4 (± 0.34) billion, and "results in a reduction in climate terms of about 50% over the period 2020-2030 and a reduction in climate terms of 80% in 2030 compared to BAU." [171]

The E.U. expressed full support for an HFC amendment, [172] and suggested combining a phasedown of HFCs in developing countries with the existing phaseout of HCFCs.[173] In April 2015, the North American group submitted their newest proposal, dated 8 March 2015.[174] On 17 April 2015, India submitted its own proposal to phase down high-GWP HFCs under the Montreal Protocol, reversing several years of opposition.[175] On 20 April 2015, the 54 members of the Africa Group submitted an informal proposal in the form of a Conference Room Paper.[176] On 30 April 2015, the E.U. submitted a proposal on behalf of its 28 member States.[177] At the same time, the Federated States of Micronesia, the first country to submit a proposal in 2009, submitted a revised proposal along with seven other Pacific Island States as co-sponsors—Kiribati, Marshall Islands, Mauritius, Palau, the Philippines, Samoa, and Solomon Islands.[178].

Fig. 8: Projected emission reductions from HFC amendment proposals



The proposed amendments to the Montreal Protocol are have the potential to decrease the projected annual HFC emissions of 5.5 to 8.8 Gt CO_2-eq/yr in 2050 to less than ~0.3 Gt CO_2-eq/yr. The above graphic, based on Velders *et al.* (2009) is indicative of the emissions reductions expected from a phasedown of high-GWP HFCs under the Montreal Protocol. Prepared by Dr. Guus Velders, based on Velders, G. J. M. *et al.* (2009) *The large contribution of projected HFC emissions to future climate forcing*, PROC. NAT'L. ACAD. SCI. U.S.A. 106:10949-10954.[179]

Total mitigation could be the equivalent of up to 200 Gt CO_2 if an HFC phaseout were completed by 2020. *See* Section 3, above. An HFC amendment would substantially eliminate the global warming caused by one of the six main Kyoto Protocol greenhouse gases and significantly improve the chances of staying below the 2°C guardrail, providing up to 6-10% of the needed mitigation. *See* Figure 5.

11. Consensus exists to amend the Montreal Protocol in 2016 to phase down HFCs

At the 27th Meeting of the Parties in November 2015 the Parties agreed to "work within the Montreal Protocol to an HFC amendment in 2016."[180] Immediately prior to the MOP, the OEWG decided to form a contact group that will sort out issues relating to the feasibility of phasing out HFCs and ways to manage HFCs.[181] Negotiations in the contact group produced an agreement to work to the HFC amendment in 2016 with meetings held throughout 2016, including an extraordinary MOP.[182] The following outlines support for addressing high-GWP HFCs under the Montreal Protocol since the proposed HFC amendment was first submitted in 2009:

2009

10 July 2009 in L'Aquila, Italy, the leaders of the G8 recognized "that the accelerated phase-out of HCFCs mandated under the Montreal Protocol is leading to a rapid increase in the use of HFCs, many of which are very potent GHGs," and committed to "work with our partners to ensure that HFC emissions reductions are achieved under the appropriate framework."[183]

November 2009, 39 countries signed the *Declaration on High-GWP alternatives to ODSs* [Ozone Depleting Substances] encouraging the Parties to the Montreal Protocol to "urgently consider phasing-down the production and consumption of high-GWP alternatives," including HFCs, and "take appropriate measures … as soon as practicable."[184]

2010

By the end of 2010, 108 Parties to the Montreal Protocol signed the *Bangkok Declaration,* calling for the use of low-GWP alternatives to CFCs and HCFCs.[185]

2012

17 February 2012, the United States, Mexico, Canada, Ghana, and Bangladesh, along with the UN Environment Programme launched the CCAC to catalyze major reductions in SLCPs with an initial focus on black carbon,

methane, and HFCs.[186]

19 May 2012, the leaders of the G8 in Camp David, U.S., agreed to join the CCAC and develop 'strategies to reduce short term pollutants – chiefly methane, black carbon, and hydrofluorocarbons.'[187]

22 June 2012, at the conclusion of the Rio + 20 *UN Conference on Sustainable Development*, more than one hundred heads of State adopted the conference declaration, *The Future We Want*, recognizing the climate threat from HFCs and calling for the gradual phasedown of their production and consumption; the UN General Assembly adopted the declaration by resolution on 11 September 2012.[188]

2013

19 April 2013, China agreed to completely phase out HCFCs over the next 17 years, which is expected to cut the equivalent of 8 Gt of CO_2 at a total cost of $385 million, or about $0.05 per tonne.[189] The Montreal Protocol's HCFC phaseout will eliminate HCFC production from emissive uses in developed country Parties by 2030 and in developing country Parties by 2040, and this agreement will give China the opportunity to choose low-GWP alternatives in lieu of HFCs to ensure that the climate benefits are realized.[190]

Through May 2013, 112 Parties joined the even stronger *Bali Declaration on Transitioning to Low Global Warming Potential Alternatives to Ozone Depleting Substances*.[191]

15 May 2013, the Arctic Council countries, including the Russian Federation, issued the *Kiruna Declaration* in which they "Urge the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer to take action as soon as possible, complementary to the UNFCCC, to phase-down the production and consumption of hydrofluorocarbons, which contribute to the warming of the Arctic region…."[192]

8 June 2013, China's President Xi Jinping and U.S. President Barack Obama agreed to "work together and with other countries to use the expertise and institutions of the Montreal Protocol to phase down the consumption and production of hydrofluorocarbons (HFCs)."[193]

25 June 2013, President Obama announced his *Climate Action Plan*, which includes phasing down HFCs under the Montreal Protocol, as well as taking action in the U.S. to control HFCs.[194]

26 June 2013, at the mid-year Open-Ended Working Group meeting of the Montreal Protocol in Bangkok, the Parties established a formal Discussion Group to discuss the management of HFCs under the Protocol.[195]

28 June 2013 the BASIC countries (Brazil, South Africa, India, and China) noted in their *Joint Statement* that they would "work multilaterally to find an agreed way" to address HFCs:

> "*Ministers emphasized that HFCs are greenhouse gases covered under the UNFCCC and its Kyoto Protocol and shall accordingly be addressed in accordance with its principles and provisions. They agreed to work multilaterally to find an agreed way forward on this issue.*" [196]

10 July 2013, the *U.S.-China Climate Change Working Group* agreed to work together to "implement the agreement on hydrofluorocarbons (HFCs) reached by President Obama and President Xi at their meeting on June 8, 2013, in Sunnylands, California."[197]

12 July 2013, fourteen Pacific small island developing states (SIDS) called for action under the Montreal Protocol to phase down HFCs. In the *Nadi Outcome Document* of the Pacific SIDS Regional Preparatory Meeting for the Third International Conference on Small Island Developing States, these fourteen nations "agreed that the Montreal Protocol be utilized to undertake the gradual phasedown of production and consumption of HFCs called for in the Rio + 20 outcome document, *The Future We Want."*[198]

3 September 2013, the 33 State partners of the CCAC and the European Commission agreed to "work toward a phasedown in the production and consumption of HFCs under the Montreal Protocol." The Coalition's State partners also agreed to "adopt domestic approaches to encourage climate-friendly HFC alternative technologies," and to "work with international standards organizations to revise their standards to include climate-friendly HFC alternatives."[199]

6 September 2013, on the margins of the G20 Summit in St. Petersburg, Chinese President Xi Jinping and U.S. President Barack Obama agreed to open formal negotiations on the amendment to phase down HFCs under the Montreal Protocol:

> "*We reaffirm our announcement on June 8, 2013 that the United States and China agreed to work together and with other countries through multilateral approaches that include using the expertise and institutions of the Montreal Protocol to phase down the production and consumption of HFCs, while continuing to include HFCs within the scope of UNFCCC and its Kyoto Protocol provisions for accounting and reporting of*

emissions. We emphasize the importance of the Montreal Protocol, including as a next step through the establishment of an open-ended contact group to consider all relevant issues, including financial and technology support to Article 5 developing countries, cost effectiveness, safety of substitutes, environmental benefits, and an amendment. We reiterate our firm commitment to work together and with other countries to agree on a multilateral solution."[200]

6 September 2013, the leaders of the world's twenty largest economies, as well as heads of State from six invited observer States, expressed their support in the St. Petersburg *G20 Leaders' Declaration* for initiatives that are complementary to efforts under the UNFCCC, including using the expertise and institutions of the Montreal Protocol to phase down the production and consumption of HFCs, while retaining HFCs within the scope of the UNFCCC and its Kyoto Protocol for accounting and reporting of emissions:

"*We are committed to support the full implementation of the agreed outcomes under the United Nations Framework Convention on Climate Change (UNFCCC) and its ongoing negotiations…. We also support complementary initiatives, through multilateral approaches that include using the expertise and the institutions of the Montreal Protocol to phase down the production and consumption of hydrofluorocarbons (HFCs), based on the examination of economically viable and technically feasible alternatives. We will continue to include HFCs within the scope of UNFCCC and its Kyoto Protocol for accounting and reporting of emissions.*"[201]

16 September 2013, Ministers representing BASIC countries agreed that HFCs should be dealt with through relevant multilateral fora guided by the principles and provisions of the UNFCCC:

"*Ministers agreed that hydrofluorocarbons (HFC) should be dealt with through relevant multilateral fora, guided by the principles and provisions of UNFCCC and its Kyoto Protocol. The availability of safe and technically and economically viable alternatives and the provision of additional financial resources by developed countries should also be taken into account*."[202]

27 September 2013, Indian Prime Minister Manmohan Singh and U.S. President Barack Obama agreed to immediately convene discussions of phasing down HFCs under the Montreal Protocol, leaving accounting and reporting of emissions in the UNFCCC:

"*The two leaders agreed to immediately convene the India-U.S. Task Force on hydrofluorocarbons (HFCs) to discuss, inter alia, multilateral approaches that include using the expertise and the institutions of the Montreal Protocol to phase down the consumption and production of HFCs, based on economically-viable and technically feasible alternatives, and include HFCs within the scope of the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol for accounting and reporting of emissions…..*"[203]

The U.S.-India climate cooperation also will include a focus on improving the efficiency of air conditioning in India, which has the potential to avoid as many as 120 large power plants by 2030:

"*Space Cooling Efficiency Collaboration: Demand for space cooling – primarily for air conditioners – constitutes a large portion of peak electricity demand in India. Air conditioners could add as much as 140 GW to peak load by 2030 and management of the peak contribution is critical for maintaining supply security and avoiding load shedding. The new U.S.-India Collaboration on Smart and Efficient Air Conditioning and Space Cooling is intended to advance policies and innovation to drive mass deployment and rapid uptake of high-efficiency cooling equipment and technologies to capture significant energy savings, potentially avoiding the need to build as many as 120 large power plants.*" [204]

See Section 4 for a further discussion of benefits of super-efficient room air conditioning.

21 to 25 October 2013, at the 25th Meeting of the Parties to the Montreal Protocol, in Bangkok, countries continued to make progress on an international agreement to phase down HFCs under the Montreal Protocol. Significantly, the Africa Group, including South Africa, announced its support for "formal negotiations to enable the amendment process." Jordan also demonstrated support for discussion of the amendment proposals, calling them "logical and well understood." Delegates reconvened the formal Discussion Group on HFC Management, this time with a broader mandate that included consideration of the high-level agreements to phase down HFCs made in preceding months. The formal Group met several times and proposed several ways forward for action on HFCs, including holding extra working meetings in 2014 to consider the amendment proposals. Brazil and China continued to engage constructively as well, and both played an important role in writing a detailed request to the Protocol's Technology and Economic Assessment Panel (TEAP) to conduct additional research on HFCs and their alternatives.[205] India, along with several other countries, expressed concern over whether technology was available and whether developed countries would be willing to pay for the transition in developing countries as

required by the Montreal Protocol. These and other concerns will be addressed in 2014 as the Amendment negotiations move forward.

19 November 2013, at the 21st E.U.-Japan summit in Tokyo, the E.U. and Japan emphasized the importance of the HFC phasedown under the Montreal Protocol:

> "*[T]hey underlined the contribution of international cooperative initiatives to the additional mitigation effort to narrow the existing gap between emission reduction pledges and what is needed according to science. In particular, they stressed the need for rapid progress on the phasedown of HFCs and for its close consideration as one of the issues to be addressed in the context of the Montreal Protocol.*"[206]

5 December 2013, U.S. and China reaffirmed the agreements on HFCs by Presidents Obama and President Xi Jinping from June 8, 2013 and September 6, 2013:

> "*Today, both countries reaffirmed the agreements reached by leaders regarding phasing down the production and consumption of the highly potent greenhouse gas hydrofluorocarbons (HFCs) using the expertise and institutions of the Montreal Protocol and to take next steps in the process, including the establishment of an open-ended contact group in the Montreal Protocol.*"[207]

2014

11 February 2014, following President Hollande's State visit with President Obama, the White House emphasized that "France is also an important partner in the global effort to phase down production and consumption hydrofluorocarbons (HFCs) using the institutions and expertise of the Montreal Protocol."[208]

19 February 2014, the North American Leaders agreed in their *Joint Statement* to "intensify our efforts to promote an amendment to the Montreal Protocol to phase down production and consumption of climate-damaging hydrofluorocarbons (HFCs)."[209]

March 2014, U.S. Secretary of State John Kerry instructed Chiefs of Mission and all other State Department staff to make climate change a priority across all platforms, domestically and internationally, including efforts to enhance the Montreal Protocol, the Major Economies Forum, Clean Energy Ministerial, and the CCAC, as well as efforts to conclude a new climate agreement applicable to all countries by 2015 to take effect in 2020.[210]

26 March 2014, the leaders of the E.U. and the U.S. issued a *Joint Statement* affirming their commitment to phasing down HFCs through the Montreal Protocol, and their commitment "to ambitious domestic action to limit HFC use and emissions."[211]

31 March 2014, the leaders of the E.U. and China issued a *Joint Statement* announcing that they "will cooperate on taking domestic action to avoid or reduce the consumption of HFCs and to work together to promote a global phase down of these substances."[212]

5 June 2014, the leaders of the G7 countries reaffirmed their commitment to phase down high-GWP HFCs under the Montreal Protocol:

> "*We will work together and with others to phase down the production and consumption of hydrofluorocarbons (HFC) under the Montreal Protocol. We will also continue to take action to promote the rapid deployment of climate-friendly and safe alternatives in motor vehicle air-conditioning and we will promote public procurement of climate-friendly HFC alternatives.*"[213]

10 July 2014, U.S. and China reaffirmed their commitment to phase down the production and consumption of HFCs.[214]

14 to 18 July, at the 34th meeting of the Open-ended Working Group (OEWG 34) of the Parties to the Montreal Protocol, the majority of countries expressed support for starting a formal contact group to negotiate the terms for the HFC phasedown. Some parties continued their opposition, including several Gulf States, so parties launched a discussion group to address issues raised by the reluctant parties.[215] The same issues were addressed during a two-day HFC management seminar organized by the Montreal Protocol Secretariat on 11-12 July 2014; the seminar was attended by more than 400 country delegates, scientific, technical, and legal experts, and industry and environmental observers.[216]

16 and 17 July, at the Working Group meeting of the CCAC in Paris, France, the CCAC announced its plan to launch "a campaign with key countries and leading industries to reduce hydrofluorocarbons" at the UN Secretary-General's Climate Summit in New York in September.[217]

23 September 2014, on the occasion of the UN Secretary-General's Climate Summit, 33 state partners of the CCAC issued a Joint Statement supporting the phase down of the production and consumption of HFCs under the

Montreal Protocol.[218] The state partners were joined by numerous organizations and companies including: the California Air Resources Board, the World Meteorological Organization, the Coca-Cola Company, Danfross, and the member companies of Refrigerants Naturally!.[219]

30 September 2014, India's Prime Minister Narendra Modi and U.S. President Barack Obama agreed on the need to take urgent action to reduce consumption and productions of HFCs under the Montreal Protocol.[220]

17 to 21 November 2014, at the 26th Meeting of the Parties to the Montreal Protocol, in Paris, countries continued to make progress in their negotiations to phase down production and consumption of HFCs. In particular, China and India indicated their willingness to consider how to move forward to discuss the HFC phasedown. In addition to the regular Open-Ended Working Group meeting 13-17 July 2015, the Parties agreed to hold an extra-ordinary three-day OEWG on 22-24 April, with a back-to-back two-day workshop on HFC management issues, with emphasis on the challenges of high ambient countries and on energy efficiency.[221] The Parties also agreed to replenish the Multilateral Fund with $507.5 million over the next three years.[222]

2015

25 January 2015, India's Prime Minister Narendra Modi and U.S. President Barack Obama agreed to make "concrete progress this year" to cut HFCs under the Montreal Protocol.[223]

6 March 2015, at the conclusion of the 15th Session of the African Ministerial Conference on the Environment in Cairo, Ministers and delegates from 54 countries of Africa urged all member States to use the Montreal Protocol to phase down the production and use of HFCs, and requested all to work towards a "contact group" to begin formal negotiations this year.[224]

In April 2015, Canada, Mexico and U.S. submitted their newest proposal to phase down HFCs under the Montreal Protocol.[225] The proposal would reduce cumulative HFC emissions between 2019 and 2050 by between 90 and 111.5 Gt CO_2, "which is equal to roughly two years of emissions of all anthropogenic greenhouse gases at current emission levels."[226]

17 April 2015, India submitted a proposal to phase down high-GWP HFCs under the Montreal Protocol.[227] The proposal calls for the continued "use of HFCs and blends of HFCs as transitional substances for phase-out of HCFCs wherever low-GWP/zero-GWP alternatives are not available," and a 15-year grace period before developing countries begin phasing down HFCs.[228]

20 April 2015, Senegal and Zimbabwe, on behalf of the 54 members of the Africa Group, submitted an informal proposal in the form of a Conference Room Paper requesting the establishment of a contact group at the 36th Open-ended Working Group meeting (OEWG 36) in July to "consider proposals to amend the Montreal Protocol, including those that have been submitted for consideration by the Meeting of the Parties."[229]

24 April 2015, at the conclusion of the 35th meeting of the Open-ended Working Group (OEWG) of the Montreal Protocol, the Parties agreed to hold additional inter-sessional meetings, "with a view to the establishment of a contact group" at the regularly scheduled OEWG in Paris in July.[230] A two-day seminar on HFC management was presented by the Montreal Protocol Secretariat on 20-21 April 2015.[231]

30 April 2015, the E.U. submitted a proposal on behalf of its 28 member States.[232]

30 April 2015, the Federated States of Micronesia, the first country to submit a proposal in 2009, submitted a revised proposal, along with seven other Pacific Island States as co-sponsors—Kiribati, Marshall Islands, Mauritius, Palau, Philippines, Samoa, and Solomon Islands.[233]

8 June 2015, the leaders of the G7 countries pledged to "continue our efforts to phase down hydrofluorocarbons (HFCs) and call on all Parties to the Montreal Protocol to negotiate an amendment this year [2015] to phase down HFCs and on donors to assist developing countries in its implementation."[234]

12 to 13 June 2015, a group of invited parties participated in an informal inter-sessional consultation in Vienna, Austria on the feasibility and ways of managing HFCs, where they discussed issues identified at OEWG 35 in April. The outcome was a bracketed text that identified potential terms of reference for a formal contract group at the OEWG 36 on 20-24 July.[235]

29 June 2015, E.U. and China agreed to "work together with other countries to agree on a multilateral solution to phase down the production and consumption of HFCs,"[236] in addition to strengthening collaboration on domestic HFC policies and measures.

30 June 2015, Brazil President Dilma Rousseff and U.S. President Barack Obama "agreed to work multilaterally in the Montreal Protocol to consider promptly amendment proposals to phase down HFCs."[237]

21 July 2015, the Parties suspended the 36th meeting of the Open-ended Working Group (OEWG), rather than adjourning, to allow additional time to complete the terms of reference for a "contact group" that will then negotiate the details of the HFC amendment.[238] The suspended OEWG will resume 29-30 October in the United Arab Emirates, which will host the MOP 1 to 5 November.

22 October 2015, Pakistani Prime Minister and U.S. President Barack Obama "affirmed that their respective countries intend to work together to amend the Montreal Protocol this year to curb the production and consumption of hydrofluorocarbons."[239]

29 to 30 October 2015, at the resumed OEWG 36, the Parties formed a contact group to analyze "*feasibility and ways of managing HFCs including development of a common understanding on issues related to flexibility of implementation, 2nd and 3rd stage conversions, guidance to the ExCom, enabling activities for capacity building, and the need for an exemption for high ambient temperature countries*."[240]

6 November 2015, at the 27th MOP, the Parties agreed on the *Dubai Pathway on Hydrofluorocarbons* to "*work within the Montreal Protocol to an HFC amendment in 2016 by first resolving challenges by generating solutions in the contact group on the feasibility and ways of managing HFCs at Montreal Protocol meetings.*"[241] The details of the amendment will be negotiated during a series of meetings in 2016, including an extraordinary OEWG and an extraordinary MOP.[242] *See* text of the agreement in Appendix I.

11. Conclusion

Global HFC production and use is rising dramatically, and the associated HFC emissions could add up to 0.5°C of additional warming by the end of the century. Markets are already responding to the signals from the scientists, customers, and from the policy community, including signals from the growing list of laws at the national and regional levels, which often include trade measures. Companies that produce climate-safe alternatives to HFCs are increasing their investment in alternatives and speeding their commercialization, and companies that are phasing out HCFCs are selecting climate-friendly alternatives rather than shifting into high-GWP HFCs. Just as the national bans, boycotts, and voluntary phaseouts of CFCs in the late 1970s and early 1980s paved the way for controls under the Montreal Protocol, similar actions occurring today are paving the way for the HFC amendment and creating the conditions for fast implementation. The agreement to finalize negotiations on an HFC amendment in 2016 will provide fast mitigation. It also provides momentum for the Paris UN climate treaty negotiations in December 2015.

List of acronyms and abbreviations

A5 Parties	developing countries qualified for grace periods and MLF financing under the Montreal Protocol
AR5	Fifth Assessment Report of the IPCC
BASIC	Brazil, South Africa, India, and China
BAU	business-as-usual
BC	black carbon
CAFE	corporate average fuel economy
CCAC	Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants
CFC	chlorofluorocarbon
CGF	Consumer Goods Forum
CH_4	methane
CO_2	carbon dioxide
CO_2-eq	carbon dioxide equivalent
E.U.	European Union
G7	Canada, France, Germany, Italy, Japan, United Kingdom, and United States
Gt	gigatonne (billion tonnes)
GWP	global warming potential
HCFC	hydrochlorofluorocarbon
HFC	hydrofluorocarbon
HFO	hydrofluoroolefin
IGSD	Institute for Governance & Sustainable Development
IISD	International Institute for Sustainable Development
IPCC	Intergovernmental Panel on Climate Change
LCCP	life-cycle climate performance
MEA	multilateral environment agreement
MLF	multilateral fund
NGO	nongovernmental organization
Non-A5 Parties	developed country Parties to the Montreal Protocol
ODS	ozone-depleting substance
PFC	perfluorocarbon
SF_6	sulfur hexafluoride
SEAD	Super-efficient Equipment and Appliance Deployment Initiative
SIDS	small island developing states
SLCPs	short-lived climate pollutants
SNAP	Significant New Alternatives Policy Program at U.S. EPA
TEAP	Technology and Economic Assessment Panel (of the UNEP Montreal Protocol)
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
U.S.	United States
U.S. EPA	United States Environmental Protection Agency
U.S. DOE	United States Department of Energy

Appendix I

The Dubai Pathway on Hydrofluorocarbons

(*Advance unedited version*)

Recognizing the [Montreal Protocols] history of success in achieving collaborative and consensus based outcomes and that HFCs are replacements for the ODS that Parties to the MP are already successfully phasing out,

1. Work within the Montreal Protocol to an HFC amendment in 2016 by first resolving challenges by generating solutions in the contact group on the feasibility and ways of managing HFCs at Montreal Protocol meetings;

2. Recognize the progress made at the 27th MOP on the challenges identified in the contact group mandate agreed at the resumed 36th OEWG (contained at Annex 1) on feasibility and ways of managing HFCs, including development of a common understanding on issues related to flexibility of implementation, 2nd and 3rd stage conversions, guidance to the ExCom, enabling activities for capacity building, and the need for an exemption for high ambient temperature countries; and endorse the concepts in Annex 2;

3. Recognize that further progress still needs to be made in particular with respect to other challenges identified in the contact group mandate, for example conversion costs, technology transfer and intellectual property rights;

4. Hold a series of OEWG and other meetings, including an Extraordinary Meeting of Parties in 2016;

5. Continue consideration at the meetings mentioned in paragraph 4 above of agenda items 6 and 7, contained in Document UNEP/Ozl.Pro. 27/1, including the submissions contained in UNEP/OzL.Pro.27/5, 27/6, 27/7 and 27/8);

Annex 1 to decision XXVII/1

Mandate for a possible contact group on the feasibility and ways of managing HFCs

The Open-ended Working Group of the Parties to the Montreal Protocol at its thirty-fifth meeting held in Bangkok from 22 to 24 April 2015, agreed that "it would continue to work inter-sessionally in an informal manner to study the feasibility and ways of managing HFCs, including, inter alia, the related challenges set out in annex II to the [report of the thirty-fifth meeting of the Open-ended Working Group], with a view to the establishment of a contact group on the feasibility and ways of managing HFCs at the thirty-sixth meeting of the Open-ended Working Group" (paragraph 128, UNEP/OzL.Pro.WG.1/35/6).

The informal meeting was convened on the 12-13 of June in Vienna on the above mentioned basis.

The parties have recognised in their interventions the success of the Montreal Protocol and its institutions in phasing out ODSs.

The management of HFCs is applicable to both A5 and non-A5 parties.

Parties agree that nothing should be considered agreed until everything is agreed.

Parties agree that they shall first resolve the challenges mentioned below by generating solutions in a contact group.

- Relevance and recognition of the special situation of developing countries and the principles under the Montreal Protocol which have enabled sufficient additional time in the implementation of commitments by A5 countries,
- Maintain the MLF as the financial mechanism, and to agree that additional financial resources will be provided by non-A5 parties to offset costs arising out of HFC management for A5 parties if obligations are agreed to. In this regard, key elements for financial support from the MLF for A5 parties will be developed by the contact group to provide guidance to the ExCom of the MLF, taking into account the concerns of parties,
- The elements in paragraph 1(a) of decision XXVI/9 including IPR issues in considering the feasibility and the ways of managing HFCs,
- Flexibility in implementation that enables countries to set their own strategies and set their own priorities in sectors and technologies,
- Exemption process and a mechanism for periodic review of alternatives including the consideration of availability or lack of availability of alternatives in all sectors in A5 countries and special needs for high ambient countries, based on all the elements listed in paragraph 1(a) of decision XXVI/9,
- Relationship with the HCFC phase out,
- Non-party trade provisions, and
- Legal aspects, synergies and other issues related to the UNFCCC in the context of HFC management under the MP,

Then, the parties will discuss in the contact group the ways of managing HFCs including the amendment proposals submitted by the parties.

Annex II of the report of the 35th OEWG meeting

- Challenges to be addressed
- Energy efficiency
- Funding requirements
- Safety of substitutes
- Availability of technologies
- Performance and challenges in high ambient temperatures
- Second and third conversions
- Capacity-building
- Non-party trade provisions
- Synergies with the United Nations Framework Convention on Climate Change (legal, financial aspects)
- Relationship with the HCFC phase-out
- Ecological effects (effects on fauna and flora)
- Implications for human health
- Social implications
- National policy implications
- Challenges to the production sector
- Rates of penetration of new alternatives
- Exemptions and ways to address lack of alternatives
- Technology transfer
- Flexibility in implementation

Appendix II

Background on IGSD's fast-action campaign to reduce HFCs and other short-lived climate pollutants

Phasing down HFCs under the Montreal Protocol is the central focus of IGSD's fast-action climate mitigation campaign, which promotes using existing laws and institutions to achieve immediate climate mitigation and complement efforts under the UNFCCC. IGSD's strategy was presented in a 2009 article written by Nobel Laureate Mario Molina, Durwood Zaelke, Veerabhadran Ramanathan, Stephen O. Andersen, & Donald Kaniaru, *Reducing abrupt climate change risk using the Montreal Protocol and other regulatory actions to complement cuts in CO_2 emissions*. The paper was written for the *Proceedings of the National Academy of Sciences* of the U.S.A. as the policy piece in a *PNAS Special Feature* on climate tipping points edited by John Schellnhuber.

The article defines fast-action strategies as those that can be started in two to three years, substantially implemented in five years in developed countries and ten years in developing countries, and can produce a response in the climate system on a timescale of decades, to complement cuts in CO_2, which operate on a longer timescale. Broad implementation of these strategies can cut the rate of global warming in half and the rate of Arctic warming by two-thirds over the next several decades.

The HFC component of this approach was updated in a November 2012 policy paper, *Strengthening Ambition for Climate Mitigation: The Role of the Montreal Protocol in Reducing Short-lived Climate Pollutants*, by Durwood Zaelke, Stephen O. Andersen, & Nathan Borgford-Parnell in RECIEL, and the science component presented in a June 2013 science paper, *The role of HFCs in mitigating 21st century climate change*, by Yangyang Xu, Durwood Zaelke, Guus J. M. Velders, and Veerabhadran Ramanathan (26 June 2013). The paper calculates that mitigating SLCPs can avoid 1.5°C of warming by end-of-century, comparable to the 1.1°C of warming that can be avoided by aggressive CO_2 mitigation by end-of-century. The paper calculates that by 2050 SLCP mitigation can avoid six times more warming than aggressive CO_2 mitigation (0.6°C from SLCP mitigation, compared to 0.1°C from CO_2 mitigation). Up to one-third of the total of 1.5°C in avoided warming from SLCP mitigation, or 0.5°C, will come from cutting HFCs.

Related research led by Ramanathan published April 2013 in NATURE CLIMATE CHANGE calculates that cutting SLCPs can reduce the rate of sea-level rise quickly by about 25%, and when coupled with aggressive CO_2 mitigation, can double this. Individual contributions to avoided sea-level rise by 2100 from different mitigation actions are: 29% from CO_2 measures and 71% from SLCP measures (13% from HFC measures, 17% from black carbon measures, and 41% from methane measures). Aixue Hu, Yangyang Xu, Claudia Tebaldi, Warren M. Washington & Veerabhadran Ramanathan (2013) *Mitigation of short-lived climate pollutants slows sea-level rise*, NATURE CLIMATE CHANGE 3:730-734.

IGSD promotes the importance of reducing HFCs and other SLCP through scientific and policy publications, several of which are listed below. IGSD also promotes the importance of SLCP mitigation in various policy venues, as well as through the media. Op-Eds by IGSD, and others, are listed below, along with a list of Editorials in *Nature*, *The Economist*, *The New York Times*, *The Washington Post*, and *Bloomberg*.

IGSD-Authored Publications on HFCs and the Montreal Protocol

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2. Nathan Borgford-Parnell, Maxime Beaugrand, Durwood Zaelke, & Stephen O. Andersen (October 2015) *Phasing down the use of hydrofluorocarbons (HFCs)*, *in* SEIZING THE GLOBAL OPPORTUNITY, a report from the New Climate Economy.
3. Stephen O. Andersen (2015) *Lessons from the stratospheric ozone layer protection for climate*, J. ENVIRON. STUD. SCI.
4. Durwood Zaelke & Nathan Borgford-Parnell (2015) *The importance of phasing down hydrofluorocarbons and other short-lived climate pollutants*, J. ENVIRON. STUD. SCI.
5. Stephen O. Andersen & Nancy J. Sherman (2015) *The importance of finding the path forward to climate-safe refrigeration and air conditioning: thinking outside the box and without limits*, J. ENVIRON. STUD. SCI.
6. Marco Gonzalez, Kristen N. Taddonio, & Nancy J. Sherman (2015) *The Montreal Protocol: how today's successes offer a pathway to the future*, J. ENVIRON. STUD. SCI.

7. Suely Carvalho, Stephen O. Andersen, Duncan Brack, & Nancy J. Sherman (2014) Alternatives to High-GWP Hydrofluorocarbons, IGSD WORKING PAPER.

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11. Romina Picolotti (2013) *Fast and refreshing*, UNEP OUR PLANET: THE FUTURE IS PRICELESS.

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16. Durwood Zaelke, Stephen O. Andersen, & Nathan Borgford-Parnell (2012) *Strengthening Ambition for Climate Mitigation: The Role of the Montreal Protocol in Reducing Short-Lived Climate Pollutants*, REVIEW OF EUROPEAN COMPLIANCE & INTERNATIONAL ENVIRONMENTAL LAW 21(3):231-242.

17. Mario Molina & Durwood Zaelke (2012) *A Climate Success Story to Build On*, UNEP OZONACTION, PROTECTING OUR ATMOSPHERE FOR GENERATIONS TO COME: 25 YEARS OF THE MONTREAL PROTOCOL.

18. Mario Molina, A. R. Ravishankara, & Durwood Zaelke (2011) *At the crossroads*, UNEP OUR PLANET: POWERING CLIMATE SOLUTIONS.

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2. *The Economist*, Editorial, "Low-hanging dirt" (3 Oct 2015)
3. *Washington Post,* Editorial, "Can Brazil follow through on its ambitious climate goals?" (3 July 2015)
4. *Washington Past,* Editorial, "Up in the Air: In India, Mr. Obama makes a start on a climate partnership" (28 Jan 2015)
5. *The New York Times*, Editorial, "A New Chapter for America and India" (27 Jan 2015)
6. *The Economic Times*, Editorial, "Lima Summit: India should commit to boost energy efficiency" (10 Dec 2014)
7. *The Economist*, Editorial, "Paris via Montreal" (20 Sept 2014)
8. *The Washington Post,* Editorial, "The globalization of pollution" (28 Jan 2014)
9. *The International New York Times*, Editorial, "Curbing a Potent Greenhouse Gas" (7 Jan 2014)
10. *The Post and Courier,* Editorial, "Stopgap remedy for climate change" (6 Dec 2013)
11. *Nature*, Editorial, "All together now' (30 October 2013)
12. *The New York Times,* Editorial, "At Last, an Action Plan on Climate" (25 June 2013)
13. *The New York Times,* Editorial, "Fresh Start for a Critical Relationship" (10 June 2013)
14. *The New York Times,* Editorial, "Climate Warnings, Growing Louder" (18 May 2013)
15. *Bloomberg*, Editorial, "How to Make Air Conditioners Less Guzzling and More Green" (23 Sept 2012)
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17. *The New York Times*, Editorial, "A Second Front in the Climate War" (17 Feb 2012)
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7. *Business Standard*, Op-Ed, Rajendra Shende "Beyond borders: India, China must show climate stewardship" (13 May 2015)
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16. *The Guardian*, Op-Ed, A. Steiner, "Davos 2014: Achim Steiner insider diary" (25 Jan 2014)
17. *Las Vegas Sun*, Op-Ed, L. Thomas, "Follow Reagan's lead and take action on climate change" (11 Dec 2013)
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27. *U-T San Diego*, Op-Ed, V. Ramanathan & D. Zaelke, "Earth Day: Saving out planet, saving ourselves" (21 April 2012)
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[2] HFCs belong to a family of factory-made gases including chlorofluorcarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), used for air conditioning, refrigeration, foam insulation, and other specialized sectors. In 1975, atmospheric chemists Molina and Rowland identified the potent stratospheric ozone depleting effects of CFCs. *See* Molina M., & Rowland F. S. (1974) *Stratospheric sink for Chlorofluoromethanes: Chlorine Aton-Catalyzed Destruction of Ozone*, NATURE 249(5460):810-812. This was followed, within a year, by the discovery of the potent greenhouse gas effect of the halocarbons CFC-11 and CFC-12. *See* Ramanathan V. (1975) *Greenhouse effect due to chlorofluorocarbons: climatic implications*, SCI. 190(4209):50-52.

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[6] Xu Y., Zaelke D., Velders G. J. M., & Ramanathan V. (2013) *The role of HFCs in mitigating 21st century climate change*, ATMOS. CHEM. PHYS., 13:6083-6089.

[7] UNEP (1987) THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER ARTICLE 5: SPECIAL SITUATION OF DEVELOPING COUNTRIES. Under the original Montreal Protocol, developing countries consuming less than 0.3/kg CFC per capita qualified under Article 5(1) for a grace period prior to controls. Subsequently, the Montreal Protocol was modified to provide financing for the so-called Article 5 Parties, and the list of Parties qualifying under Article 5 was adjusted to reflect the special circumstances of various Parties. 147 Parties currently qualify under Article 5, *see* UNEP (2014) *List of Parties categorized as operating under Article 5 paragraph 1 of the Montreal Protocol (considered as developing countries)*.

[8] Speech, Shende R. *2009 U.S.EPA's Stratospheric Ozone Protection and Climate Protection Awards* (21 April 2009) ("Humanity has already benefited by about 60% improvement in energy efficiency in domestic refrigerators since the industry started looking at their design in order to change from CFC-12."); *and* U.S. E.P.A. (2002) BUILDING OWNERS SAVE MONEY, SAVE THE EARTH: REPLACE YOUR CFC AIR-CONDITIONING CHILLER, 6-7 ("The most energy-efficient new chillers will reduce electric generation and associated greenhouse gas emissions by up to 50% or more compared to the CFC chillers they replace.").

[9] Shah N., Wei M., Letschert V., & Phadke A., (2015) BENEFITS OF LEAPFROGGING TO SUPEREFFICIENCY AND LOW GLOBAL WARMING POTENTIAL REFRIGERANTS IN AIR CONDITIONING, Ernest Orlando Lawrence Berkeley National Laboratory.

[10] The Montreal Protocol's Technology and Economic Assessment Panel (TEAP) uses the term "low-GWP' to refer to refrigerants with GWPs of 300 or lower while "moderate-GWP" refers to refrigerants with GWPs of 1,000 or lower.[10] Refrigerants with a GPW of over 1000 are considered 'high-GWP".

[11] Myhre G., *et al.* (2013) CHAPTER 8: ANTHROPOGENIC AND NATURAL RADIATIVE FORCING, *in* IPCC (2013) CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS, Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

[12] NASA (2015) FACTSHEET: OZONE DEPLETION BY HYDROFLUOROCARBONS, 1 ("Ozone depletion potentials (ODPs) for HFCs range from 0.39x10-3 to 30.0x10-3, approximately, 100 times larger than previous ODP estimates that were based solely on chemical effects. Per unit mass, CFC-11 causes about 400 times more ozone depletion than the HFCs, while HCFC-22 causes 8 times more ozone depletion…. Reducing HFC emissions, and thus their radiative forcing, would reduce the HFC impacts on the stratosphere, lessening the temperature and circulation responses and the resulting ozone depletion. Hence, emerging HFC species that have low atmospheric concentrations, short lifetimes, and are weak radiative forcing agents would have proportionately smaller impacts on stratospheric climate and ozone."); *and* Hurwitz M. M., Fleming E. L., Newman P. A., Li F., Mlawer E., Cady-Pereira K., & Bailey R. (2015) *Ozone depletion by hydrofluorocarbons*, GEOPHYS. RES. LETT. 42(20):8686-8692.

[13] Velders G. J. M, *et al.* (2012) *Preserving Montreal Protocol Climate Benefits by Limiting HFCs*, SCI. 335(6071):922-923.

[14] U.S. EPA (2014) INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990 – 2012, Table ES-2 (between 2005 and 2012, U.S. HFC emissions from the substitution of ozone depleting substances increased by 40%; *see also* Montreal Protocol Technology and Economic Assessment Panel (2009) TASK FORCE DECISION XX/8 REPORT: ASSESSMENT OF ALTERNATIVES TO HCFCS AND HFCS AND UPDATE OF THE TEAP 2005 SUPPLEMENT REPORT DATA; Velders G. J. M., *et al.* (2009) *The large contribution of projected HFC emissions to future climate forcing*, PROC. NAT'L. ACAD. SCI. U.S.A. 106(27):10949, 10949 ("[T]he growth in demand for these compounds [HFCs] is based on GDP and population (8, 12). However, the new scenarios incorporate more recent information such as (*i*) rapid observed growth in demand, substantiated by atmospheric observations, for products and equipment using HCFCs and HFCs in developing countries (see *SI Text*); (*ii*) reported increases in consumption of HCFCs in developing countries; (*iii*) replacement patterns of HCFCs by HFCs as reported in developed countries; (*iv*) accelerated phaseout schedules of

HCFCs in developed and developing countries, and; (*v*) increases in reported use of HFC-134a in mobile AC in developed and developing countries."); *and* Phadke A., Adhyankar N., & Shah N., AVOIDING 100 NEW POWER PLANTS BY INCREASING EFFICIENCY OF ROOM AIR CONDITIONERS IN INDIA: OPPORTUNITIES AND CHALLENGES, Lawrence Berkeley National Laboratory at 9 ("The example of China is illuminating for understanding the rapid growth in household appliance ownership as a result of rising incomes and urbanization. The saturation of air conditioners in urban China went from nearly zero in 1992 to about 100% by 2007 i.e. within a span of 15 years [3]. . . . [W]e believe that the AC ownership in India is may witness similar growth.").

[15] According to the World Resources Institute Climate Analysis Indicators Tool (CAIT), CO_2-eq emissions of fluorinated gases (f-gases), which include HCFCs, HFCs, SF_6 and PFCs, in China increased by 111% between 2000 and 2005 (and 2,775% between 1990 and 2010), compared to a 68% increase in CO_2, 8% increase in methane, and 6% increase in N_2O. HCFC and HFC emissions increased by 78% in India over the same period, compared to 19% for CO_2, 10% for methane, and 6% for N_2O. HCFC and HFC emissions in the U.S. increased by 30% between 2000 and 2005 compared to 1.5% for CO_2, and a 5% decrease in methane and N_2O. According to the U.S. EPA (2014) , Table ES-2, U.S. HFC emissions from the substitution of ozone depleting substances grew by nearly 41% between 2005 and 2012, and HFCs are the only greenhouse gases that saw total emissions increase between 2011 and 2012. E.U. CO_2-eq emissions of HFCs increased by 298% between 1990 and 2012, and are the only greenhouse gases, measured by CO_2-eq emissions, that have increased every year over that period. According to the Australian Government's 2011 submission to the UNFCCC, HFC emissions in Australia increased by 578.5% between 1990 and 2011; the only other two greenhouse gas emissions to increase over that period were CO_2 and N_2O, which increased 46.3% and 36.1% respectively. Australian Government (2013) AUSTRALIA'S SIXTH NATIONAL COMMUNICATION ON CLIMATE CHANGE: A REPORT UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE; *see also* European Environment Agency (2014) ANNUAL EUROPEAN UNION GREENHOUSE GAS INVENTORY 1990 – 2012 AND INVENTORY REPORT 2014, No 9/2014.

[16] The high growth rates of HFCs have been validated by two atmospheric measurement groups: the NOAA Earth Systems Research Laboratory, and the NASA sponsored Advanced Global Atmospheric Gases Experiment (AGAGE). AGAGE measurements of HFC-134a concentrations in particular show that atmospheric concentrations have increased by 388-560% between 2000 and 2013. *See* Montzka, S. A., *et al.* (2014) *Recent Trends in Global Emissions of Hydrochlorofluorocarbons and Hydrofluorocarbons—Reflecting on the 2007 Adjustment to the Montreal Protocol*, J. PHYS. CHEM. (ASAP); AGAGE (2014) HFC-134a; *and* NOAA (2014) MAUNA LOA, HAWAII, UNITED STATES HFC-134A TIME SERIES. Working Group I of the IPCC Fifth Assessment Report relies upon both of these groups to show increasing emissions of synthetic gases. *See* Hartmann, D.L., *et al.* (2013) OBSERVATIONS: ATMOSPHERE AND SURFACE, *in* IPCC (2013) CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS, Figure 2.4.

[17] Montzka, S. A., *et al.* (2014) *Recent Trends in Global Emissions of Hydrochlorofluorocarbons and Hydrofluorocarbons—Reflecting on the 2007 Adjustment to the Montreal Protocol*, J. PHYS. CHEM. (ASAP) 119(19):4439, 4439 ("HFC global emission magnitudes related to this substitution totaled 0.51 ("0.03, +0.04) $GtCO_2$-eq/y in 2012, a magnitude about two times larger than emissions reported to the United Nations Framework Convention on Climate Change (UNFCCC) for these HFCs. Assuming accurate reporting to the UNFCCC, the results imply that developing countries (non-Annex I Parties) not reporting to the UNFCCC now account for nearly 50% of global HFC emissions used as substitutes for ozone-depleting substances (ODSs). Global HFC emissions (as CO_2-eq) from ODS substitution can be attributed approximately equally to mobile air conditioning, commercial refrigeration, and the sum of all other applications.").

[18] Velders G. J. M, *et al.* (2012) *Preserving Montreal Protocol Climate Benefits by Limiting HFCs*, SCI. 335:922, 922 ("The current contribution to climate forcing of HFCs used as ODS substitutes is about 0.012 W/m2 . . . In an upper-range scenario, global radiative forcing from HFCs increases from about 0.012 W/m2 in 2010 to 0.25 to 0.40 W/m2 in 2050.").

[19] Xu Y., Zaelke D., Velders G. J. M., & Ramanathan V. (2013) *The role of HFCs in mitigating 21st century climate change*, ATMOS. CHEM. PHYS. 13:6083-6089; *see also* Hare B. *et al.* (2012) CLOSING THE 2020 EMISSIONS GAP: ISSUES, OPTIONS AND STRATEGIES; *and* Ramanathan V. & Xu Y. (2010) *The Copenhagen Accord for limiting global warming: Criteria, constraints, and available avenues*, PROC. NAT'L ACAD. SCI. U.S.A. 107(18):8055-8062 (The Ramanathan & Xu study was the first to model the climate benefit of HFC mitigation in combination with SLCPs, CO_2, and other long-lived greenhouse gases.).

[20] Velders G. J. M., *et al.* (2014) *Growth of climate change commitments from HFC banks and emissions*, ATMOS. CHEM. PHYS. DISCUSS. 14:4563, 4568 ("The annual HFC emissions in our scenarios reach up to 12% of the upper-range annual CO_2 emissions (RCP8.5) in 2050 and 75% for the CO_2 scenario with strong mitigation (RCP3PD)"); *see also* UNEP (2011) HFCS: A CRITICAL LINK IN PROTECTING CLIMATE AND THE OZONE LAYER – A UNEP SYNTHESIS REPORT; *and* Montzka S. A. (2012) HFCs in the Atmosphere: Concentrations, Emissions, Impacts, ASHRAE.

[21] Velders G. J. M., *et al.* (2014) *Growth of climate change commitments from HFC banks and emissions*, ATMOS. CHEM. PHYS. DISCUSS. 14:4563, 4568 ("In these scenarios, the HFC bank grows to 39–64 GtCO2-eq compared with an annual CO_2 emission of 12–74 GtCO2-eq yr^{-1} in 2050 (Table 2). So, the estimated HFC bank sizes range from a factor of less than 1 to more than 5 year's worth of CO2-eq emissions in 2050 for the scenarios compared here.").

[22] Velders G. J. M., *et al.* (2014) *Growth of climate change commitments from HFC banks and emissions*, ATMOS. CHEM. PHYS. DISCUSS. 14:4563, 4568 ("In these scenarios, the HFC bank grows to 39–64 GtCO2-eq compared with an annual CO_2 emission of 12–74 GtCO2-eq yr^{-1} in 2050 (Table 2). So, the estimated HFC bank sizes range from a factor of less than 1 to more than 5 year's worth of CO2-eq emissions in 2050 for the scenarios compared here.").

[23] Velders G. J. M. *et al.* (2009) *The large contribution of projected HFC emissions to future climate forcing*, PROC. NAT'L. ACAD. SCI. U.S.A. 106(27):10949-10954. A 2015 paper by Velders *et al.* presents estimates of regional emissions using new sources of data for regions and sectors and new assumptions about market saturation premised on western temperate climate rather than the hotter and more humid climates typical of many developing countries where refrigeration and air conditioning growth will be

highest; both HFC business-as-usual scenarios (Velders et al., 2009 & 2015) should be considered as lower limits of future HFC emissions. The avoided warming from an HFC phase down calculated in Xu, *et al.* (2013) would be even larger without the assumption about market saturation, and might be slightly smaller with earlier market saturation. *See* Velders G. J. M., Fahey D. W., Daniel J. S., Andersen S. O., & McFarland M. (2015) *Future atmospheric abundances and climate forcings from scenarios of global and regional hydrofluorocarbon (HFC) emissions*, ATMOS. ENVIR. 123:200-209.

[24] Xu Y., Zaelke D., Velders G. J. M., & Ramanathan V. (2013) *The role of HFCs in mitigating 21st century climate change*, ATMOS. CHEM. PHYS., 13:6083-6089; *see also* Hare, B. *et al.* (2013) CLOSING THE 2020 EMISSIONS GAP: ISSUES, OPTIONS AND STRATEGIES.

[25] Velders G. J. M., *et al.* (2014) *Growth of climate change commitments from HFC banks and emissions*, ATMOS. CHEM. PHYS. DISCUSS. 14:4563-4572 ("If, for example, the HFC production were to be phased out in 2020 instead of 2050, the cumulative emissions avoided would be about 91–146 GtCO2-eq from 2020 to 2050, while a bank of about 39–64 GtCO2-eq is also avoided in 2050, an additional benefit to climate protection of about 40 % compared with the cumulative emissions reduction alone.").

[26] Velders G. J. M., *et al.* (2014) *Growth of climate change commitments from HFC banks and emissions*, ATMOS. CHEM. PHYS. DISCUSS. 14:4563, 4563 ("If, for example, HFC production were to be phased out in 2020 instead of 2050, not only could about 91–146GtCO2-eq of cumulative emission be avoided from 2020 to 2050, but an additional bank of about 39–64 GtCO2- eq could also be avoided in 2050.").

[27] Davis S. J. & Socolow R. H. (2014) *Commitment Accounting of CO_2 Emissions*, ENVTL. RES. LTRS. 9, 1–9, 4 ("The point of view is from 2012, a 40 year lifetime is assumed for all generators, and all fossil fuel-fired electricity-generating units ('generators') that were built globally between 1950 and 2012 are included. Global committed emissions from these generators total 629 (508–761) Gt CO_2 (light green area; only the central estimate reflecting a 40 year lifetime is shown), of which 322 Gt CO_2 were realized emissions by 2012 (black area), and 307 (192–439) Gt CO_2 were remaining commitments as of 2012 (dark green area). The error estimates in parentheses here are for assumed lifetimes of 30 and 50 years, presented in table 1 (along with the results of assuming lifetimes of 20 and 60 years). Thus, the range of estimated remaining commitments in 2012 (192–439Gt CO_2) assigns an uncertainty of 40% to our central estimate of 307 Gt CO_2.").

[28] Zaelke *et al.* (2014). Prepared by Dr. D. Fahey based upon UNEP (2012) THE MONTREAL PROTOCOL AND THE GREEN ECONOMY: ASSESSING THE CONTRIBUTIONS AND CO-BENEFITS OF A MULTILATERAL ENVIRONMENTAL AGREEMENT; *and* Velders G. J. M., *et al.* (2014) *Growth of climate change commitments from HFC banks and emissions*, ATMOS. CHEM. PHYS. DISCUSS. 14:4563-457. Internal citations: (1) Velders G. J. M., *et al.* (2007) *The importance of the Montreal Protocol in protecting climate*, PROC. NAT'L. ACAD. SCI. U.S.A. 104(12):4814-4819; (2) Velders G.J.M. *et al.* (2007) THE IMPORTANCE OF THE MONTREAL PROTOCOL IN PROTECTING CLIMATE, *in* THE MONTREAL PROTOCOL, CELEBRATING 20 YEARS OF ENVIRONMENTAL PROGRESS (2007) *ed.* Kaniaru D. (Cameron May, London), UK; (3) UNFCCC (2014) *CDM Insights: Project Activities* (data as of 30 April 2014) (The CDM Secretariat projects that 3,790,067,617 CERs are available for all 2540 project activities through the end of the current crediting period; however, based upon past rates of issuance, the Secretariat estimates that only 2,946,111,824 will be issued.); (4) Velders G. J. M. *et al.* (2009) *The large contribution of projected HFC emissions to future climate forcing*, PROC. NAT'L. ACAD. SCI. U.S.A. 106(27):10949-10954. (Estimates are for direct emissions and do not include indirect benefits from improvements in energy efficiency or other lifecycle emissions reductions.). *See also* World Meteorological Organization and UNEP, *Scientific Assessment of Ozone Depletion: 2014* (10 September 2014) (This two-year effort by 280 scientists from 36 countries calculates that the success of the Montreal Protocol has put the stratospheric ozone layer on the path to recovery in the next few decades; that it also has provided climate mitigation of "about 10 gigatonnes of avoided CO2-equivalent emissions per year, which is about five times larger than the annual emissions reduction target for the first commitment period (2008–2012) of the Kyoto Protocol"; and that the high growth rate of HFCs threatens to cancel the treaty's past climate mitigation.)

[29] Xu Y., Zaelke D., Velders G. J. M., & Ramanathan V. (2013) *The role of HFCs in mitigating 21st century climate change*, ATMOS. CHEM. PHYS. 13:6083-6089.

[30] Xu Y., Zaelke D., Velders G. J. M., & Ramanathan V. (2013) *The role of HFCs in mitigating 21st century climate change*, ATMOS. CHEM. PHYS. 13:6083, 6087 ("Given the limited knowledge regarding climate sensitivity (0.5 to 1.2°C/(W/m^{-2})), the absolute value of projected temperature at the end of 21st century is also uncertain (vertical bars in Fig. 3), but the relative contribution of HFC to reducing the warming is still significant and less subject to such uncertainty.").

[31] Hu A., *et al.* (2013) *Mitigation of short-lived climate pollutants slows sea-level rise*, NATURE CLIMATE CHANGE 3(8):730-734, 732.

[32] Hu A., *et al.* (2013) *Mitigation of short-lived climate pollutants slows sea-level rise*, NATURE CLIMATE CHANGE 3(8):730-734, 732.

[33] The SLCP percentages are derived from Fig. 2C in Hu, *et al*., (2013) *Mitigation of short-lived climate pollutants slows sea-level rise*, NATURE CLIMATE CHANGE 3(8):730-734; *see also* IGSD Press Release (14 April 2013), *Reducing Air Pollution, Chemical Coolants Can Quickly Cut Sea-Level Rise*, and accompanying summary of Hu, *et al*.'s study**.**

[34] De Larminat P. (2013) *Development of Climate Friendly Alternatives for Chillers* (presentation at Bangkok Technology Conference, 29 June 2013) ("In practice, the share of indirect emissions is around 90/95% of total emissions. Can range from 70% to more than 98% depending on the application.").

[35] Speech, Shende R. *2009 U.S.EPA's Stratospheric Ozone Protection and Climate Protection Awards* (21 April 2009) ("Humanity has already benefited by about 60% improvement in energy efficiency in domestic refrigerators since the industry started looking

at their design in order to change from CFC-12."); *and* U.S. E.P.A. (2002) BUILDING OWNERS SAVE MONEY, SAVE THE EARTH: REPLACE YOUR CFC AIR-CONDITIONING CHILLER, 6-7 ("The most energy-efficient new chillers will reduce electric generation and associated greenhouse gas emissions by up to 50% or more compared to the CFC chillers they replace.").

[36] U.S. EPA (2002) BUILDING OWNERS SAVE MONEY, SAVE THE EARTH: REPLACE YOUR CFC AIR CONDITIONING CHILLER, 2 ("Building owners around the world have saved millions of dollars in electricity bills by upgrading air conditioning chiller installations and through concurrent investments to reduce building cooling load. Today's chillers use about one-third or less electricity compared to those produced just two decades ago. Building owners can typically pay back the investment cost of replacing an old CFC chiller in five years or less in virtually all locations that cool for more than three months a year."); *and* Todesco G. (2005) CHILLERS + LIGHTING + TES: WHY CFC CHILLER REPLACEMENT CAN BE ENERGY-SAVINGS WINDFALL, ASHRAE JOURNAL 47(3):18, 18 ("These CFC chillers serve an estimated 3.4 billion to 4.7 billion ft² (315 million to 440 million m²) of commercial floor space with a total electricity consumption of 49,000 to 66,000 GWh/year, and an annual electricity operating cost of $3.4 billion to $4.8 billion. In addition, the cooling and lighting loads in these buildings contribute an estimated 3,600 to 9,200 MW to the summer peak demand of North American utilities. The electricity consumption and peak electrical demand can be reduced significantly by replacing the remaining CFC chillers with new efficient plants. The performance of chillers has improved significantly in the last 12 years compared to chillers manufactured in the 1970s and 1980s.").

[37] Press Release, York International, *Taking the bite out of CFC replacement by improving air conditioning efficiency* (14 February 1996) ("Now that production of chlorofluorocarbons (CFCs) has ended, the majority of commercial and institutional building owners and industrial plant managers have a chance to turn adversity into opportunity. That's the premise of a white paper being offered by York International Corp., a major manufacturer of chillers -- the large refrigeration machines at the heart of most large-building air-conditioning systems. While there's no escaping eventual replacement or conversion of the 60,000 or more air-conditioning systems in the U.S. that use CFCs as refrigerants, the good news, according to York International, is that the energy efficiency of these systems can be dramatically improved with new technology, meaning quicker paybacks and long-term cost savings. The savings, in fact, have been calculated to range between $200,000 and $2 million, depending on local weather conditions, over a 25-year operating life.").

[38] U.S. EPA (2002) BUILDING OWNERS SAVE MONEY, SAVE THE EARTH: REPLACE YOUR CFC AIR CONDITIONING CHILLER, 7.

[39] GEF (2009) CHILLER ENERGY EFFICIENCY PROJECT, 4 ("Given chillers normally consume more than 30% of the total energy consumption in large commercial buildings and industrial establishments, implementation of this project would support India's efforts in reaching its goal and also in raising awareness of the potential energy savings in large energy consumers.").

[40] UNEP & CCAC (2014) LOW-GWP ALTERNATIVES IN COMMERCIAL REFRIGERATION: PROPANE, CO_2 AND HFO CASE STUDIES, 30 (For example, in one of the case studies, "it is projected that the carbon footprint of the store will be reduced by 85% relative to a baseline store. Of the 85% reduction, 58% is attributable to reduced energy use while the remaining 27% is attributable to the direct emissions avoided by using propane as the refrigerant."). Similar energy efficiency gains have been achieved in Japan. ATMOsphere (2014) ATMOSPHERE ASIA 2014 SUMMARY REPORT.

[41] Consumer Goods Forum (2009) SUCCESS STORIES ABOUT HFC-FREE REFRIGERATION AND ENERGY EFFICIENCY: BARRIERS AND SOLUTIONS, 7.

[42] Consumer Goods Forum (2009) SUCCESS STORIES ABOUT HFC-FREE REFRIGERATION AND ENERGY EFFICIENCY: BARRIERS AND SOLUTIONS, 7.

[43] Shah N., Wei M., Letschert V., & Phadke A., (2015) BENEFITS OF LEAPFROGGING TO SUPEREFFICIENCY AND LOW GLOBAL WARMING POTENTIAL REFRIGERANTS IN AIR CONDITIONING, Ernest Orlando Lawrence Berkeley National Laboratory, ("While there is some uncertainty associated with emissions and growth projections, moving to efficient room air conditioning (~30% more efficient than current technology) in parallel with lowGWP refrigerants in room air conditioning could avoid up to ~25 billion tonnes of CO2 in 2030, ~33 billion in 2040, and ~40 billion in 2050, i.e. cumulative savings upto 98 billion tonnes of CO2 by 2050.").

[44] Shah N., Wei M., Letschert V., & Phadke A., (2015) BENEFITS OF LEAPFROGGING TO SUPEREFFICIENCY AND LOW GLOBAL WARMING POTENTIAL REFRIGERANTS IN AIR CONDITIONING, Ernest Orlando Lawrence Berkeley National Laboratory, 26 ("The world room air conditioner market is growing fast with increasing urbanization, electrification, rising incomes and falling air conditioner prices in many developing economies. We estimate an additional 700 million units will be added to the global AC stock by 2030 and 1.6 billion by 2050 under current trends. In the absence of policy to mitigate the impact of this growth, it is expected to have a large-scale impact on electricity generation capacity and peak load particularly in economies with hot climates, and contribute significantly to GHG emissions.").

[45] Shah N., Wei M., Letschert V., & Phadke A., (2015) BENEFITS OF LEAPFROGGING TO SUPEREFFICIENCY AND LOW GLOBAL WARMING POTENTIAL REFRIGERANTS IN AIR CONDITIONING, Ernest Orlando Lawrence Berkeley National Laboratory; *See also* Natural Resources Defense Council (2012) *Bhaskar Deol Guest Blog: Reducing Delhi's Power Crunch Through Appliance Efficiency* ("Two recent studies, one by Maharashtra Electricity Regulatory Commission (MERC), and another by India's Bureau of Energy Efficiency (BEE), show that AC power demand forms a lion's share of peak demand in Indian cities. The MERC study pegs power demand from ACs at 40% of the total demand for the city of Mumbai in a peak summer month and the BEE study estimates that a staggering 60% of peak demand is used up by air-conditioners."); *and* The Economic Times, *Air Conditioner Sales Soar up to 30 percent* (4 June 2013) ("The sizzling summer may have made consumers bear the brunt of heat but air conditioner makers are laughing all the way to the bank with sales soaring by up to 30 per cent this season.").

[46] Phadke A., Adhyankar N., Shah N. (2014) AVOIDING 100 NEW POWER PLANTS BY INCREASING EFFICIENCY OF ROOM AIR CONDITIONERS IN INDIA: OPPORTUNITIES AND CHALLENGES, Lawrence Berkeley National Laboratory, at 16-17, Table 4 ("We estimate that about 30% of the urban households are likely to own a room air conditioner by 2020 and about 73% are likely to own a room air conditioner by 2030.").

[47] Shah N., Wei M., Letschert V., & Phadke A., (2015) BENEFITS OF LEAPFROGGING TO SUPEREFFICIENCY AND LOW GLOBAL WARMING POTENTIAL REFRIGERANTS IN AIR CONDITIONING, Ernest Orlando Lawrence Berkeley National Laboratory, 28 ("For example, air conditioning represents about 30% of current and forecasted summer load in warm climates such as California, about 40-60% of the total summer load on typical summer days in metropolitan areas in hot climates like Delhi, India compared to typical winter days and can even triple summer load in very hot areas such as New South Wales, Australia.").

[48] Shah N., Wei M., Letschert V., & Phadke A., (2015) BENEFITS OF LEAPFROGGING TO SUPEREFFICIENCY AND LOW GLOBAL WARMING POTENTIAL REFRIGERANTS IN AIR CONDITIONING, Ernest Orlando Lawrence Berkeley National Laboratory.

[49] Shah N., Wei M., Letschert V., & Phadke A., (2015) BENEFITS OF LEAPFROGGING TO SUPEREFFICIENCY AND LOW GLOBAL WARMING POTENTIAL REFRIGERANTS IN AIR CONDITIONING, Ernest Orlando Lawrence Berkeley National Laboratory.

[50] Shah N., Wei M., Letschert V., & Phadke A., (2015) BENEFITS OF LEAPFROGGING TO SUPEREFFICIENCY AND LOW GLOBAL WARMING POTENTIAL REFRIGERANTS IN AIR CONDITIONING, Ernest Orlando Lawrence Berkeley National Laboratory, 26 As can be seen from Table 10, economies with larger AC markets (and therefore larger AC stocks) have a higher estimated peak load reduction. For example estimated peak load reduction from efficiency improvement and refrigerant transition in China and India are 132- 310GW and 31-71GW in 2030 respectively. This is equivalent to avoiding building 260-620 medium-sized 500MW peak power plants in China and 60-140 medium-sized 500MW peak power plants in India respectively. This scale is comparable to India's renewable energy capacity targets of 100GW of solar and 75GW of wind energy generation capacity."). *See also* Phadke A., Adhyankar N., Shah N., AVOIDING 100 NEW POWER PLANTS BY INCREASING EFFICIENCY OF ROOM AIR CONDITIONERS IN INDIA: OPPORTUNITIES AND CHALLENGES, Lawrence Berkeley National Laboratory, 1 ("The total potential energy savings from Room AC efficiency improvement in India using the best available technology will reach over 118 TWh in 2030; potential peak demand saving is found to be 60 GW by 2030. This is equivalent to avoiding 120 new coal fired power plants of 500 MW each."); *see also* White House Office of the Press Secretary, *Fact Sheet: The United States and India – Strategic and Global Partners* (27 September 2013) ("Demand for space cooling – primarily for air conditioners – constitutes a large portion of peak electricity demand in India. Air conditioners could add as much as 140 GW to peak load by 2030 and management of the peak contribution is critical for maintaining supply security and avoiding load shedding. The new U.S.-India Collaboration on Smart and Efficient Air Conditioning and Space Cooling is intended to advance policies and innovation to drive mass deployment and rapid uptake of high-efficiency cooling equipment and technologies to capture significant energy savings, potentially avoiding the need to build as many as 120 large power plants.").

[51] Shah N., *et al.* (2013) COOLING THE PLANET: OPPORTUNITIES FOR DEPLOYMENT OF SUPER-EFFICIENT ROOM AIR CONDITIONERS, Lawrence Berkeley National Laboratory, 69 ("As shown above in figure 4-5, for most economies ESEERs (European Seasonal Energy Efficiency Ratio) of over 6 W/W are attainable at costs (to the consumer) of conserved electricity between 5 and 15 cents per kWh. In economies with a higher cost of capital (i.e. discount/interest rates) such as Brazil, or low hours of use such as Mexico or China, higher efficiency ACs carry a larger cost of conserved electricity, when compared to India or UAE. For countries such as Japan where ACs are used for both heating and cooling, and India or UAE, where ACs are used for many hours annually, very high ESEERs are attainable at low cost per unit of electricity saved.").

[52] Shah N., Wei M., Letschert V., & Phadke A., (2015) BENEFITS OF LEAPFROGGING TO SUPEREFFICIENCY AND LOW GLOBAL WARMING POTENTIAL REFRIGERANTS IN AIR CONDITIONING, Ernest Orlando Lawrence Berkeley National Laboratory, 27.

[53] Carvalho S., *et al.* (2014) ALTERNATIVES TO HIGH-GWP HYDROFLUOROCARBONS; UNEP (2011) HFCS: A CRITICAL LINK IN PROTECTING CLIMATE AND THE OZONE LAYER – A UNEP SYNTHESIS REPORT; and Montreal Protocol Technology and Economic Assessment Panel (2009) Task Force Decision XX/8 Report: Assessment of Alternatives to HCFCs and HFCs and Update of the TEAP 2005 Supplement Report Data; Montreal Protocol Technology and Economic Assessment Panel (2010) TEAP 2010 PROGRESS REPORT, VOL. 1 , 27–33.

[54] Montreal Protocol Technology and Economic Assessment Panel (2010) TEAP 2010 PROGRESS REPORT, VOL I, 3.

[55] Myhre G., *et al.* (2013) CHAPTER 8: ANTHROPOGENIC AND NATURAL RADIATIVE FORCING, *in* IPCC (2013) CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS, Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

[56] Shah N., Wei M., Letschert V., & Phadke A., (2015) BENEFITS OF LEAPFROGGING TO SUPEREFFICIENCY AND LOW GLOBAL WARMING POTENTIAL REFRIGERANTS IN AIR CONDITIONING, Ernest Orlando Lawrence Berkeley National Laboratory, 10 (Table 3 "Status of development of alternative refrigerants in various sectors").

[57] Montreal Protocol Technology and Economic Assessment Panel (2010) TEAP 2010 PROGRESS REPORT, VOL I, 4 ("Choosing the lowest GWP substance in the technology replacing HCFCs may not always be the optimum approach because the GHG emissions from product manufacturing and product energy use often dominate the life-cycle carbon footprint.").

[58] Montreal Protocol Technology and Economic Assessment Panel (1999) THE IMPLICATIONS TO THE MONTREAL PROTOCOL OF THE INCLUSION OF HFCS AND PFCS IN THE KYOTO PROTOCOL, 11.

[59] U.S. EPA (2013) BENEFITS OF ADDRESSING HFCS UNDER THE MONTREAL PROTOCOL, Tables 4-6; *see also* Climate and Clean Air Coalition to Reduce Short-lived Climate Pollutants (CCAC) (2014) LOW-GWP ALTERNATIVES IN COMMERCIAL REFRIGERATION

PROPANE, CO_2, AND HFO CASE STUDIES, 5 ("Research was conducted to generate a list of potential case studies for consideration taking into account all of the currently available zero- and low-GWP refrigerants in commercial refrigeration applications, including "natural" refrigerants, such as hydrocarbons, carbon dioxide (CO_2), and ammonia, as well as the other major category of alternatives comprising man-made chemicals such as the unsaturated HFCs known as hydrofluoroolefins (HFOs). HFOs are a new class of unsaturated HFC refrigerants which have lower GWPs and shorter atmospheric lifetimes when compared to other HFCs.").

[60] Myhre G., *et al.* (2013) CHAPTER 8: ANTHROPOGENIC AND NATURAL RADIATIVE FORCING, *in* IPCC (2013) CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS, Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Table 8.A.1. *See also* Hodnebrog O. *et al.* (2013) *Global warming potentials and radiative efficiencies of halocarbons and related compounds: A comprehensive review*, REV. GEOPHYS, 333 (calculating that HFO-1234yf and HFO-1234ze have a lifespan of 0.02 years and a GWP of less than 1).

[61] Myhre G., *et al.* (2013) CHAPTER 8: ANTHROPOGENIC AND NATURAL RADIATIVE FORCING, *in* IPCC (2013) CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS, Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Table 8.A.1. R-32 systems require one-third less refrigerant charge for equivalent capacity, and achieve higher energy efficiency than the higher-GWP HFCs or hydrocarbons in room air conditioners at high ambient temperatures. *See* Yajima R., *et al.* (2000) *R32 As a Solution for Energy Conservation and Low Emission*, INTERNATIONAL REFRIGERATION AND AIR CONDITIONING CONFERENCE Paper, 509 ("By adoption of smaller diameter tubes for heat exchangers, with R32 the refrigerant charge amount can be reduced to 57% of that of R22 mother unit and with R410A to 62%. As for the heat exchanger performance, both the condensing and cooling heat-exchanging capacity increase and the COP [Coefficient of Performance] improves by adoption of smaller diameter tubes. …We can reduce TEWI [Total Environmental Warming Impact] by 18% in comparison with R410A. The direct warming impact decreases down to 7% of TEWI in case of R32.") *and* Hideki Tsujii and Hiroyuki Imada (2013) SYSTEM DROP-IN TEST OF REFRIGERANT R-32 IN A VRF MULTI-SPLIT HEAT PUMP ("R32 makes performance higher with 83% of R410A charge in case of using the existing R410A system…. R32 contributes to improvement in both capacity and EER [Energy Efficiency Ratio]/COP.")

[62] Velders G. J. M., *et al.* (2009) *The large contribution of projected HFC emissions to future climate forcing*, PROC. NAT'L. ACAD. SCI. U.S.A. 106:10949-10954, 2. *See also* Andersen S. O., Halberstadt M., & Borgford-Parnell N. (2013) *Stratospheric ozone, global warming, and the principle of unintended consequences—An ongoing science and policy success story*, J. OF THE AIR & WASTE MNGMT ASSN 63(6):607-647; *and* Montreal Protocol Technology and Economic Assessment Panel (2013) TEAP 2010 PROGRESS REPORT, VOL. I , 50-51.

[63] Institute for Governance & Sustainable Development, National Resource Defense Council, & Council on Energy, Environment & Water (March 2014) *Maximizing energy efficiency gains when transitioning to new MAC refrigerants: Global automakers moving to HFO-1234yf, except some German automakers waiting for CO_2 systems*.

[64] Institute for Governance & Sustainable Development, National Resource Defense Council, & Council on Energy, Environment & Water (March 2014) *Maximizing energy efficiency gains when transitioning to new MAC refrigerants: Global automakers moving to HFO-1234yf, except some German automakers waiting for CO_2 systems*.

[65] Montreal Protocol Technology and Economic Assessment Panel (May 2013) TEAP 2013 PROGRESS REPORT VOLUME I, 51.

[66] U.S. E.P.A. (2013) BENEFITS OF ADDRESSING HFCS UNDER THE MONTREAL PROTOCOL, 19 ("In 2011, approximately 16% of new refrigerated truck and trailer systems sold in Norway were equipped with cryogenic refrigeration systems. One of Norway's largest food distributors has committed to making cryogenic system-equipped vehicles the standard for all of their future purchases. In addition, a major manufacturer of cryogenic systems has partnered with one of Norway's largest refrigerant suppliers to provide CO_2 filling stations across the country. Cryogenic systems are currently used in other European countries (e.g., Sweden, Denmark, Finland, France, the Netherlands, and Germany), and are being piloted in the United States.").

[67] UNEP (2011) HFCS: A CRITICAL LINK IN PROTECTING CLIMATE AND THE OZONE LAYER – A UNEP SYNTHESIS REPORT *citing* Montreal Protocol Technology and Economic Assessment Panel (2011) REPORT OF THE REFRIGERATION, AIR CONDITIONING AND HEAT PUMP TECHNICAL OPTIONS COMMITTEE: 2010 ASSESSMENT.

[68] Rajadhyaksha D. (2013) *Development and Handling of Hydrocarbon Air-Conditioners – The Godrej Experience* (Godrej & Boyce Mfg. Co. Ltd presentation at Bangkok Technology Conference, 29 June 2013).

[69] White Paper, Morey Publishing (2015) HYDROCARBONS: THE QUEST FOR A GREEN SOLUTION TO THE CHANGING FUTURE OF REFRIGERATION AND AIR-CONDITIONING, 10.

[70] Rajadhyaksha D. (2013) *Development and Handling of Hydrocarbon Air-Conditioners – The Godrej Experience* (Godrej & Boyce Mfg. Co. Ltd presentation at Bangkok Technology Conference, 29 June 2013); *see also* Press Release, Godrej Appliances *Godrej Appliances Raises the Bar for Energy Efficient Products in India* (20 March 2012); *and* Press Release, Godrej Appliances *Godrej Appliances Starts a Global Revolution with Its Green Air Conditioners* (3 April 2012).

[71] Montreal Protocol Technology and Economic Assessment Panel (2013) TEAP 2013 PROGRESS REPORT, VOL. I, 49; *see also* Stanga M. (2013) *Update on R32 Air-conditioning and Heat Pump Manufacturing and Sales* (Daikin Industries, Ltd. presentation at Bangkok Technology Conference, 29 June 2013).

[72] Montreal Protocol Technology and Economic Assessment Panel (2013) TEAP 2013 PROGRESS REPORT, VOL. I, 49.

[73] UNEP (2011) HFCS: A CRITICAL LINK IN PROTECTING CLIMATE AND THE OZONE LAYER – A UNEP SYNTHESIS REPORT, 29.

[74] UNEP (2011) HFCS: A CRITICAL LINK IN PROTECTING CLIMATE AND THE OZONE LAYER – A UNEP SYNTHESIS REPORT, 29.

[75] Myhre G., *et al.* (2013) CHAPTER 8: ANTHROPOGENIC AND NATURAL RADIATIVE FORCING, *in* IPCC (2013) CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS , Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Table 8.A.1; *see also* Hodnebrog O., *et al.* (2013) *Global warming potentials and radiative efficiencies of halocarbons and related compounds: A comprehensive review* , REV. GEOPHYS. 51(2):300-378, Table 5.

[76] Honeywell (2013) *Honeywell Solstice Liquid Blowing Agent* ("Performance: Up to 10-12% better than hydrocarbon (Cyclopentane); 2% better than HFC-245fa. We expect even more as formulations are fine-tuned."); *see also* Press Release, Whirlpool Corporation, *Whirlpool Corporation Partners with Honeywell, Announces Use of Next Generation Solstice® Liquid Blowing Agent in U.S. Refrigerators* (22 January 2014) ("The global warming potential (GWP) of the new foam blowing agent is 99.9% lower than 245fa the most common foam blowing agent widely used within the U.S. industry, resulting in a more environmentally-responsible household refrigerator."); *and* Arkema (2013) *Forane 1233zd Blowing Agent: Technical Profile*.

[77] UNEP (2011) HFCS: A CRITICAL LINK IN PROTECTING CLIMATE AND THE OZONE LAYER – A UNEP SYNTHESIS REPORT, 29.

[78] Schwarz W., *et al.* (September 2011), PREPARATORY STUDY FOR A REVIEW OF REGULATION (EC) NO 842/2006 ON CERTAIN FLUORINATED GREENHOUSE GASES, FINAL REPORT, Annex IV: Global Data/Input Sheets; *see also* Zeiger B., *et al.* (2014) ALTERNATIVES TO HCFCS/HFCS IN DEVELOPING COUNTRIES WITH A FOCUS ON HIGH AMBIENT TEMPERATURES.

[79] Schwarz W., *et al.* (September 2011), PREPARATORY STUDY FOR A REVIEW OF REGULATION (EC) NO 842/2006 ON CERTAIN FLUORINATED GREENHOUSE GASES, FINAL REPORT, Annex IV: Global Data/Input Sheets.

[80] Schwarz W. *et al.* (September 2011), PREPARATORY STUDY FOR A REVIEW OF REGULATION (EC) NO 842/2006 ON CERTAIN FLUORINATED GREENHOUSE GASES, FINAL REPORT, Annex VI Abatement technologies by sectors; *see also* Zeiger B., *et al.* (2014) ALTERNATIVES TO HCFCS/HFCS IN DEVELOPING COUNTRIES WITH A FOCUS ON HIGH AMBIENT TEMPERATURES ("An analysis by sectors shows that a climate-friendly replacement for the current and future of HCFCs and high GWP HFCs is possible in most applications: • 55% of HCFCs can be replaced by natural refrigerants and foam blowing agents and additional 13% by unsaturated HFCs (i.e. HFOs) in the short term. • 22% of HCFCs can be replaced in the short term by HFCs with moderate GWP and by HFCHFO blends in the medium term. • Alternatives for the remainder are not yet available at the same efficiency level and at feasible cost. Here, low GWP solutions are expected by 2025.")

[81] UNEP (2011) HFCS: A CRITICAL LINK IN PROTECTING CLIMATE AND THE OZONE LAYER – A UNEP SYNTHESIS REPORT *citing* Montreal Protocol Technology and Economic Assessment Panel (2011) REPORT OF THE REFRIGERATION, AIR CONDITIONING AND HEAT PUMP TECHNICAL OPTIONS COMMITTEE: 2010 ASSESSMENT.

[82] Rajadhyaksha D. (2013) *Development and Handling of Hydrocarbon Air-Conditioners – The Godrej Experience* (Godrej & Boyce Mfg. Co. Ltd presentation at Bangkok Technology Conference, 29 June 2013); *see also* Press Release, Godrej Appliances, *Godrej Appliances Raises the Bar for Energy Efficient Products in India* (20 March 2012); Press Release, Godrej Appliances, *Godrej Appliances Starts a Global Revolution with Its Green Air Conditioners* (3 April 2012); *and* Press Release, Indian Bureau of Energy Efficiency, *Energy Performance Standards for Air Conditioners Comprehensively Upgraded in India* (2 May 2012).

[83] Chin L. (2013) *Recent Developments in Low GWP Refrigerants for Air Conditioning and Refrigeration Applications* (Honeywell presentation at Bangkok Technology Conference, 29 June 2013).

[84] Stanga M. (2013) *Update on R32 Air-conditioning and Heat Pump Manufacturing and Sales -Progress Since Last OEWG in Bangkok 2012* (Daiken Industries, Ltd presentation at Bangkok Technology Conference, 29 June 2013).

[85] U.S. EPA (2013) BENEFITS OF ADDRESSING HFCS UNDER THE MONTREAL PROTOCOL, 20-21; *see also* CCAC (2014) LOW-GWP ALTERNATIVES IN COMMERCIAL REFRIGERATION: PROPANE, CO_2, AND HFO CASE STUDIES.

[86] U.S. EPA (2013) BENEFITS OF ADDRESSING HFCS UNDER THE MONTREAL PROTOCOL, 20-21; *see also* CCAC (2014) LOW-GWP ALTERNATIVES IN COMMERCIAL REFRIGERATION: PROPANE, CO_2, AND HFO CASE STUDIES.

[87] UNEP (2015) DISTRICT ENERGY IN CITIES: UNLOCKING THE POTENTIAL OF ENERGY EFFICIENCY AND RENEWABLE ENERGY, 11 ("The development of modern (i.e., energy-efficient and climate-resilient) and affordable district energy systems in cities is one of the least-cost and most-efficient solutions for reducing greenhouse gas emissions and primary energy demand. A transition to such systems, combined with energy efficiency measures, could contribute as much as 58 per cent of the carbon dioxide (CO2) emission reductions required in the energy sector by 2050 to keep global temperature rise to within 2–3 degrees Celsius…. District energy is a proven energy solution that has been deployed for many years in a growing number of cities worldwide. In several European cities, such as Copenhagen (Denmark), Helsinki (Finland) and Vilnius (Lithuania), nearly all of the required heating and cooling is supplied via district networks. The largest district cooling capacity is in the United States, at 16 gigawatts-thermal (GWth), followed by the United Arab Emirates (10 GWth) and Japan (4 GWth).").

[88] Yabase H. (2013) *District Cooling-Experience and Opportunities in case of Absorption Chiller* (Kawasaki Thermal Engineering Co., Ltd presentation at Bangkok Technology Conference, 29 June 2013).

[89] U.S. EPA (2013) BENEFITS OF ADDRESSING HFCS UNDER THE MONTREAL PROTOCOL, 20-21; *see also* Climate and Clean Air Coalition (CCAC) to Reduce Short-lived Climate Pollutants (2014) LOW-GWP ALTERNATIVES IN COMMERCIAL REFRIGERATION: PROPANE, CO_2, AND HFO CASE STUDIES; Council on Energy, Environment & Water, Institute for Governance & Sustainable Development, Natural Resources Defense Council, and The Energy and Resources Institute (TERI), in cooperation with the Confederation of Indian Industry (2013) COOLING INDIA WITH LESS WARMING: THE BUSINESS CASE FOR PHASING DOWN HFCS IN ROOM AND VEHICLE AIR CONDITIONERS; Andersen S. O., Baker J. A., Craig T., and Kapoor S. H. (2014) *The New Business Case for Secondary Loop Mobile A/C Systems (SL-MACs)*, ATA ITALIAN TECHNICAL MAGAZINE. 67:17-29; *and* Myhre G., *et al.* (2013)

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[90] U.S. EPA (2014) *Global Warming Potentials and Ozone Depletion Potentials of Some Ozone-Depleting Substances and Alternatives Listed by the SNAP Program*.

[91] Myhre G., *et al.* (2013) CHAPTER 8: ANTHROPOGENIC AND NATURAL RADIATIVE FORCING, *in* IPCC (2013) CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS , Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Table 8.A.1.

[92] Myhre G., *et al.* (2013) CHAPTER 8: ANTHROPOGENIC AND NATURAL RADIATIVE FORCING, *in* IPCC (2013) CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS , Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Table 8.A.1; *and* Arkema (2013) *Forane 1233zd, a Low Global Warming Potential Blowing Agent for Polyurethane Applications* (presentation at the 4th Ozone2Climate Technology Roadshow and Industry Roundtable, 6-9 November 2013).

[93] Carvalho S., *et al.* (2014) ALTERNATIVES TO HIGH-GWP HYDROFLUOROCARBONS, 38.

[94] Shah N., Wei M., Letschert V., & Phadke A., (2015) BENEFITS OF LEAPFROGGING TO SUPEREFFICIENCY AND LOW GLOBAL WARMING POTENTIAL REFRIGERANTS IN AIR CONDITIONING, Ernest Orlando Lawrence Berkeley National Laboratory, 26 (Table 9 "Relative contribution to overall GHG benefits from efficiency versus refrigerant transition").

[95] Zeiger B., *et al.* (2014) ALTERNATIVES TO HCFCS/HFCS IN DEVELOPING COUNTRIES WITH A FOCUS ON HIGH AMBIENT TEMPERATURES ("An analysis by sectors shows that a climate-friendly replacement for the current and future of HCFCs and high GWP HFCs is possible in most applications: • 55% of HCFCs can be replaced by natural refrigerants and foam blowing agents and additional 13% by unsaturated HFCs (i.e. HFOs) in the short term. • 22% of HCFCs can be replaced in the short term by HFCs with moderate GWP and by HFCHFO blends in the medium term. • Alternatives for the remainder are not yet available at the same efficiency level and at feasible cost. Here, low GWP solutions are expected by 2025.")

[96] Zeiger B, *et al.* (2014) ALTERNATIVES TO HCFCS/HFCS IN DEVELOPING COUNTRIES WITH A FOCUS ON HIGH AMBIENT TEMPERATURES.

[97] Oak Ridge National Laboratory (2015) *Alternative Refrigerant Evaluation for High-Ambient Temperature Environments: R-22 and R-41A Alternatives for Mini-Split Air Conditioners*, 35 ("This performance evaluation shows that viable replacements exist for both R-22 and R-410A at high ambient temperatures. Multiple alternatives for R-22 performed well, and most R-410A alternatives matched or exceeded the performance of R-410A.").

[98] *See, e.g.*, *Davos 2014: Achim Steiner Insider Diary* (25 January 2014) Guardian Sustainable Business Blog (statement by UN Under-Secretary General and Executive Director of the UN Environment Programme Achim Steiner: "Next came 'short-lived climate pollutants' - part of this years' Davos focus on climate change. After working in UNEP for five years to mature cutting edge science into options for action, one of those Davos moments happened. Major business leaders and public officials agreed to join hands in moving on HFCs, methane and black carbon, which drive global warming but also affect our health and economies. Its like teeth wheels clicking into place - you know you have changed gears.").

[99] Consumer Goods Forum (2013) BETTER LIVES THROUGH BETTER BUSINESS; *and* Press Release, Consumer Goods Forum, *3rd Refrigeration Summit Warms Retailers to Uptake of Natural Refrigeration Systems* (5 June 2013) ("Reducing the use of HFC refrigerants is high on the CGF sustainability agenda due to their impact on global warming.").

[100] Air-Conditioning, Heating, and Refrigeration Institute *AHRI Responds to President Obama's Climate Change Plan* (2 July 2013) ("'AHRI supports the continued efforts by the United States and its North American partners to engage in discussions at the Montreal Protocol, especially the North American amendment regarding the future of HFCs…'").

[101] European Fluorocarbon Technical Committee [EFTC] (2012) *HFC Producers Support Action Under the Montreal Protocol for a Consumption Cap and Reduction of HFCs* (31 Oct. 2012) ("[EFTC] would like to take the opportunity to encourage Parties to the Montreal Protocol to move forward with a constructive dialogue to achieve an agreement for a global cap and reduction for HFC consumption on a GWP-weighted basis.") The members of the EFTC are Mexichem Flour, Arkema, DuPont, Solvay Fluor, and Honeywell Fluorine Products. It is a sector group of The European Chemical Industry Council.

[102] Refrigerants, Naturally! *Refrigerants, Naturally! Calls for An Immediate HFC-Phasedown Under the Montreal Protocol* (June 2013) (Refrigerants, Naturally! members, including PepsiCo, Red Bull, Coca-Cola, and Unilever, "support the proposed amendments to include HFCs in the Montreal Protocol in cooperation with the UNFCCC. An international agreement to bring HFCs into the regulatory regime of the Montreal Protocol would be an important step towards a phase-down and eventual phase-out of these substances.").

[103] The Alliance for Responsible Atmospheric Policy (2011) INDUSTRY ACTIONS TO RESPONSIBLY MEET SOCIETY'S NEEDS: REFRIGERATION, AIR CONDITIONING, THERMAL INSULATION AND OTHER APPLICATIONS ("The Alliance for Responsible Atmospheric Policy (Alliance) supports a planned, orderly global phasedown of substances with high global warming potentials (GWPs), improved application energy efficiency, leakage reduction, and recovery/reuse or destruction at application end-of-life.").

[104] Press Release, White House, *FACT SHEET: Obama Administration and Private-Sector Leaders Announce Ambitious Commitments and Robust Progress to Address Potent Greenhouse Gases* (15 October 2015). The companies and organizations that pledged HFC reductions include: Chemours, Daikin Industries Ltd., Danfoss, Demilec, Dow Chemical, Fomo Products,

Hillphoenix, Honeywell, Johnson Controls, Inc, NCFI Polyurethanes, Roundy's Supermarkets, Inc, Target, Thermo Fisher Scientific, The Alliance for Responsible Atmospheric Policy, The Air Conditioning, Heating and Refrigeration Institute (AHRI); see also Press Release, White House, *FACT SHEET: Obama Administration Partners with Private Sector on New Commitments to Slash Emissions of Potent Greenhouse Gases and Catalyze Global HFC Phase Down.* (16 September 2014). In 2014, 12 companies and organizations also pledged HFC reductions, including: The Alliance for Responsible Atmospheric Policy, Air Conditioning Heating & Refrigeration Institute, Arkema, Coca-Cola, Carrier, Danfross, DuPont, Emerson Climate Technologies, Goodman Manufacturing Company, Hillphoenix, Honeywell, Johnson Controls, Kroger, Lapolla, Los Angeles Department of Water and Power (LADWP), Mission Pharmacal, PepsiCo, Red Bull, SEVO Systems, Target, Thermo King, & True Manufacturing.

[105] DuPont *DuPont Position Statement on Montreal Protocol* (10 June 2013) ("…DuPont is now engaged in advocacy work to add hydrofluorocarbons (HFCs) to the Montreal Protocol.").

[106] DuPont *Opteon Refrigerant Has Low GWP;* (2013); *see also* Press Release, Honeywell (29 March 2007) *DuPont, Honeywell Announce Refrigerants Global Joint Venture Agreement* (29 March 2007) ("DuPont and Honeywell today announced a global joint development agreement to accelerate the development and commercialization of next generation, low global warming refrigerants for the automotive air conditioning industry.").

[107] CCAC (2014) LOW-GWP ALTERNATIVES IN COMMERCIAL REFRIGERATION: PROPANE, CO_2, AND HFO CASE STUDIES.

[108] Refrigerants, Naturally! *History and Achievements.* (2013).

[109] Coca-Cola Cooler Choice: Freezing Out HFC In Favor Of Natural Refrigerant (22 January 2014) (Coca-Cola reports that "we have placed the 1 millionth HFC-free cooler, using natural refrigerant, in the marketplace. This marks significant progress toward our 2015 system-wide goal for all new cold-drink equipment to be HFC-free.").

[110] Refrigerants Naturally! PepsiCo (2013); Red Bull (2013) *Efficient Cooling*; Unilever (2014) *Targets & Performance*; Fleury J-M (2011) *Roll out and Experience of Natural Refrigerants based technology at Carrefour*, presentation at ATMOsphere Europe 2011, Brussels, 11-12 October 2011; *and* U.S. EPA (2013) BENEFITS OF ADDRESSING HFCS UNDER THE MONTREAL PROTOCOL ("Sanyo has produced CO_2 compressors since 2001, originally developed for heat pump water heaters. Using this technology, Sanyo developed the first CO_2 vending machine, which was field tested in February 2004 in Australia. Results from these tests showed that the CO_2 system consumed 17% less energy compared to the comparable HFC-134a system during the summer season. Beginning in 2005, CO_2 vending machines began being sold in Japan and have represented a significant and growing portion of the Japanese market—estimated at 116,000 units in 2010.").

[111] The Consumer Goods Forum (2012) *The CGF Good Practices About HFC-Refrigeration and Energy Efficiency*; *see also* U.S. EPA (2013) BENEFITS OF ADDRESSING HFCS UNDER THE MONTREAL PROTOCOL, ("Sobeys, Canada's second largest food retailer, installed its first transcritical CO_2 system in July 2006 and has plans to implement the technology in all of its 1,300 stores in 15 years […] Supervalu opened an ammonia-based refrigeration system in their Albertsons store in Carpinteria, California in 2012, the first in the United States.").

[112] Myhre G., *et al.* (2013) CHAPTER 8: ANTHROPOGENIC AND NATURAL RADIATIVE FORCING, *in* IPCC (2013) CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS, Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Table 8.A.1.

[113] Myhre G., *et al.* (2013) CHAPTER 8: ANTHROPOGENIC AND NATURAL RADIATIVE FORCING, *in* IPCC (2013) CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS , Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Table 8.A.1; *see also* Hodnebrog O., *et al.* (2013) *Global warming potentials and radiative efficiencies of halocarbons and related compounds: A comprehensive review*, REV. GEOPHYS. 51(2):300-378, Table 5.

[114] Press Release, Whirlpool Corporation, *Whirlpool Corporation Partners with Honeywell, Announces Use of Next Generation Solstice® Liquid Blowing Agent in U.S. Refrigerators* (22 January 2014) ("Whirlpool Corporation announced it has implemented the use of Honeywell's Solstice® Liquid Blowing Agent [HFO-1233zd(E)], into its environmentally responsible and energy efficient insulation used in U.S.-made refrigerators and freezers. The global warming potential (GWP) of the new foam blowing agent is 99.9% lower than 245fa the most common foam blowing agent widely used within the U.S. industry, resulting in a more environmentally-responsible household refrigerator. The conversion of all U.S. manufacturing centers is scheduled to be completed by the end of 2014 and the impact to the global warming effect will be the equivalent of removing more than 400,000 cars from the road.").

[115] Refrigerants Naturally! (2013) *PepsiCo*.

[116] Press Release, Coca-Cola, *Coca-Cola Installs 1 Millionth HFC-Free Cooler Globally, Preventing 5.25MM Metric Tons of CO_2* (22 January 2014); *see also* Coca-Cola (2013) *Cooling Equipment: Pushing Forward with HFC-Free*.

[117] Red Bull (2013) *Efficient Cooling*; *see also* Refrigerants Naturally! (2014) *Red Bull*.

[118] Unilever (2014) *Targets & Performance.*

[119] Hydrocarbons21 (2012) *McDonald's Europe Installs Over 3,300 Pieces of HFC-free Refrigeration Equipment*.

[120] The Consumer Goods Forum (2012) *The CGF Good Practices About HFC-Refrigeration and Energy Efficiency*.

[121] The Consumer Goods Forum (2012) *The CGF Good Practices About HFC-Refrigeration and Energy Efficiency*.

[122] Sobeys (2012) *Sustainability Scorecard for 2012*.

[123] Press Release, Whirlpool Corporation, *Whirlpool Corporation Partners with Honeywell, Announces Use of Next Generation Solstice® Liquid Blowing Agent in U.S. Refrigerators* (22 January 2014) ("Whirlpool Corporation announced it has implemented the use of Honeywell's Solstice® Liquid Blowing Agent [HFO-1233zd(E)], into its environmentally responsible and energy efficient insulation used in U.S.-made refrigerators and freezers. The global warming potential (GWP) of the new foam blowing agent is 99.9% lower than 245fa the most common foam blowing agent widely used within the U.S. industry, resulting in a more environmentally-responsible household refrigerator. The conversion of all U.S. manufacturing centers is scheduled to be completed by the end of 2014 and the impact to the global warming effect will be the equivalent of removing more than 400,000 cars from the road." Honeywell further states that its new product will improve energy efficiency by 2% over HFC-245fa, and by 10-12% over hydrocarbon (Cyclopentane).").

[124] U.S. EPA (2014) INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990-2012; *and* European Environment Agency (2013) FLUORINATED GREENHOUSE GASES 2012; China Association of Fluoride and Silicone Organic Industry (CAFSI); Zhang J. & C. Wang (2014) *China's hydrofluorocarbons challenge*, NATURE CLIMATE CHANGE 4:943-945; *and* European Environment Agency (2013) FLUORINATED GREENHOUSE GASES 2012.

[125] China State Council (2014) 2014-2015 Energy Conservation, Emissions Reduction and Low Carbon Development Action Plan (in Chinese) ("为确保全面完成'十二五'节能减排降碳目标, 制定本行动方案……加强对氢氟碳化物（HFCs）排放的管理，加快氢氟碳化物销毁和替代，'十二五'期间累计减排 2.8 亿吨二氧化碳当量.") (English translation: "The action plan is made in order to meet all the energy conservation and emission reduction targets set for the twelfth five year period…. Strengthen the management of HFCs emission. Accelerate the destruction and replacement of HFCs. The total emission reduction of HFCs should reach 0.28 billion tonnes CO_2-eq during the twelfth five year period.").

[126] China State Council (2014) 2014-2015 Energy Conservation, Emissions Reduction and Low Carbon Development Action Plan (in Chinese); *see also* Zhang J. & C. Wang (2014) *China's hydrofluorocarbons challenge*, NATURE CLIMATE CHANGE 4:943-945.

[127] E.U. (2014) *Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated gases and repealing Regulation (EC) No 842/2006*; see also Press Release, Council of the European Union, *Council Adopts Regulation On Fluorinated Greenhouse Gases* (14 April 2014); and Press Release, European Parliament, *Cooling Without Climate Warming: Parliament Backs F-gas Ban* (12 March 2014).

[128] *See e.g.*, European Commission (2013) IMPLEMENTATION OF DIRECTIVE 2006/40/EC – STATE OF PLAY.

[129] Executive Office of the President (2013) THE PRESIDENT'S CLIMATE ACTION PLAN, 10 ("Hydrofluorocarbons (HFCs), which are primarily used for refrigeration and air conditioning, are potent greenhouse gases. In the United States, emissions of HFCs are expected to nearly triple by 2030, and double from current levels of 1.5 percent of greenhouse gas emissions to 3 percent by 2020. To reduce emissions of HFCs, the United States can and will lead both through international diplomacy as well as domestic actions. In fact, the Administration has already acted by including a flexible and powerful incentive in the fuel economy and carbon pollution standards for cars and trucks to encourage automakers to reduce HFC leakage and transition away from the most potent HFCs in vehicle air conditioning systems. Moving forward, the Environmental Protection Agency will use its authority through the Significant New Alternatives Policy Program to encourage private sector investment in low-emissions technology by identifying and approving climate-friendly chemicals while prohibiting certain uses of the most harmful chemical alternatives. In addition, the President has directed his Administration to purchase cleaner alternatives to HFCs whenever feasible and transition over time to equipment that uses safer and more sustainable alternatives."); *See also* Bianco N. *et al*. (2013) CAN THE U.S. GET THERE FROM HERE?: USING EXISTING FEDERAL LAWS AND STATE ACTION TO REDUCE GREENHOUSE GAS EMISSIONS, World Resources Institute, 1.

[130] In 2013, Congressman Peters (D-California) introduced the *Super Pollutant Emissions Reduction Act of 2013*. This was followed by the Senate *Super Pollutants Act of 2014*, introduced by a bipartisan team of senators Murphy (D-Connecticut) and Collins (R-Maine). *See* H.R. 1943 (2013) SUPER Act of 2013, 113th Congress 1st Session (introduced); *and* S. 14456 (2014) Super Pollutants Act of 2014, 113th Congress 2nd Session. In addition, 16 members of the U.S. Congress sent a letter in December 2013 urging U.S. EPA Administrator Gina McCarthy to use the agency's authority to reduce the use of HFCs in the U.S. ("We are writing to ask your agency to pursue commonsense policies that accelerate the replacement phasedown of hydrofluorocarbons (HFCs) in this country and globally. … We encourage you to focus your agency on HFC applications where technology solutions and alternative products are already available or soon to be in the market, similar to what the European Union has done with their Mobile Air Conditioning Directive. The agency should look to where market transitions are already underway and where EPA action could hasten the pace of those transitions, both domestically and elsewhere. We think that such actions would not only have significant cost-effective environmental benefits but would also strengthen the Administration's hand in the Montreal Protocol negotiations.") Press Release, Office of U.S. Senator for Delaware Tom Carper, *Members of Congress Urge EPA Administrator McCarthy to Reduce Use of Harmful Climate Change-Causing Pollutant* (4 December 2013).

[131] U.S. EPA (2015) *Protection of Stratospheric Ozone: Change of Listing Status for Certain Substitutes under the Significant New Alternatives Policy Program*, 40 CFR Part 82.

[132] The White House Office of the Press Secretary, *EO 13693 Planning for Federal Sustainability in the Next Decade* (19 March 2015) ("Through a combination of more efficient Federal operations such as those outlined in this Executive Order (order), we have the opportunity to reduce agency direct greenhouse gas emissions by at least 40 percent over the next decade while at the same time fostering innovation, reducing spending, and strengthening the communities in which our Federal facilities operate. *** ii) purchasing sustainable products and services identified by EPA programs including: (A) Significant New Alternative Policy

(SNAP) chemicals or other alternatives to ozone-depleting substances and high global warming potential hydrofluorocarbons, where feasible, as identified by SNAP;").

[133] U.S. Federal Register, *Federal Acquisition Regulation; High Global Warming Potential Hydrofluorocarbons* (11 May 2015) ("DoD, GSA, and NASA are proposing to amend the Federal Acquisition Regulation (FAR) to implement Executive branch policy in the President's Climate Action Plan to procure, when feasible, alternatives to high global warming potential (GWP) hydrofluorocarbons (HFCs). This will allow agencies to better meet the greenhouse gas emission reduction goals and reporting requirements of the Executive Order (E.O.) 13693 of March 25, 2015, Planning for Sustainability in the Next Decade. E.O. 13693 subsumes both E.O. 13423 of January 24, 2007, Strengthening Federal Environmental, Energy, and Transportation Management as well as E.O. 13514 of October 5, 2009, Federal Leadership in Environmental, Energy, and Economic Performance. *** This rule proposes to modify the existing FAR clauses at 52.223-11, Ozone-Depleting Substances, and 52.223-12, Refrigeration Equipment and Air Conditioners, to address high GWP HFCs, as well as ozone-depleting substances. In addition, the rule proposes to add two new clauses specifically focused on use of alternatives, where feasible, in place of high GWP HFCs in aerosol cans (as propellants or solvents) and as foam blowing agents.").

[134] U.S. EPA (2010) *EPA and NHTSA Finalize Historic National Program to Reduce Greenhouse Gases and Improve Fuel Economy for Cars and Trucks*. See generally Institute for Governance & Sustainable Development, National Resource Defense Council, & Council on Energy, Environment & Water (March 2014) *Update on the HFC phase-down in Mobile Air Conditioning: Global automakers moving to HFO-1234yf, except some German automakers waiting for CO_2 systems*. Eliminating U.S. HFC consumption could provide nearly a quarter of the reductions needed to reach the U.S.'s 2020 emissions reduction goal (17% below 2005 emissions). Bianco N. et al. (2013), CAN THE U.S. GET THERE FROM HERE?: USING EXISTING FEDERAL LAWS AND STATE ACTION TO REDUCE GREENHOUSE GAS EMISSIONS, World Resources Institute, 3–4.

[135] California Air Resources Board (2014) Reducing Short-Lived Climate Pollutants in California: Fighting climate change and protecting public health ("F-gases - Regulations adopted under AB 32 will reduce emissions 25 percent by 2020. Consumer uses: Consumer product regulations are reducing F-gas emissions from small containers of automotive refrigerant and aerosol propellants. Large refrigeration systems: The Refrigerant Management Program requires inspections, registration, and repairs to avoid leaks from large refrigeration systems. Offset protocol for 'ODS' gases: The Cap-and-Trade program includes an offset protocol for the recovery and destruction of ozone-depleting substances from used appliances. Automotive refrigerant improvements: California's Low Emission Vehicle Standards provide credit for the use of refrigerants with lower global warming potentials and from avoiding leaks in new vehicles.").

[136] CA SB-605 (2014) *Short-lived climate pollutants*, ("SECTION 1. Chapter 4.2 ("*** no later than January 1, 2016, the state board shall complete a comprehensive strategy to reduce emissions of short-lived climate pollutants in the state. * * * (d) For purposes of this section, "short-lived climate pollutant" means an agent that has a relatively short lifetime in the atmosphere, from a few days to a few decades, and a warming influence on the climate that is more potent than that of carbon dioxide.").

[137] California Air Resources Board (CARB) (2015) DRAFT SHORT-LIVED CLIMATE POLLUTANT REDUCTION STRATEGY.

[138] Environmental Defense Fund (2015) *California: An Emissions Trading Case Study*, 4 (The cap-and-trade program is composed of three compliance periods. . . . The third compliance period will run from 2018 to 2020. The program applies to: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), nitrogen trifluoride and other fluorinated GHGs. The system covers approximately 450 entities.").

[139] India-California Air Pollution Mitigation Program (ICAMP), *Initiative for Mitigating Air Pollution from the Transportation Sector*, FIRST DRAFT, October 2013.

[140] India-California Air Pollution Mitigation Program (ICAMP) (2014) *Options to reduce road transport pollution in India* at xvi ("[ICAMP's] primary objectives are to improve human health and crop yields through reduction of air pollution (PM2.5, ozone, and black carbon), particularly from the road transportation sector. The secondary objective is to mitigate negative effects of regional climate change such as reductions in precipitation, warming, and melting of Himalayan glaciers. Towards this latter objective, ICAMP has a goal to target those air pollutants that also reduce radiative forcing of global warming. Such air pollutants (e.g., black carbon and gases that produce ozone) are referred to as short-lived climate pollutants (SLCP)."); *Id.*, 4 ("Black carbon and ozone, along with methane and hydrofluoro carbons (HFCs) are referred to as short-lived climate pollutants.").

[141] The Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (2014) CCAC - Initiatives.

[142] The Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (2014) Promoting HFC Alternative Technology and Standards.

[143] UNEP (2014) SUBMISSION BY PARTIES ON THE IMPLEMENTATION OF DECISION XIX/6, UNEP/OzL.Pro.WG.1/34/INF/4/Add.2; *see also* Schwarz W., *et al.* (2011) PREPARATORY STUDY FOR A REVIEW OF REGULATION (EC) NO 842/2006 ON CERTAIN FLUORINATED GREENHOUSE GASES: FINAL REPORT.

[144] The Government of Belgium (2013) BELGIUM'S SIXTH NATIONAL COMMUNICATION ON CLIMATE CHANGE UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE, 154.

[145] Comité pour la fiscalité écologique (2013) OPPORTUNITÉ D'UNE TAXATION DES FLUIDES FRIGORIGÈNES (in French); *see also* Everything R744 *HFCs to be Taxed in France?* (26 April 2013); *and* Schwarz W., *et al.* (2011) PREPARATORY STUDY FOR A REVIEW OF REGULATION (EC) NO 842/2006 ON CERTAIN FLUORINATED GREENHOUSE GASES: FINAL REPORT, 50.

[146] Bolovic L. (2012) *Implementation of recommendations, new or revised legislation/policy measures related to ODS and F-gases as part of HPMP implementation in Serbia* (presentation at Meeting on establishing ODS and F-gas legislation and review of F-gas regulation, 10-11 July 2012).

[147] Congreso de los Diputados (2013) Boletin oficial de las cortes generales congreso de los diputados, serie A, num. 51-1, BOCG-10-A-54-1 (in Spanish); *see also* Ammonia 21 (July 2013) *Spain Considers F-gas Tax at €20/tCO_2eq*.

[148] OzoneAction, *Turkey to strengthen legislation on ozone-depletion and fluorinated gases* (18 February 2013).

[149] UNEP (2014) SUBMISSION BY PARTIES ON THE IMPLEMENTATION OF DECISION XIX/6, UNEP/OzL.Pro.WG.1/34/INF/4/Add.2, 38.

[150] Brack, D (2015) NATIONAL LEGISLATION ON HYDROFLUOROCARBONS, 16 ("The government provides support for the retrofitting of refrigeration systems (specifically refrigerators) and air-conditioning systems (split, window and rooftop types) to hydrocarbons. The government also possesses the power to apply control measures to the import of HFCs, though it is not clear whether these control measures have been applied.")

[151] Brack, D (2015) NATIONAL LEGISLATION ON HYDROFLUOROCARBONS, 16 ("Seychelles is introducing a new policy on HFCs from 2015. It includes tax incentives to encourage the import of low-GWP alternatives: zero import duty and value-added tax (VAT) on substances that are both zero ODP and zero GWP, 100 per cent tax on products with very high GWPs. In addition, all new buildings, including hotels (the main users of HCFCs in Seychelles), are required to ensure that ozonesafe, low-GWP alternatives are used.")

[152] China Refrigeration Institute (2012) GB 28009-2011, Safety Codes for Cold Storage; *see also* Ammonia 21 (2012) *China Will Release the First Safety Standard for Cold Stores*; Zhou X. (2013) Policies and Regulations for Ozone Protection – Experiences from China (presentation at Bangkok Technology Conference, 21 July 2012); *and* U.S. EPA (2013) BENEFITS OF ADDRESSING HFCS UNDER THE MONTREAL PROTOCOL; *and* Ammonia 21 (July 2012) *China Will Release the First Safety Standard for Cold Stores*.

[153] UNEP (2012) Advancing Ozone and Climate Protection Technologies: Next Steps – Meeting Summary (Bankgkok, Thailand 21-22 July 2012).

[154] Honeywell (2015) HFC PHASEDOWN.

[155] Zaelke D., Andersen S. O., & Borgford-Parnell N. (2012) *Strengthening ambition for climate mitigation: the role of the Montreal Protocol in reducing short-lived climate pollutants*, REV. EUR. COMP. & INT'L ENVTL. LAW 21(3):231-242; *and* Andersen S. O., Halberstadt M. L., & Borgford-Parnell N. (2013) *Stratospheric ozone, global warming, and the principle of unintended consequences – An ongoing science and policy success story*, J. AIR & WASTE MGMT. ASS'N., 63(6):607-647.

[156] Xu Y., Zaelke D., Velders G. J. M., & Ramanathan V. (2013) *The role of HFCs in mitigating 21st century climate change*, ATMOS. CHEM. PHYS. 13:6083-6089; *see also* World Meteorological Organization and UNEP (2014) SCIENTIFIC ASSESSMENT OF OZONE DEPLETION: 2014 ("This two-year effort by 280 scientists from 36 countries calculates that the success of the Montreal Protocol has put the stratospheric ozone layer on the path to recovery in the next few decades; that it also has provided climate mitigation of "about 10 gigatonnes of avoided CO_2-equivalent emissions per year, which is about five times larger than the annual emissions reduction target for the first commitment period (2008–2012) of the Kyoto Protocol"; and that the high growth rate of HFCs threatens to cancel the treaty's past climate mitigation."). *See* note 19 and Figure 4 for calculations of total climate mitigation provided by Montreal Protocol, which is 10 to 20 times more than total for Kyoto Protocol's first commitment period.

[157] Estrada F., Perron P., & Martínez-López B. (2013) *Statistically derived contributions of diverse human influences to twentieth-century temperature changes*, NAT. GEOSCI. 6:1050–1055 ("Our statistical analysis suggests that the reduction in the emissions of ozone-depleting substances under the Montreal Protocol, as well as a reduction in methane emissions, contributed to the lower rate of warming since the 1990s.").

[158] Picolotti R. (2011) *An equitable arrangement*, *in* UNEP (2011) OUR PLANET: POWERING CLIMATE SOLUTIONS.

[159] Sarma M. S., Andersen S. O., Zaelke D., & Taddonio K. (2009) *Ozone Layer, International Protection*, *in* R. Wolfrum (ed.) (2012) THE MAX PLANCK ENCYCLOPEDIA OF PUBLIC INTERNATIONAL LAW; *see also* Andersen S. O. & Sarma K. M. (2002) PROTECTING THE OZONE LAYER: THE UNITED NATIONS HISTORY, 59-60; *and* Hunter D., Salzman J., & Zaelke D. (2011) (4th ed) INTERNATIONAL ENVIRONMENTAL LAW AND POLICY,, 544 and 578.

[160] Velders G. J. M., *et al.* (2007) *The importance of the Montreal Protocol in protecting climate*, PROC. NAT'L. ACAD. SCI. U.S.A. 104:4814-4819.

[161] UNEP (2014) REPORT OF THE TENTH MEETING OF THE CONFERENCE OF THE PARTIES TO THE VIENNA CONVENTION FOR THE PROTECTION OF THE OZONE LAYER AND THE TWENTY-SIXTH MEETING OF THE PARTIES TO THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER, UN Doc UNEP/OzL.Conv.10/7 ("[The parties agree] [t]o adopt a budget for the Multilateral Fund for the Implementation of the Montreal Protocol for 2015–2017 of $507,500,000 on the understanding that $64,000,000 of that budget will be provided from anticipated contributions due to the Multilateral Fund and other sources for the 2012-2014 triennium, and that $6,000,000 will be provided from interest accruing to the Fund during the 2015–2017 triennium."); *and* UNEP (2012) REPORT OF THE SIXTY-FIFTH MEETING OF THE EXECUTIVE COMMITTEE OF THE MULTILATERAL FUND FOR THE IMPLEMENTATION OF THE MONTREAL PROTOCOL, UN Doc. UNEP/OzL.Pro/ExCom/65/60/Corr.1, Annex 1.

[162] UNEP (2014) REPORT OF THE TENTH MEETING OF THE CONFERENCE OF THE PARTIES TO THE VIENNA CONVENTION FOR THE PROTECTION OF THE OZONE LAYER AND THE TWENTY-SIXTH MEETING OF THE PARTIES TO THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER.

[163] Sarma M. S., Andersen S. O., Zaelke D., & Taddonio K. (2009) *Ozone Layer, International Protection*, *in* R. Wolfrum (ed.) (2012) THE MAX PLANCK ENCYCLOPEDIA OF PUBLIC INTERNATIONAL LAW; *see also* UNEP Ozone Secretariat (2013) *Assessment Panels*; *and* Andersen. S. O. & Sarma, K. M. (2002) PROTECTING THE OZONE LAYER: THE UNITED NATIONS HISTORY, 59-60; *and* Hunter D., Salzman J., & Zaelke D. (2011) INTERNATIONAL ENVIRONMENTAL LAW AND POLICY, 4th ed., 544 and 578.

[164] UNEP (2011) *Compliance Assistance Programme, Regional Networks of National Ozone Units*.

[165] Sarma M. S., Andersen S. O., Zaelke D., & Taddonio K. (2009) *Ozone Layer, International Protection*, *in* R. Wolfrum (ed.) (2012) THE MAX PLANCK ENCYCLOPEDIA OF PUBLIC INTERNATIONAL LAW; and UNEP Ozone Secretariat (2013) *The Assessment Panels* ; *see also* Andersen. S. O. & Sarma, K. M. (2002) PROTECTING THE OZONE LAYER: THE UNITED NATIONS HISTORY, 59-60; *and* Hunter D., Salzman J., & Zaelke D. (2011) INTERNATIONAL ENVIRONMENTAL LAW AND POLICY, 4th ed., 544 and 578.

[166] Sarma M. S., Andersen S. O., Zaelke D., & Taddonio K. (2009) *Ozone Layer, International Protection*, *in* R. Wolfrum (ed.) (2012) THE MAX PLANCK ENCYCLOPEDIA OF PUBLIC INTERNATIONAL LAW; *see also* Andersen S. O. & Sarma K. M. (2002) PROTECTING THE OZONE LAYER: THE UNITED NATIONS HISTORY, 59-60; *and* Hunter D., Salzman J., & Zaelke D. (2011) INTERNATIONAL ENVIRONMENTAL LAW AND POLICY, 4th ed., 544 and 578.

[167] Sarma, M. S., Andersen S. O., Zaelke D., & Taddonio K. (2009) *Ozone Layer, International Protection*, *in* R. Wolfrum (ed.) (2012) THE MAX PLANCK ENCYCLOPEDIA OF PUBLIC INTERNATIONAL LAW; *and* Andersen S. O. & Sarma K. M. (2002) PROTECTING THE OZONE LAYER: THE UNITED NATIONS HISTORY, 59-60.

[168] Zaelke D., Andersen S. O., & Borgford-Parnell N. (2012) *Strengthening ambition for climate mitigation: the role of the Montreal Protocol in reducing short-lived climate pollutants*, REV. EUR. COMP. & INT'L ENVTL. LAW 21(3):231-242.

[169] Proposed amendment to the Montreal Protocol submitted by Canada, Mexico and the United States of America, UNEP/OzL.Pro.WG.1/35/3 (8 March 2015) ("Cumulative benefits of the HFC phasedown estimated by the U.S. Government are about 1,900 million metric tons of carbon dioxide equivalent (MMT CO2eq) through 2020, and about 84,100 MMTCO2eq through 2050. • Cumulative benefits from HFC-23 byproduct emissions controls as estimated by the U.S. Government amount to an additional 11,300 MMTCO2eq through 2050.").

[170] Öko-Recherche GmbH, *et al.* (2010) PREPARATORY STUDY FOR THE REVIEW OF REGULATION (EC) NO 842/2006 ON CERTAIN FLUORINATED GREENHOUSE GASES - WORKING DOCUMENT 1 - COVERING PRELIMINARY RESULTS FROM ONGOING ANALYSIS (TASKS 1-3), 53 ("The lower range is calculated on the basis of historic cost effectiveness criteria of the MLF applied under the present HCFC phase out. The upper cost range is based on the experts' estimates of actual incremental costs for conversions in each subsector and take into consideration that some of the low GWP alternatives to HFCs (such as HC and CO2) require more expensive transition and system changes similar to the approved HCFC guidelines.").

[171] Öko-Recherche GmbH, *et al.* (2010) PREPARATORY STUDY FOR THE REVIEW OF REGULATION (EC) NO 842/2006 ON CERTAIN FLUORINATED GREENHOUSE GASES - WORKING DOCUMENT 1 - COVERING PRELIMINARY RESULTS FROM ONGOING ANALYSIS (TASKS 1-3), 53 ("The lower range is calculated on the basis of historic cost effectiveness criteria of the MLF applied under the present HCFC phase out. The upper cost range is based on the experts' estimates of actual incremental costs for conversions in each subsector and take into consideration that some of the low GWP alternatives to HFCs (such as HC and CO2) require more expensive transition and system changes similar to the approved HCFC guidelines.").

[172] European Union (2014) ENABLING A GLOBAL PHASE-DOWN OF HFCS, A DISCUSSION PAPER SUBMITTED BY THE EUROPEAN UNION ("The EU fully supports an amendment of the Montreal Protocol to achieve a global phase down of the consumption and production of hydrofluorocarbons (HFCs). Non-Article 5 countries, as major consumers of HFCs, must take the lead in this effort. At the same time, the EU believes that a broader base of support for an HFC amendment to the Montreal Protocol could be built up by more directly addressing the different situations in Article 5 and non-Article 5 countries in their progress in phasing-out HCFCs. The respective commitments have to respond to specific national circumstances, such as climate conditions and the expected growth of the refrigeration and air conditioning sector."). In 2013 the European Union also called on the UNFCCC parties to support a phasedown of HFCs under the Montreal Protocol. European Union, SUBMISSION BY LITHUANIA AND THE EUROPEAN COMMISSION ON BEHALF OF THE EUROPEAN UNION AND ITS MEMBER STATES (16 September 2013) ("We must build upon and widen the support of G20 Leaders to phase down HFCs under the Montreal Protocol. As such we call on all Parties to the UNFCCC for their support, and would like to see this discussed specifically in Warsaw in the context of ADP WS2.").

[173] European Union (2014) ENABLING A GLOBAL PHASE-DOWN OF HFCS, A DISCUSSION PAPER SUBMITTED BY THE EUROPEAN UNION (Version 6 November 2014) ("The respective commitments have to respond to specific national circumstances, such as climate conditions and the expected growth of the refrigeration and air conditioning sector. The EU believes that it would be consistent with the Montreal Protocol's design to consider for: *** a freeze of the combined HCFCs and HFCs consumption on the basis of the combined climate impacts of HCFC and HFC expressed in CO_2 equivalent, beginning in [2019], while maintaining the existing HCFC phase-out schedule for consumption and production. The longer-term phase-down of the combined consumption of these chemicals in Article 5 countries would be agreed in the coming years.").

[174] Proposed amendment to the Montreal Protocol submitted by Canada, Mexico and the United States of America, UNEP/OzL.Pro.WG.1/35/3 (8 March 2015).

[175] Proposed amendment to the Montreal Protocol submitted by India, UNEP/OzL.Pro.WG.1/35/4 (17 April 2015).

[176] Process to regulate the production and consumption of hydrofluorocarbons under the Montreal Protocol on Substances that Deplete the Ozone Layer – Submission by Zimbabwe and Senegal on behalf of Africa States, UNEP/OzL.Pro.WG.1/35/CRP.1 (20 April 2015) ("Requests the Open-ended Working Group at its thirty-sixth meeting in July 2015: 1. To agree to establish a contact group to consider proposals to amend the Montreal Protocol, including those that have been submitted for consideration by the Meeting of the Parties.").

[177] Proposed amendment to the Montreal Protocol submitted by European Union and its Member States, UNEP/OzL.Pro.WG.1/36/5 (30 April 2015).

[178] Proposed amendment to the Montreal Protocol submitted by Kiribati, Marshall Islands, Mauritius, Micronesia (Federated States of), Palau, Philippines, Samoa and Solomon Islands, UNEP/OzL.Pro.WG.1/36/6 (30 April 2015).

[179] Additional mitigation is possible when banks of HFCs are collected and destroyed, with about 39–64 $GtCO_2$-eq available if this is done in 2020. *See* Velders G. J. M., *et al.* (2007) *The importance of the Montreal Protocol in protecting climate*, PROC. NAT'L. ACAD. SCI. U.S.A. 104:4814-4819; *and* Velders G. J. M., *et al.* (2014) *Growth of climate change commitments from HFC banks and emissions*, ATMOS. CHEM. PHYS. DISCUSS. 14:4563-4572 ("If, for example, HFC production were to be phased out in 2020 instead of 2050, not only could about 91–146GtCO2-eq of cumulative emission be avoided from 2020 to 2050, but an additional bank of about 39–64 GtCO2-eq could also be avoided in 2050.").

[180] UNEP (2015) Decision XXVII/1: Dubai Pathway on Hydrofluorocarbons (HFCs) ("Work within the Montreal Protocol to an HFC amendment in 2016 by first resolving challenges by generating solutions in the contact group on the feasibility and ways of managing HFCs at Montreal Protocol meetings"). *See also* UNEP News Centre (2015) *Montreal Protocol Parties Devise Way Forward to Protect Climate Ahead of Paris COP21* ("The parties agreed to work together, within the Montreal Protocol, towards an HFC amendment in 2016 by first resolving challenges and generating solutions in the contact group on the feasibility and ways of managing HFCs at Montreal Protocol meetings. This outcome was agreed after extensive negotiations during the 27th Meeting of the Parties (MOP27) to the Protocol, hosted by the Government of the United Arab Emirates in Dubai from 1 to 5 November.").

[181] UNEP (2015) Decision XXVII/1: Dubai Pathway on Hydrofluorocarbons (HFCs) ("Recognize the progress made at the 27th MOP on the challenges identified in the contact group mandate agreed at the resumed 36th OEWG (contained at Annex 1) on feasibility and ways of managing HFCs, including development of a common understanding on issues related to flexibility of implementation, 2nd and 3rd stage conversions, guidance to the ExCom, enabling activities for capacity building, and the need for an exemption for high ambient temperature countries; and endorse the concepts in Annex 2."). *See also* IISD Reporting Services (2015) *Summary of the Twenty-Seventh Meeting of the Parties to the Montreal Protocol: 1–5 November 2015* Earth Negotiations Bulletin 19(115) ("MOP 27 immediately followed the two-day resumed session of the 36th Open-ended Working Group (OEWG 36), which had agreed on a mandate for a contact group on the feasibility and ways of managing hydrofluorocarbons (HFCs). The contact group was established and HFCs were the "major topic" under debate throughout the week.").

[182] UNEP (2015) Decision XXVII/1: Dubai Pathway on Hydrofluorocarbons (HFCs) ("Recognize that further progress still needs to be made in particular with respect to other challenges identified in the contact group mandate, for example conversion costs, technology transfer and intellectual property rights."). *See also* IISD Reporting Services (2015) *Summary of the Twenty-Seventh Meeting of the Parties to the Montreal Protocol: 1–5 November 2015* Earth Negotiations Bulletin 19(115) ("Following protracted negotiations that finally concluded in the early hours of Friday morning, parties agreed to a "roadmap" for negotiating an HFC amendment; this agreement included provision for an additional OEWG meeting and an extraordinary MOP in 2016."). *See also* UNEP News Centre (2015) *Montreal Protocol Parties Devise Way Forward to Protect Climate Ahead of Paris COP21* ("The parties recognized the progress made at MOP27 on discussing the challenges on feasibility and ways of managing HFCs, on issues related to flexibility of implementation, second and third stage conversions, guidance to the Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol, enabling activities for capacity building, and the need for an exemption for high ambient temperature countries. Further progress still needs to be made with respect to other challenges. The parties will continue their deliberations in 2016 with a series of Open-Ended Working Group meetings and others, including an extraordinary Meeting of the Parties.").

[183] G8 (2009) G8 DECLARATION: RESPONSIBLE LEADERSHIP FOR A SUSTAINABLE FUTURE ("66. We recognize that the accelerated phase-out of HCFCs mandated under the Montreal Protocol is leading to a rapid increase in the use of HFCs, many of which are very potent GHGs. Therefore we will work with our partners to ensure that HFC emissions reductions are achieved under the appropriate framework. We are also committed to taking rapid action to address other significant climate forcing agents, such as black carbon. These efforts, however, must not draw away attention from ambitious and urgent cuts in emissions from other, more long-lasting, greenhouse gases, which should remain the priority.").

[184] UNEP (2009) DECLARATION ON HIGH-GWP ALTERNATIVES TO ODSS, *in* UNEP (2009) REPORT OF THE TWENTY-FIRST MEETING OF THE PARTIES TO THE MONTREAL PROTOCOL ON SUBSTANCES THE DEPLETE THE OZONE LAYER (The 2009 Declaration was signed by Angola, Cameroon, Canada, Chad, Comoros, Congo, Dominican Republic, Egypt, Fiji, Gabon, Grenada, Guinea Bissau, Indonesia, Japan, Kiribati, Madagascar, Marshall Islands, Mali, Mauritania, Mauritius, Mexico, Micronesia, Morocco, Namibia, New Zealand, Nigeria, Papau New Guinea, Palau, Saint Lucia, Solomon Islands, Somalia, Sudan, Switzerland, Timor-Leste, Togo, Tonga, Tunisia, United States, Zambia.).

[185] UNEP (2010) DECLARATION ON THE GLOBAL TRANSITION AWAY FROM HYDROCHLOROFLUOROCARBONS (HCFCS) AND CHLOROFLUOROCARBONS (CFCS); *see also* UNEP (2011) REPORT OF THE COMBINED NINTH MEETING OF THE CONFERENCE OF THE PARTIES TO THE VIENNA CONVENTION ON THE PROTECTION OF THE OZONE LAYER AND THE TWENTY-THIRD MEETING OF THE PARTIES TO THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER, para. 155-157; *and* UNEP (2012) REPORT OF THE

TWENTY-FOURTH MEETING OF THE PARTIES TO THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER, para 188.

[186] Climate and Clean Air Coalition to Reduce Short Lived Climate Pollutants (2014) *Executive Summary*.

[187] Press Release, The White House Office of the Press Secretary (2012) *Fact Sheet: G-8 Action on Energy and Climate Change* ("In the spirit of increasing mitigation efforts, we agree to collectively join the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants, launched on February 16, 2012. This new initiative will enhance our collective ambition in addressing climate change by complementing efforts to address CO_2 emissions. By developing strategies to reduce short term pollutants – chiefly methane, black carbon, and hydroflurocarbons – we can help reduce global warming, improve health, and increase agricultural productivity, as well as energy security"); *and* Press Release, The White House Office of the Press Secretary (2012) *Camp David Declaration*.

[188] United Nations (2012) RESOLUTION ADOPTED BY THE GENERAL ASSEMBLY: THE FUTURE WE WANT, A/RES/66/288 ("222. We recognize that the phase-out of ozone-depleting substances is resulting in a rapid increase in the use and release of high global-warming potential hydrofluorocarbons to the environment. We support a gradual phase-down in the consumption and production of hydrofluorocarbons.").

[189] UNEP Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol (2013) REPORT OF THE SIXTY-NINTH MEETING OF THE EXECUTIVE COMMITTEE, Ozl.Pro/ExCom/69/40, 30; *and* Press Release, Multilateral Fund for the Implementation of the Montreal Protocol, Multilateral Fund approves landmark project for China with ozone and climate benefits – up to $385 million of funding over the next 17 years (22 April 2013) ("In a landmark decision the Multilateral Fund's Executive Committee has agreed to provide China, the largest producer and consumer of HCFCs, an amount up to US $385 million for the entire elimination of its industrial production of ozone depleting substances (ODS) by the year 2030").

[190] China State Council (2014) 2014-2015 Energy Conservation, Emissions Reduction and Low Carbon Development Action Plan (in Chinese).

[191] European Council (2013) SUBMISSION BY IRELAND AND THE EUROPEAN COMMISSION OF THE EUROPEAN UNION AND ITS MEMBER STATES ("The 2011 Bali Declaration under the Montreal Protocol lists 112 signatories committed to explore further and pursue effective means of transitioning to environmentally friendly alternatives to high GWP HFCs.").

[192] Arctic Council Secretariat (2013) *Kiruna Declaration: On the occasion of the Eighth Ministerial Meeting of the Arctic Council*. Further support for addressing HFCs is expressed in the 2012 *G8 Camp David Declaration* (focusing on the package of four short-lived climate pollutants, which includes HFCs); the 2009 *G8 Declaration* ("Therefore we will work with our partners to ensure that HFC emissions reductions are achieved under the appropriate framework."); *and* the 2008 *Declaration of Leaders* from the Major Economies Meeting on Energy Security and Climate Change. ("To enable the full, effective, and sustained implementation of the Convention between now and 2012, we will: … Continue to promote actions under the Montreal Protocol on Substances That Deplete the Ozone Layer for the benefit of the global climate system…").

[193] Press Release, The White House Office of the Press Secretary, *United States and China Agree to Work Together on Phase - Down of HFCs* (8 June 2013).

[194] Executive Office of the President (2013) THE PRESIDENT'S CLIMATE ACTION PLAN (mentioning the Significant New Alternatives Policy Program as a policy tool to "encourage private sector investment in low-emissions technology by identifying and approving climate-friendly chemicals while prohibiting certain uses of the most harmful chemical alternatives"); *and* Press Release, The White House Office of the Press Secretary *Remarks by the President on Climate Change* (25 June 2013). *See also* Bianco N., *et al.* (2013) CAN THE U.S. GET THERE FROM HERE?: USING EXISTING FEDERAL LAWS AND STATE ACTION TO REDUCE GREENHOUSE GAS EMISSIONS, World Resources Institute, 1 (In the U.S., "Eliminating HFCs represents the biggest opportunity for GHG emissions reductions behind power plants," and would provide 23% of the emissions reductions needed to achieve the U.S.'s 2020 reduction goal (17% below 2005 emissions)).

[195] IISD Reporting Services (2013) *Summary of the Thirty-third Meeting of the Open-ended Working Group of the Parties to the Montreal Protocol on Substances That Deplete the Ozone Layer: 24-28 June 2013*, EARTH NEGOTIATIONS BULLETIN 19(94) 1, 10.

[196] Press Release, Republic of South Africa Department of Environmental Affairs, *Joint Statement Issued at the Conclusion of the 15th BASIC Ministerial Meeting on Climate Change* (28 June 2013).

[197]Press Release, U.S. Department of State, *U.S.-China Climate Change Working Group Fact Sheet* (10 July 2013); *see also* Press Release, U.S. Department of State, *Report of the U.S.-China Climate Change Working Group to the Strategic and Economic Dialogue* (10 July 2013) ("Additionally, President Barack Obama and President Xi Jinping made the announcement on June 8, 2013 that the United States and China agreed to work together and with other countries through multilateral approaches that include using the expertise and institutions of the Montreal Protocol to phase down the production and consumption of HFCs, while continuing to include HFCs within the scope of UNFCCC and its Kyoto Protocol provisions for accounting and reporting of emissions. The Working Group will work effectively to carry forward this effort."); *and* Press Release, U.S. Department of State, *U.S.-China Strategic and Economic Dialogue V Strategic Track Select Outcomes* (12 July 2013) ("They will also work together to implement the agreement of Presidents Obama and Xi on HFCs.").

[198] Pacific SWIDS Regional Preparatory Meeting (2013) The Nadi Outcome Document: Accelerating Integrated Approach to Sustainable Development (emphasis added).

[199] Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (2013) COMMUNIQUÉ OF THE THIRD MEETING OF THE HIGH LEVEL ASSEMBLY.

[200] Press Release, White House Office of the Press Secretary, *United States and China Reach Agreement on Phase Down of HFCs* (6 September 2013).

[201] The St. Petersburg *G20 Leaders' Declaration* includes Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, United Kingdom, United States, and the European Union, as well as support from invited observer countries: Ethiopia, Spain, Senegal, Brunei, Kazakhstan, and Singapore. G20 (2013) G20 Leaders' Declaration.

[202] Press Release, Republic of South Africa Department of Environmental Affairs, *Joint Statement Issued at the Conclusion of the 16th BASIC Ministerial Meeting on Climate Change* (16 September 2013) (The BASIC countries were silent on HFCs this year. *See* India Ministry of Environment & Forests, *Joint Statement on the 18th BASIC Ministerial Meeting on Climate Change* (8 August 2014)); *see also* UNEP (2013) REPORT OF THE THIRTY-THIRD MEETING OF THE OPEN-ENDED WORKING GROUP OF THE PARTIES TO THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER, 21-22. ("155. Several representatives raised concerns over the level of financial support that would need to be available [for an HFC phasedown under the Montreal Protocol], especially given developing countries" limited resources and competing priorities for public funding. Several representatives raised their concern over the availability of funding for both HCFC phase-out and potential HFC phase-down and one representative highlighted the inadequate amounts that his country had thus far received for assisting with HCFC phase-out […] 160. Several representatives from high-ambient-temperature regions explained that the matter of the availability of [HFC] alternatives was a particular concern to them. In their countries, summer temperatures could reach as high as 55° C; in such circumstances, air conditioning was not a luxury but a necessity. Concerns over flammability and safety further limited the availability of alternatives to HFCs […] 162. Several representatives, from parties operating under paragraph 1 of Article 5 and from parties not so operating, underlined the need for the latter to take the lead in demonstrating the technical and economic feasibility of new alternatives.").

[203] Press Release, White House Office of the Press Secretary, *U.S.-India Joint Statement* (27 September 2013) ("They also supported complementary initiatives, through multilateral approaches that include using the expertise and the institutions of the Montreal Protocol to phase down the production and the consumption of HFCs, based on the examination of economically viable and technically feasible alternatives. They will continue to include HFCs within the scope of UNFCCC and its Kyoto Protocol for accounting and reporting of emissions…. Recognizing that climate change is a defining challenge of our time and that there are mutual benefits to intensifying cooperation," the two leaders also announced an India-U.S. Climate Change Working Group "to develop and advance action-oriented cooperation, as well as to begin an enhanced dialogue focusing on working closely in developing an ambitious climate change agreement for the post-2020 period….").

[204] Press Release, White House Office of the Press Secretary, *Fact Sheet: The United States and India – Strategic and Global Partners* (27 September 2013).

[205] Press Release, Environmental News Network, *Steady March Towards Action on Reducing HFCs Under Montreal Protocol* (25 October 2013). In the decision requesting action by the TEAP, the Parties agreed to: (1) estimate current and future demand for alternatives, including HFCs, and also requested an assessment of the economic costs and implications, and environmental benefits of various scenarios that avoid high-GWP alternatives to currently used ODS, including, HFCs; (2) convene a workshop back-to-back with the 34th OEWG in summer 2014 to continue discussions on HFC management; (3) provide to the Ozone Secretariat, on a voluntary basis, information regarding the avoidance of HFCs under the existing HCFC phase-out; and (4) request the Executive Committee of the Multilateral Fund to consider whether additional demonstration projects to validate low-GWP alternatives and technologies, and additional activities to maximize the climate benefits in the HCFC production sector, would be useful in assisting developing country Parties in further minimizing the environmental impacts of the HCFC phase-out. UNEP (2013) DRAFT REPORT OF THE TWENTY-FIFTH MEETING OF THE PARTIES TO THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER, UNEP/Ozl.Pro.25/L.1; *see also* UNEP (2013) DRAFT DECISION XXV/[X[: RESPONSE TO THE REPORT BY THE TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL ON INFORMATION ON ALTERNATIVES TO OZONE-DEPLETING SUBSTANCES.

[206]Press Release, Council of the European Union, *21st E.U.-Japan Summit Joint press statement* (19 November 2013).

[207] Press Release, White House Office of the Vice President, *U.S. Fact Sheet on Strengthening U.S.-China Economic Relations* (5 December 2013).

[208] Press Release, White House Office of the Press Secretary, *Fact Sheet: U.S. Cooperation with France on Protecting the Environment, Building a Clean Energy Economy, and Addressing Climate Change* (11 February 2014).

[209] Press Release, White House Office of the Press Secretary, *Joint Statement by North American Leaders - 21st Century North America: Building the Most Competitive and Dynamic Region in the World* (19 February 2014).

[210] U.S. Department of State Official Blog (2014) *We Need To Elevate the Environment in Everything We Do* ("This challenge demands elevated urgency and attention from all of us… Here's what this guidance means in practice: I. Lead by example through strong action at home and abroad … at the federal, regional, and local level. II. Conclude a new international climate change agreement … applicable to all countries by 2015 to take effect in 2020. III. Implement The Global Climate Change Initiative…. IV. Enhance multilateral engagement … including the Major Economies Forum, Clean Energy Ministerial, Montreal Protocol, and the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants. V. Expand bilateral engagement … on clean energy…. VI. Mobilize financial resources … and leverage billions of dollars of funding to transform our energy economies and promote sustainable land use, as well as working to limit public incentives for high-carbon energy production and fossil fuels. VII. Integrate climate change with other priorities…, including women's empowerment, urbanization, conflict and national security.

and our own management and operations."). *See also* U.S. Department of State, *Fact Sheet: Addressing Climate Change: A Top U.S. Priority* (5 March 2014).

[211] Press Release, Council of the European Union, *E.U.-U.S. Summit: Joint Statement* (26 March 2014).

[212] Press Release, European Commission, *Joint Statement: Deepening the E.U.-China Comprehensive Strategic Partnership for mutual benefit* (31 March 2014), para. 18; *see also* para. 10 (where the E.U. and China "reaffirmed their commitment to implement their G20 commitments.").

[213]Press Release, The White House Office of the Press Secretary, *The Brussels G-7 Summit Declaration* (5 June 2014) (The G-7 includes Canada, France, Germany, Italy, Japan, the U.K. the U.S., the President of the European Council, and the President of the European Commission.).

[214] Press Release, U.S. Department of State, *Joint U.S.-China Press Statements at the Conclusion of the Strategic & Economic Dialogue* (10 July 2014) ("We are working together to phase down the production and the consumption of hydrofluorocarbons, which is a potent greenhouse gas.").

[215] UNEP (2014) REPORT OF THE THIRTY-FOURTH MEETING OF THE OPEN-ENDED WORKING GROUP OF THE PARTIES TO THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER ("the Working Group agreed that interested parties would hold an informal discussion, facilitated by Ms. Gudi Alkemade (Netherlands) and Mr. Obed Meringo Baloyi (South Africa), on the management of HFCs, including the legal and technical issues raised at previous meetings and during the HFC management workshop, and develop options for addressing the issues raised, including the relationship between the Montreal Protocol and the Framework Convention on Climate Change and its Kyoto Protocol."). ; *see also* International Institute for Sustainable Development (2014) *Workshop on Hydrofluorocarbon (HFC) Management and Thirty-forth meeting of the Open-ended Working Group (OEWG 34) of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer*.

[216] UNEP (2014) WORKSHOP ON HYDROFLUOROCARBON MANAGEMENT: CONLCUSIONS AND IDENTIFICATION OF FURTHER DISCUSSION POINTS, SUMMARY BY THE RAPPORTEURS; *see also* International Institute for Sustainable Development (2014) *Workshop on Hydrofluorocarbon (HFC) Management and Thirty-fouth meeting of the Open-ended Working Group (OEWG 34) of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer*.

[217] CCAC, *Climate and Clean Air Coalition now open to private sector partners* (17 July 2014); *see also* International Institute for Sustainable Development (2014) *Working Group meeting of the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC)*.

[218] CCAC, (2014) *UN Climate Summit commitments to reduce short-lived climate pollutants and their impacts in Oil & Gas, Green Freight, HFCs Alternatives, and Municipal Solid Waste*.

[219] CCAC, (2014) *UN Climate Summit commitments to reduce short-lived climate pollutants and their impacts in Oil & Gas, Green Freight, HFCs Alternatives, and Municipal Solid Waste*.

[220] Press Statement, The White House, *U.S.-India Joint Statement* (30 September 2014). ("They pledged to urgently arrange a meeting of their bilateral task force on HFCs prior to the next meeting of the Montreal Protocol to discuss issues such as safety, cost, and commercial access to new or alternative technologies to replace HFCs. The two sides would thereafter cooperate on next steps to tackle the challenge posed by HFCs to global warming.") *see also* U.S. Department of State, *U.S.-India Energy and Climate Change Cooperation* (30 September 2014).

[221] UNEP (2014) DECISION XXVI/9: RESPONSE TO THE REPORT BY THE TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL ON INFORMATION ON ALTERNATIVES TO OZONE-DEPLETING SUBSTANCES.

[222] UNEP (2014) DECISION XXVI/10: 2015-2017 REPLENISHMENT OF THE MULTILATERAL FUND. ("1. To adopt a budget for the Multilateral Fund for the Implementation of the Montreal Protocol for 2015–2017 of $507,500,000 on the understanding that $64,000,000 of that budget will be provided from anticipated contributions due to the Multilateral Fund and other sources for the 2012-2014 triennium, and that $6,000,000 will be provided from interest accruing to the Fund during the 2015–2017 triennium. The parties note that outstanding contributions from some parties with economies in transition in the period 2012–2014 stands at $8,237,606;").

[223] Press Release, The White House, *U.S.-India Joint Statement साँझा प्रयास - सबका विकास" – "Shared Effort; Progress for All"* (25 January 2015) ("The President and Prime Minister reaffirmed their prior understanding from September 2014 concerning the phase down of HFCs and agreed to cooperate on making concrete progress in the Montreal Protocol this year."). *See also* The White House, *Fact Sheet: U.S. and India Climate and Clean Energy Cooperation* (25 January 2015) ("The United States and India agreed on:…Cooperating on Hydroflurocarbons (HFCs): Building on their prior understandings from September 2014 concerning the phasedown of HFCs, the leaders agreed to cooperate on making concrete progress in the Montreal Protocol this year.").

[224] *Cairo Declaration on Managing Africa's Natural Capital for Sustainable Development and Poverty Eradication* (6 March 2015) ("43. To urge member States to use the experience, expertise and institutions of the Montreal Protocol on Substances that Deplete the Ozone Layer to phase down the production and consumption of HFCs while continuing to use other existing mechanisms for accounting and reporting of emissions of these substances; 44. To request the parties to the Montreal Protocol on Substances that Deplete the Ozone Layer to work towards establishing an open-ended contact group during its meetings in 2015 onwards to consider, among other things, financial and technological support to Africa to manage HFCs that might result in phasing down the production and consumption of HFCs, taking into account the cost-effectiveness and safety of substitutes and environmental benefits;").

[225] Proposed amendment to the Montreal Protocol submitted by Canada, Mexico and the United States of America, UNEP/OzL.Pro.WG.1/35/3 (8 March 2015).

[226] Proposed amendment to the Montreal Protocol submitted by Canada, Mexico and the United States of America, UNEP/OzL.Pro.WG.1/35/3 (8 March 2015) ("Similar to the 2014 North American proposal, this revised amendment proposal has the potential to produce environmental benefits of more than 90 gigatons of carbon dioxide equivalent (C02eq) cumulatively by 2050 which is equal to roughly two years of emissions of all anthropogenic greenhouse gases at current emission levels. Therefore, this proposal represents our ideas on how we could avoid rapid HFC growth and achieve substantial environment benefits. We welcome other ideas that we know will be forthcoming and we look forward to working with others to achieve an outcome that is acceptable to all countries.").

[227] Proposed amendment to the Montreal Protocol submitted by India, UNEP/OzL.Pro.WG.1/35/4 (17 April 2015).

[228] Proposed amendment to the Montreal Protocol submitted by India, UNEP/OzL.Pro.WG.1/35/4 (17 April 2015).

[229] Process to regulate the production and consumption of hydrofluorocarbons under the Montreal Protocol on Substances that Deplete the Ozone Layer – Submission by Zimbabwe and Senegal on behalf of Africa States, UNEP/OzL.Pro.WG.1/35/CRP.1 (20 April 2015) ("Requests the Open-ended Working Group at its thirty-sixth meeting in July 2015: 1. To agree to establish a contact group to consider proposals to amend the Montreal Protocol, including those that have been submitted for consideration by the Meeting of the Parties.").

[230] IISD Reporting Services, Summary of The Workshop on Hydrofluorocarbon Management and the Thirty-Fifth Meeting of The Open-Ended Working Group of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer (27 April 2015) ("On Friday afternoon Co-Chair Paul Krajnik resumed plenary. The EU informed parties that the informal consultation led to an agreement to continue intersessional discussions, in an informal manner, to study the feasibility and ways of managing HFCs, with a view to the establishment of a contact group on feasibility and ways of managing HFCs at OEWG 36. The intersessional discussions are to examine a list of related challenges, including inter alia: energy efficiency; funding requirements; safety of substitutes; availability of technologies; performance and challenges in high-ambient temperatures; capacity building; non-party trade; synergies with the UNFCCC; the relationship to the HCFCs phase-out; ecological effects; implications for human health; social implications; challenges to the production sector; exemptions and ways to address lack of alternatives; and technology transfer.").

[231] All the information on the Workshop on Hydrofluorocarbon Management including pre-session documents and presentations can be found on the website of Montreal Protocol Secretariat.

[232] Proposed amendment to the Montreal Protocol submitted by European Union and its Member States, UNEP/OzL.Pro.WG.1/36/5 (30 April 2015).

[233] Proposed amendment to the Montreal Protocol submitted by Kiribati, Marshall Islands, Mauritius, Micronesia (Federated States of), Palau, Philippines, Samoa and Solomon Islands, UNEP/OzL.Pro.WG.1/36/6 (30 April 2015).

[234] G-7 (2015) LEADERS' DECLARATION G7 SUMMIT – THINK AHEAD, ACT TOGETHER, 13.

[235] Ozone Secretariat, *Proposal of the Co-Convenors* (13 June 2015).

[236] European Council and Council of the European Union, *EU-China Joint Statement on Climate Change* (29 June 2015).

[237] The White House Office of the Press Secretary, *U.S.-Brazil Joint Statement on Climate Change* (30 June 2015).

[238] IISD Reporting Services (2015) *Summary Highlights of the Meeting of the 36th Meeting of the Open-Ended Working Group of the Parties to the Montreal Protocol: 20-14 July 2015*.

[239] Ministry of Foreign Affairs Government of Pakistan, *2015 Joint Statement By President Barak Obama And Prime Minister Nawaz Sharif* (22 October 2015); *see also* The White House Office of the Press Secretary, *2015 Joint Statement By President Barak Obama And Prime Minister Nawaz Sharif* (22 October 2015) ("Further, to advance global efforts to address a leading cause of climate change, President Obama and Prime Minister Sharif affirmed that their respective countries intend to work together to amend the Montreal Protocol this year to curb the production and consumption of hydrofluorocarbons.").

[240] UNEP (2015) Decision XXVII/1: Dubai Pathway on Hydrofluorocarbons (HFCs) ("Recognize the progress made at the 27th MOP on the challenges identified in the contact group mandate agreed at the resumed 36th OEWG (contained at Annex 1) on feasibility and ways of managing HFCs, including development of a common understanding on issues related to flexibility of implementation, 2nd and 3rd stage conversions, guidance to the ExCom, enabling activities for capacity building, and the need for an exemption for high ambient temperature countries; and endorse the concepts in Annex 2."). *See also* IISD Reporting Services (2015) *Summary of the Twenty-Seventh Meeting of the Parties to the Montreal Protocol: 1–5 November 2015* Earth Negotiations Bulletin 19(115) ("MOP 27 immediately followed the two-day resumed session of the 36th Open-ended Working Group (OEWG 36), which had agreed on a mandate for a contact group on the feasibility and ways of managing hydrofluorocarbons (HFCs). The contact group was established and HFCs were the "major topic" under debate throughout the week.").

[241] UNEP (2015) Decision XXVII/1: Dubai Pathway on Hydrofluorocarbons (HFCs) ("Work within the Montreal Protocol to an HFC amendment in 2016 by first resolving challenges by generating solutions in the contact group on the feasibility and ways of managing HFCs at Montreal Protocol meetings"). *See also* UNEP News Centre (2015) *Montreal Protocol Parties Devise Way Forward to Protect Climate Ahead of Paris COP21* ("The parties agreed to work together, within the Montreal Protocol, towards an HFC amendment in 2016 by first resolving challenges and generating solutions in the contact group on the feasibility and ways

of managing HFCs at Montreal Protocol meetings. This outcome was agreed after extensive negotiations during the 27th Meeting of the Parties (MOP27) to the Protocol, hosted by the Government of the United Arab Emirates in Dubai from 1 to 5 November.").

[242] UNEP (2015) Decision XXVII/1: Dubai Pathway on Hydrofluorocarbons (HFCs) ("Hold a series of OEWG and other meetings, including an Extraordinary Meeting of Parties in 2016."). *See also* IISD Reporting Services (2015) *Summary of the Twenty-Seventh Meeting of the Parties to the Montreal Protocol: 1–5 November 2015* Earth Negotiations Bulletin 19(115) ("Following protracted negotiations that finally concluded in the early hours of Friday morning, parties agreed to a "roadmap" for negotiating an HFC amendment; this agreement included provision for an additional OEWG meeting and an extraordinary MOP in 2016.").