Primer on Hydrofluorocarbons

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Institute for Governance & Sustainable Development

IGSD Working Paper: November 2013

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Acknowledgements
We thank our outside reviewers for their valuable contributions.

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IGSD's mission is to promote just and sustainable societies and to protect the environment by advancing the understanding, development, and implementation of effective, accountable, and democratic 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, to complement 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 capture, reuse, and store CO_2 after it is emitted, including biosequestration and strategies to turn biomass into more stable forms of carbon for long-term storage.

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1. Summary

The first volume of the IPCC's *Fifth Assessment Report* released September 2013 concludes that climate change is unequivocal, significantly caused by human activities, occurring faster and with impacts that are more severe than anticipated, 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 climate pollutant, hydrofluorocarbons (HFCs), 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. They are factory-made gases used in air conditioning, refrigeration, foam insulation, and other specialized sectors. World leaders recognized the threat posed by the growth of HFCs in the outcome document of the Rio +20 Summit in 2012 and called for the gradual phase-down of their production and consumption. Six countries, with the support of more than 100 others, have submitted proposals to undertake such a phase-down under the Montreal Protocol. Support for this approach is growing rapidly, including most recently from the leaders of the G20 largest economies. A phase-down of HFCs under the Montreal Protocol would prevent up to 0.5°C warming by 2100, using a treaty that has the experience and expertise to ensure that reductions are fast, effective, and efficient. In addition, an HFC phase-down under the Montreal Protocol would catalyze significant energy efficiency gains in air conditioning and refrigeration systems, in the range of 30 to 60%, and significantly reduce carbon dioxide (CO_2) emissions. An HFC phase-down under the Montreal Protocol will provide a level playing field for producers and consumers in lieu of a patchwork of regional and national regulations. It also will build momentum for a successful climate agreement under the UNFCCC in 2015 to go into effect in 2020. Indeed, this simple step to protect the climate is the acid test for all multilateral climate efforts.

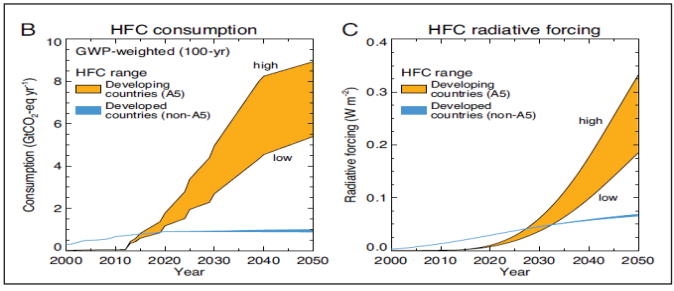
2. High growth rates for HFCs will cause significant warming

The current high growth rate for HFCs will cause significant future warming. While HFCs have caused less than 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.[2] HFC growth is accelerating as they replace chlorofluorocarbons (CFCs), which were previously phased out under the Montreal Protocol, and hydrochlorofluorocarbons (HCFCs), which are now being phased out.[3]

Without fast action, HFCs 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.[4] Continued growth in HFCs will add up to 0.1°C of global average temperature rise by mid-century, which will increase five-fold to 0.5°C by 2100.[5] HFCs and other fluorinated greenhouse gases, which include sulfurhexafluoride (SF_6) and perfluorocarbons (PFCs), are the fastest growing climate pollutants in many countries, including the U.S., EU, Australia, China, and India.[6]

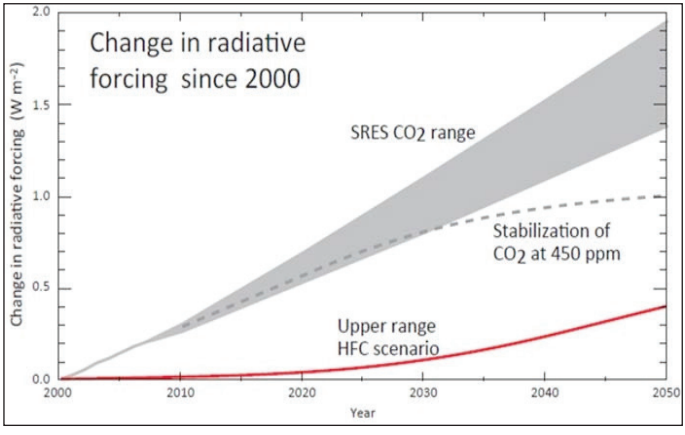
If left unchecked, by 2050, annual HFC emissions could be equivalent to 20% of annual CO_2 emissions under a business-as-usual (BAU) scenario, and up to 40% of annual CO_2 emissions under a 450 ppm CO_2 stabilization scenario.[7] Without fast action, by 2050, uncontrolled growth in HFCs would cancel much of the climate benefit achievable under an aggressive CO_2 450 ppm mitigation scenario. (In Fig. 2, *compare* radiative forcing reduced from CO_2 mitigation to radiative forcing increased from HFC growth.)

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



Velders G. J. M. *et al.* (2009), *The large contribution of projected HFC emissions to future climate forcing*, PROC. NAT'L. ACAD. SCI. USA 106:10949.

Fig. 2: 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. 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.

3. Phasing down HFCs will prevent significant warming

Phasing down HFCs will avoid up to 0.5°C of warming by 2100 under a high HFC growth scenario, and up to 0.35°C under a low HFC growth scenario; avoiding this warming is essential for staying within the long-term international goal of stabilizing

global temperature rise at or below 2°C over pre-industrial temperatures by the end-of-century (*see* Fig. 3).[8] Phasing down HFCs will prevent the equivalent of up to 8.8 billion tonnes of CO_2 *per year* in emissions by 2050 (*see* Fig. 1); by 2050, the cumulative total will be equivalent to 100 billion tons of CO_2-eq in avoided emissions (with a range of 76-134 billion) (*see* Fig. 4).[9]

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 (*see* Fig. 3).[10]

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."[11]

Reducing HFCs and the other SLCPs can significantly reduce future climate impacts, including slowing sea-level rise. Recent research led by Professor Veerabhadran Ramanathan at Scripps Institution of Oceanography, University of California, San Diego, calculates that reducing 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.[12] Combined SLCP and CO_2 mitigation can reduce cumulative sea-level rise by 31% in 2100.[13] 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).[14]

Fig. 3: 21st Century warming prevented by SLCP and CO_2 mitigation

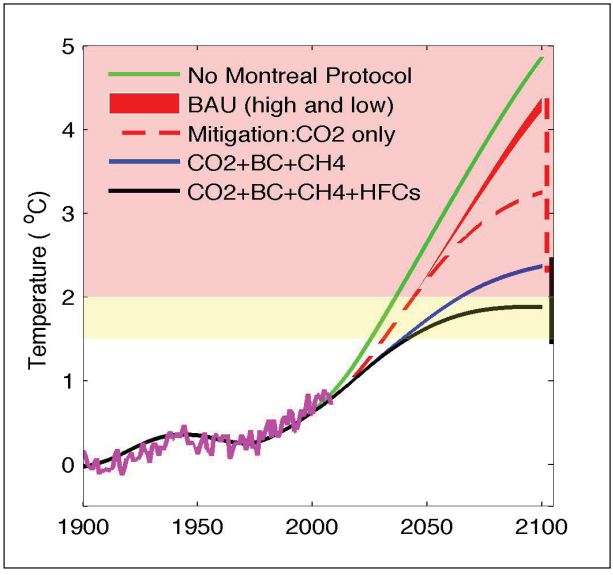


Figure 3 depicts model simulated temperature change under various mitigation scenarios that include CO_2 and SLCPs (BC, CH_4, HFCs). BAU case (red solid line with spread) considers both high and low estimates of future HFC growth. Note this uncertainty of temperature projection related to HFC scenarios 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. Xu Y., Zaelke D., Velders G. J. M., & Ramanathan, V. (June 2013) *The role of HFCs in mitigating 21st century climate change*, Atmos. Chem. Phys. 13:6083-6089.

4. Phasing down HFCs will catalyze significant gains in energy efficiency and additional climate benefits from CO_2 reductions

In addition to the direct climate benefits from HFC mitigation, a global HFC phase-down 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. 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.[15]

The phase-out 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.[16] These efficiency improvements were the result of replacing old products and equipment with a new generation of higher efficiency machines.[17] When refrigeration and air conditioning manufacturers redesigned their systems to be CFC-free, many took the opportunity to improve the efficiency of their designs.[18] For example, the U.S. Environmental Protection Agency estimated that CFC-free chillers were up to 50% more energy efficient in the U.S. and over 30% more efficient in India than the CFC-based machines they replaced.[19]

Similar energy efficiency improvements are expected with an HFC phase-down. A number of global companies that are already transitioning away from HFCs report significant gains in energy efficiency. For example, the Coca-Cola Company and PepsiCo have both reported energy efficiency gains of up to 47% in their new CO_2 and hydrocarbon-based refrigeration equipment over baseline HFC-based models.[20] Global supermarket chains Tesco

and Unilever both report a 10% gain from new hydrocarbon-based commercial refrigeration equipment and freezer cabinets over HFC-models.[21]

Although there have already been improvements in the efficiency of air conditioning and refrigeration equipment over the last several decades, substantial potential still remains. For example, a 2013 assessment by the Super-efficient Equipment and Appliance Deployment Initiative (SEAD) found that deploying super-efficient air conditioners can significantly reduce energy use and CO_2 emissions by 2020 and avoid the need for approximately123 medium-sized (500-megawatt) power plants, with the largest potential savings in India, China, and the EU (*see* Table 1).[22] A recent study by the U.S. Department of Energy's Lawrence Berkeley National Laboratory calculates that, in India alone, the potential energy savings from improving the energy efficiency of room air conditioning could avoid the equivalent of 120 new medium-sized coal power plants in 2030.[23]

The energy efficiency gains catalyzed by the HFC amendment will have the added benefit of easing pressure on aging electricity grids, especially in developing countries where air conditioning use is growing rapidly; in many cities in India, for example, air conditioning accounts for 40 to 60% of peak electricity demand during the summer months.[24] The efficiency gains also would lower the cost of operating the equipment and save consumers money.[25]

Table 1: Energy savings potential from deployment of super-efficient room A/C[26]

Country	Economically Justified 2020 Energy Savings (3Twh/year)*	Technically Possible 2020 Energy Savings (3Twh/year)*
India	19	29
China	16	33
EU	11	30
Japan	8	9
Brazil	6	10
UAE	2	2
Korea	1	4
Australia	0.35	2
USA	0.2	0.24
Mexico	0.15	1
Russia	0	4
Canada	0	0.24
Total	**64**	**123**

* 3Twh/year is roughly equivalent to one 500 MW power plant or 1.77 million barrels of diesel[27]

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

The Montreal Protocol has the experience and expertise to ensure a fast, effective, and efficient phase-down 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

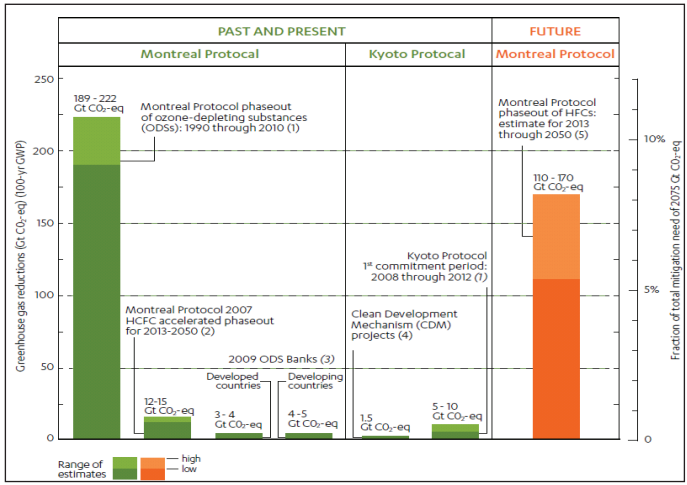
the HCFCs currently being phased out.[28] Because all CFCs and HCFCs are also greenhouse gases, between 1990 and 2010 the Montreal Protocol reduced CO_2-eq emissions nearly twenty times more than the 5 to 10 billion tonnes of CO_2-eq reduction goal of the first commitment period of the Kyoto Protocol (*see* Fig. 4).

The Montreal Protocol has universal ratification and has demonstrated robust implementation of the principle of "common but differentiated responsibilities."[29] This includes having developed countries undertake control measures first, followed by a grace period before developing countries are required to act, often up to 10 years, with funding for the cost of the developing country phase-out provided by the Multilateral Fund (MLF).[30] Since it was established in 1991, the MLF has provided more than U.S. $3 billion in funding.[31] The Montreal Protocol has an in-depth understanding of all sectors it finances, including detailed knowledge of technical options.[32] The Montreal Protocol also supports institutional strengthening for all 147 developing country Parties.[33] The combination of these features has allowed all Parties to comply with the control measures; to date, the Parties have phased out 97% of nearly 100 damaging chemicals.[34]

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.[35] 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.[36]

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.[37]

Fig. 4: Climate protection of the Montreal Protocol and the Kyoto Protocol



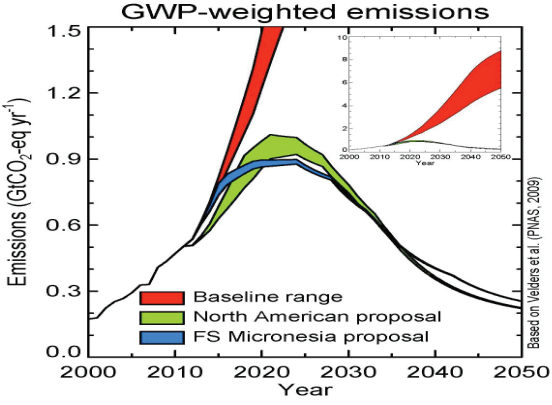
Source: UNEP (2012) THE MONTREAL PROTOCOL AND THE GREEN ECONOMY: ASSESSING THE CONTRIBUTIONS AND CO-BENEFITS OF A MULTILATERAL ENVIRONMENTAL AGREEMENT.

6. The consensus is growing to amend the Montreal Protocol to phase down HFCs

Two similar proposals have been submitted to amend the Montreal Protocol to phase down high-GWP HFCs, one by the Federated States of Micronesia, co-sponsored by Morocco and the Maldives, and the other by the U.S., Canada, and Mexico.[38] The amendments would reduce 85-90% of HFC production and consumption and provide climate mitigation equivalent to 100 billion tonnes of CO_2 emissions between 2016 and 2050 (range of

76-134 billion tonnes) (*see* Fig. 5), at very low cost, estimated at less than ten cents per CO_2-eq tonne.[39] This would substantially eliminate the global warming caused by one of the six Kyoto Protocol greenhouse gases and significantly improve the chances of staying below the 2°C global warming guardrail (*see* Fig. 3).

Fig. 5: Projected HFC emission reductions from Micronesian and North American proposals



The North American proposal and the Micronesian proposal are similar; both decrease the cumulative (2013-2050) direct GWP-weighted emissions of HFCs to 22-24 billion tonnes CO_2-eq from 110-170 billion tonnes CO_2-eq, for a total of ~87 to 146 billion tonnes CO_2-eq in mitigation. This is equivalent to a reduction from projected annual emissions of 5.5 to 8.8 billion tonnes CO_2-eq/yr in 2050 to less than ~0.3 billion tonnes CO_2-eq/yr. Prepared for IGSD 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. USA 106:10949.[40] (Dr. Velders' updated calculations show that as of 2013 the amendments can provide 76 to 134 billion tonnes CO_2-eq. by 2050.).

Support for an HFC amendment is growing rapidly. 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.[41] Through May 2013, 112 Parties joined the even stronger *Bali Declaration on Transitioning to Low Global Warming Potential Alternatives to Ozone Depleting Substances*.[42]

On 17 February 2012, the United States, Mexico, Canada, Ghana, and Bangladesh, along with the UN Environment Programme launched the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC) to catalyze major reductions in SLCPs with an initial focus on black carbon, methane, and HFCs.[43]

On 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 phase-down of their production and consumption; the UN General Assembly endorsed the declaration by resolution on 11 September 2012.[44]

On 19 April 2013, China agreed to completely phase out HCFCs over the next 17 years, which is expected to cut the equivalent of 8 billion tonnes of CO_2 at a total cost of $385 million, or about $0.05 per tonne.[45] The Montreal Protocol's HCFC phase-out will eliminate HCFC production from emissive uses in developing countries, 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.

On 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…."[46]

On 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)."[47]

On 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.[48]

On 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.[49]

On 28 June 2013 the BASIC countries 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." [50]

On 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."[51]

On 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 phase-down of production and consumption of HFCs called for in the Rio + 20 outcome document, *The Future We Want*."[52]

On 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."[53]

On 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:[54]

> "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."[55]

On 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:[56]

> "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."

On 16 September 2013, Ministers representing BASIC countries (Brazil, South Africa, India, and China) 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."[57]

On 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….
>
> 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." [58]

"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….",

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:

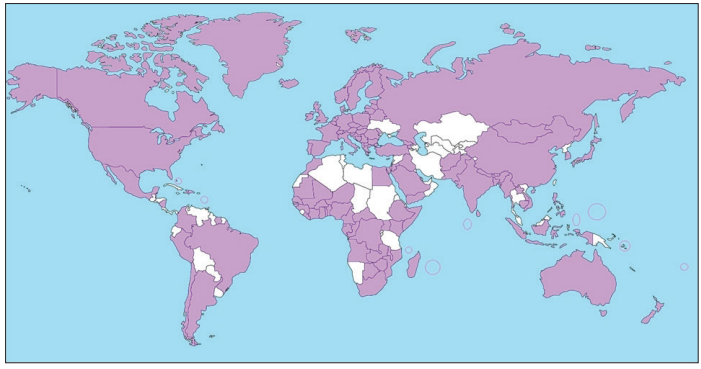
> "Space Cooling Efficiency Collaboration: Demand for space cooling – primarily for air conditioners – constitutes a large portion of peak electricity demand in India. Air conditioners could add as much as 140 GW to peak load by 2030 and management of the peak contribution is critical for maintaining 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." [59]

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

At the 25th Meeting of the Parties to the Montreal Protocol, which took place from 21 to 25 October 2013 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.[60] 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 developed countries as required by the Montreal Protocol. These and other concerns will be address in 2014 as the Amendment negotiations move forward.

Fig. 6: Map of countries that generally support a phase-down of HFCs through October 2013



7. National and regional policy support is growing to phase down HFCs

In addition to support for phasing down HFCs at the international level under the Montreal Protocol, support is growing at the national and regional levels (*see* Table 1 and Fig. 6).[61] In Europe, this includes regulations on the use and disposal of HFCs, for example: setting minimum charges of f-gases lower than that of the EU F-gas Regulation in Denmark and France; mandating refrigerant leakage checks for mobile equipment in Germany, Sweden, and The Netherlands; establishing maximum annual leakage rates for stationary equipment in Germany, Belgium and Luxembourg; mandating storage of equipment records in Czech Republic, France, The Netherlands and Germany; mandating storage of electronic records in Hungary and Slovakia; creating national databases of equipment containing HFCs in Hungary, Slovenia, and Estonia; requiring mandatory reporting of equipment records in Sweden, Hungary and Poland; instituting producer responsibility schemes

requiring producers and suppliers of HFCs to take back recovered bulk HFCs for further recycling, reclamation and destruction in Sweden and Germany; and extending certification requirements of the EU F-gas Regulation to uncovered groups of personnel and companies in The Netherlands and France.

Taxes have been imposed on HFCs or are under consideration in France,[62] Spain,[63] Norway, Denmark, Sweden, Slovenia, and Poland.[64] In 2012, Australia established an ambitious scheme imposing a carbon price on HFCs,[65] which complements its existing regulations on the manufacture, import, and export of synthetic greenhouse gases.[66] Similarly, New Zealand adopted levy rates for goods containing HFCs that are linked to the price of carbon.[67]

The EU is currently strengthening its broader f-gas regulations., with a particular focus on HFCs.[68] As part of its regulatory regime to control f-gases, the European Directive on mobile air conditioning systems already bans the use of f-gases with GWPs higher than 150; new type vehicles are covered as of 1 January 2013, and all vehicles sold in the EU will be covered by 2017.[69] In The Netherlands, maximum f-gas emission thresholds were established in the permits for the aluminum industry, the semiconductor industry and HCFC-22 manufacturing facilities.[70] In the UK, Gregory Barker, Minister for Climate Change, announced on 5 June 2013 that he was forming a task force on HFCs within the retail sector.[71] In Switzerland, a strengthened national f-gas regulation will ban HFCs in several air conditioning and refrigeration applications.[72]

In addition to the levies and other restrictions on HFCs in Australia and New Zealand, Japan recently revised its national law to phase down HFCs, promote low-GWP equipment and products, improve containment in commercial equipment, and require registration and approval of fillers and recyclers.[73]

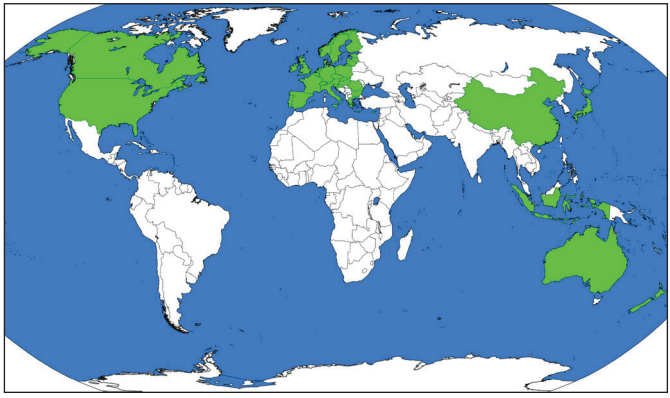
The U.S. is taking actions at national and state levels to address HFC growth. In June 2013, President Obama included domestic action on HFCs as part of his *Climate Action Plan*.[74] Congressman Scott Peters introduced the *Super Pollutant Emissions Reduction Act of 2013* to establish a U.S. task force to reduce super climate pollutants under existing authorities.[75] The U.S. allows manufacturers of cars and light-trucks to generate credits towards 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.[76] California's legislation regulating refrigerants requires a self-sealing valve on all containers, improved labeling instructions, a recycling program for used containers, and an education program that emphasizes best practices for vehicle recharging.[77] Additional requirements regarding registration, reporting, and leak detection became effective in 2012.[78] In Canada, a revised Refrigerant Code of Practice recognizes expanding use of ammonia in cooling systems as an alternative to HFCs.[79]

Table 2: Select national HFC regulations

Regulations on HFCs	Countries/Regions
Taxation	Norway,[80] Denmark,[81] Sweden, Slovenia,[82] and Poland[83], Spain*,[84] France*,[85]
Regulations over import and export	Australia[86]
Carbon price on HFCs	Australia,[87] New Zealand[88]
Mandatory registration, reporting, leak detection and storage of records	U.S. (California),[89] Germany, Sweden, the Netherlands, Hungary, Poland, Slovakia, Czech Republic, and France[90]
Certification requirements for companies and personnel	France and the Netherlands[91]
Disposal and destruction requirements	Japan,[92] U.S. (California), [93] Sweden, and Germany[94]
Restrictions of usage through imposition of maximum emission threshold, annual leakage rates or minimum charges of f-gases	The Netherlands, Germany, Belgium, Luxembourg, Denmark, and France[95]
Regulations of manufacturing and usage	Japan,[96] U.S. (California), [97] China,[98] Australia[99]
Establishment of national databases	Hungary, Slovenia, and Estonia[100]
Ban on usage	EU (f-gases with a GWP higher than 150 in MACs),[101] Switzerland (HFC in several AC and refrigeration application),[102] Denmark[103]
Prioritization of climate-friendly HFC alternatives	China,[104] U.S.,[105] Canada,[106] Indonesia[107]
Education program	U.S. (California) [108]

* Proposed legislation.

Fig. 7: Map of countries with existing HFC regulations



8. Business support is growing to phase down HFCs

Business support is growing for phasing down HFCs. The *Consumer Good 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.[109] Other industry groups support reducing HFCs under the Montreal Protocol, including the Air-Conditioning, Heating and Refrigeration Institute,[110] the European Fluorocarbon Technical Committee,[111] and Refrigerants, Naturally!.[112] The Alliance for Responsible Atmospheric Policy, whose 48 members include Trane, Whirlpool, Sub-Zero, and Mitsubishi, also supports a global phase-down of high-GWP refrigerants.[113]

Individual companies across the value chain are developing and implementing alternative refrigerants. DuPont endorses the HFC phase-down under the Montreal Protocol[114] and DuPont and

Honeywell, both manufacturers of HFCs, are actively developing lower GWP alternative refrigerants and have several currently being commercialized, as discussed in Section 9 below.[115] On the retailer and point-of-sale side, the companies in the Refrigerants, Naturally! group, including Coca-Cola, PepsiCo, Red Bull, and Unilever are taking action to eliminate the use of HFCs within their respective companies.[116] Coca-Cola began using HFC-free insulation for new equipment, which reduced direct HFC emissions by 75%, identified a feasible natural refrigerant, and pledged to eliminate HFCs in all new equipment by 2015.[117] PepsiCo, Red Bull, Unilever, and Carrefour started installing a substantial amount of natural refrigerant point-of-sale equipment.[118] 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.[119] Table 2 summarizes several of these measures.

Table 3: Examples of corporate reductions of HFCs

Companies	HFC-Free Achievements & Goals
PepsiCo[120]	200,000 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[121]	800,000 HFC-free units in 2012, plan to triple by 2015 100% HFC-free insulating foam for new refrigeration equipment 100% HFC-free new cold drink equipment purchases by 2015
Red Bull[122]	313,000 HFC-free units in 2012 Procurement 100% hydrocarbon since 2010
Unilever[123]	800,000 HFC-free freezers in 2012 Working with Ben & Jerry's Ice-cream to roll out HC freezers in U.S.
McDonalds[124]	3,300 HFC-free meat freezers, frozen food storage, reach-ins & salad refrigerated display cases 2012. Investing in ammonia industrial refrigeration in U.S.
Nestle[125]	1,000 hydrocarbon ice cream freezers in Europe, Australia, Spain, Malaysia, Chile, and the U.S. Nestle uses natural refrigerants in 90% of its industrial cooling for food processing.
Heineken[126]	130,000 hydrocarbon refrigerated beverage displays Aiming for 50% reduction in carbon footprint of installed refrigerators by 2020
Sobeys[127]	"Natural Refrigerant Commitment" requires that CO_2 refrigeration systems are installed in all new full-service stores

9. Energy efficient alternatives to HFCs are available for all major sectors

Low-GWP alternatives to high-GWP HFCs are widely and increasingly available.[128] Alternatives to existing high-GWP HFCs fall into two basic categories: non-fluorinated substances with low- or zero-GWP, and fluorinated substances with low- to mid-range GWPs. The Montreal Protocol's 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.[129] For comparison, the GWP of HFC-134a, one of the most commonly used high-GWP HFC refrigerants today, is 1,430.[130]

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.[131] 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" greenhouse gas emissions for a particular refrigerant and application. LCCP was developed by TEAP and includes direct and indirect greenhouse gas emissions, energy embodied in product materials, greenhouse gas emissions during chemical manufacturing, and end-of-life loss (typically refrigerant leakage).[132] (*See* Section 4 for a discussion of the energy efficiency gains that will be catalyzed by an HFC phase-down.)

Commercially available non-fluorinated or "natural refrigerants" primarily include: ammonia with a GWP of zero, hydrocarbons with GWPs of less than 4 (e.g. propane and isobutane), and CO_2 with a GWP of one. Alternative fluorinated substances include primarily the "HFOs" with GWPs of less than four (HFC-1234yf, HFC-1233zd and HFC-1234ze) and HFC-32 with a GWP of

677. Alternative methods and processes, not involving chemical refrigerants, are termed "not-in-kind" alternatives.

In the mobile air conditioning sector, which represents up to half of HFC emissions on a CO_2-equivalent basis, available low-GWP alternatives include HFO-1234yf, CO_2, and HFC-152a.[133] In 2012, more than ten car models sold worldwide used the low-GWP refrigerant HFO-1234yf, which new research indicates has a GWP of less than one.[134] Several German car manufacturers announced in March 2013 that they are developing CO_2 as a low-GWP alternative for vehicle air-conditioning.[135] In Norway, approximately 16% of new refrigerated truck and trailer systems were equipped with HFC-free cryogenic refrigeration systems in 2011; use of these systems is expected to expand further in the future.[136]

In commercial refrigeration, globally, up to 65% of the sector has already switched to 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.[137] *See* Table 3, above, for examples of multinational 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.[138] The Indian manufacturer, Godrej, has developed a line of propane room air conditioners that are 11% more efficient than the minimum requirements for the 5-Star energy efficiency rating set by the Indian Bureau of Energy Efficiency.[139] China, Japan, India, Indonesia, and other countries have projects underway using moderate-GWP HFC-32 with high levels of operating efficiency.[140] CO_2 air conditioning is also available in some regions.[141]

In the foam sector, low-GWP alternatives include hydrocarbons, CO_2/water and fibrous materials.[142] Hydrocarbons and CO_2/water comprise 28-76% of the global market for polyurethane foam products, while fibrous materials comprise 59% of the market for insulation in Western Europe.[143] HFC-1233zd, which is expected to be commercially available in mid-2014, is a liquid blowing agent that according to new research has a GWP of less than one.[144] Companies are developing additional high-GWP HFC alternatives and a number of developing countries intend to adopt low-GWP alternatives for foam products as part of their HCFC phase-out plans.[145]

In all major sectors, 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%.[146] A 2011 study for the European Commission concluded that technically feasible and cost-effective low-GWP alternatives exist for all major HFC subsectors.[147] 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 HFC-based equipment.[148]

The TEAP also concluded that low-GWP alternatives are able 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."[149]

These conclusions are consistent with industry research. For example, tests of room air conditioning utilizing hydrocarbon refrigerants showed energy improvements of up to 20% over HFC models.[150] HFO and HFC-32 producers also report high levels

of energy efficiency with use of their air conditioning products, particularly in hot climates.[151] 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" as the most energy efficient room air conditioning available.[152] In the commercial refrigeration sector, supermarkets are improving energy efficiency by 15-30% when they switch to low-GWP alternatives.[153] For example, Sobeys, Canada's second largest food retailer found that the new CO_2 transcritical system it was using required 18% to 21% less energy than the high-GWP HFC equipment it replaced.[154]

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. When powered by renewable sources of energy, such as solar thermal, this type of cooling system can have virtually no climate impact.[155]

There are many other alternatives in the research and development pipeline waiting for the right market signals. A decision to phase-down HFCs under the Montreal Protocol will provide a definitive signal to industry to accelerate development and deployment of additional climate-friendly alternatives.

10. 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. World Leaders have called for a phase-down of HFC production and consumption. Such a phase-down would be effectively and efficiently implemented under the Montreal Protocol, which has over 25 years of experience phasing down nearly 100 f-gases used in the same sectors, and for the

same purposes, as HFCs. International support for using the expertise and institutions of the Montreal Protocol to phase down HFCs is growing in strength and momentum, with recent support from the leaders of the G20 large economies, as well as with agreements between the U.S. and China and the U.S. and India. Other recent calls for action on HFCs under the Montreal Protocol have come from the Pacific small island developing states and from the member countries of the Arctic Council, as well as from the 33 state partners to the CCAC. The formation earlier this year of a formal Discussion Group on HFC Management under the Montreal Protocol is another positive sign that action will soon be taken to prevent the growth of HFCs in a manner that will support further international cooperation on climate change.

Markets are already responding to the signals from the scientific community 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 use the current f-gases are avoiding shifting into high-GWP HFCs and instead selecting climate-friendly alternatives. Just as the national bans, boycotts, and voluntary phase-outs 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. Success with HFCs in 2014 will build momentum for a successful UN climate treaty in 2015, while failure will damage global confidence in the viability of any multilateral solution to climate change.

List of acronyms and abbreviations

BC	black carbon
CAFÉ	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
EU	European Union
GWP	global warming potential
HCFC	hydrochlorofluorocarbon
HFC	hydrofluorocarbon
LCCP	life-cycle climate performance
ODS	ozone-depleting substance
PFC	perfluorocarbon
SF_6	sulfur hexafluoride
SLCP	short-lived climate pollutants
TEAP	Technology and Economic Assessment Panel (of the UNEP Montreal Protocol)
UNEP	United Nations Environment Programme
UNFCC	United Nations Framework Convention on Climate Change
U.S.	United States
U.S. EPA	United States Environmental Protection Agency

Appendix

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

Phasing down HFC 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, to 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* 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 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 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, *Mitigation of short-lived climate pollutants slows sea-level rise*, Nature Climate Change (14 April 2013).

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 Publications on HFCs and the Montreal Protocol

1. 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.

2. Stephen O. Andersen, Marcel L. Halberstadt, & Nathan Borgford-Parnell (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.

3. 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*.

4. Durwood Zaelke, & Nathan Borgford-Parnell (2013) *Primer on Short-Lived Climate Pollutants*.

5. 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*, Rev. Eur. Comp. & Int'l Envtl. Law 21(3):231-242.

6. Mario Molina & Durwood Zaelke (2013), *A comprehensive approach for reducing anthropogenic climate impacts including risk of abrupt climate changes*, Fate of Mountain Glaciers in the Anthropocene, *Proceedings of the Working Group*, 2-4 April 2011, Paul J. Crutzen, Lennart Bengtsson

& Veerabhadran Ramanathan (eds) (Pontifical Academy of Sciences, *Scripta Varia* 118).

7. 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.

8. Mario Molina, A. R. Ravishankara, & Durwood Zaelke (2011) *At the crossroads*, UNEP Our Planet: Powering Climate Solutions.

9. Romina Picolotti (December 2011) *An equitable arrangement*, UNEP Our Planet: Powering Climate Solutions.

10. Stephen O. Andersen & Kristen Taddonio (December 2011) *Tipping the Balance*, UNEP OzonAction's December 2011 Special Issue.

11. Mario Molina, Durwood Zaelke, Veerabhadran Ramanathan, Stephen O. Andersen, & Donald Kaniaru (2009) *Reducing abrupt climate change risk using the Montreal Protocol and other regulatory actions to complement cuts in CO_2 emissions*, Proc. National Academy of Sciences 106(49):20616-20621.

12. 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. National Academy of Sciences 106:10949.

13. Romina Picolotti (15 July 2010) *A Proposal to Change the Political Strategy of Developing Countries in Climate Negotiations*, IISD's MEA Bulletin.

14. K. Madhava Sarma, Stephen O. Andersen, Durwood Zaelke, & Kristen Taddonio (2009), *Ozone Layer, International*

Protection, *in* R. Wolfrum (ed.), The Max Planck Encyclopedia of Public International Law (Oxford University Press, 2008-2012), online edition.

15. Durwood Zaelke, Peter Grabiel, & Elise Stull (6 November 2008), *Avoiding Tipping Points for Abrupt Climate Changes with Fast-Track Climate Mitigation Strategies*, IISD's MEA Bulletin.

16. K. Madhava Sarma & Durwood Zaelke (27 June 2008), *Start, then Strengthen: The Importance of Immediate Action for Climate Mitigation*, IISD's MEA Bulletin.

17. Guus J. M. Velders, Stephen O. Andersen, John S. Daniel, David W. Fahey, & McFarland M. (2007) *The importance of the Montreal Protocol in protecting climate*, Proc. National Academy of Sciences 104:4814.

Select Editorials and Op-Eds on HFCs and the Montreal Protocol

Editorials:

1. *Nature*, Editorial, "All together now' (30 October 2013)

2. *The New York Times,* Editorial, "At Last, an Action Plan on Climate" (25 June 2013)

3. *The New York Times,* Editorial, "Fresh Start for a Critical Relationship" (10 June 2013)

4. *The New York Times,* Editorial, "Climate Warnings, Growing Louder" (18 May 2013)

5. *Bloomberg*, Editorial, "How to Make Air Conditioners Less Guzzling and More Green" (23 Sept 2012)

6. *The Washington Post,* Editorial, "Ways to fight warming: Strategies that would reduce emissions" (26 Feb 2012)
7. *The New York Times*, Editorial, "A Second Front in the Climate War" (17 Feb 2012)
8. *The Economist*, Editorial, "Piecemeal possibilities" (17 Feb 2011)
9. *Nature*, "More in Montreal: Momentum builds for ozone treaty to take on greenhouse gases" (3 Nov 2011)
10. *The Economist*, Editorial, "Unpacking the problem" (3 Dec 2009)
11. *Nature*, Editorial, "Time for early action" (1 July 2009)

Op-Eds:

1. *Los Angeles Times*, Op-Ed, D. Zaelke & P. Bledsoe, "Climate policy's twin challenges' (16 Aug 2013)
2. *Washington Post,* Op-Ed, J. Yong Kim, "U.S. takes key climate change steps, but the world must do more" (27 June 2013)
3. *Roll Call,* Op-Ed, D. Zaelke & P. Bledsoe, "India Can Join the U.S. and China to Cut Super Greenhouse Gases" (20 June 2013)
4. *The Hill,* Op-Ed, D. Zaelke & P. Bledsoe, "A climate victory waiting for presidents Obama and Xi" (6 June 2013)
5. *The New York Times,* Op-Ed, D. Zaelke & V. Ramanathan, "Going Beyond Carbon Dioxide" (7 Dec 2012)
6. *The International Herald Tribune,* Op-Ed, M. Molina & D. Zaelke, "A Climate Success Story to Build On" (26 Sept 2012)

7. *The Hill*, Op-Ed by D. Zaelke & A. Light, "Rio meeting can still produce a key climate outcome" (20 June 2012)
8. *U-T San Diego*, Op-Ed by V. Ramanathan & D. Zaelke, "Earth Day: Saving out planet, saving ourselves" (21 April 2012)
9. *The Hill,* Op-Ed by M. Molina & D. Zaelke, "How to cut climate change in half" (14 Feb 2012)
10. *New York Times*, Op-Ed, V. Ramanathan and D. Victor, "To Fight Climate Change, Clear the Air" (28 Nov 2010)
11. *The Guardian*, Op-Ed, A. Steiner, "CO_2 is not the only cause of climate change," (11 Sept 2009)

Endnotes

[1] Alexander L., *et al.* (2013) Climate Change 2013: The Physical Science Basis: Summary for Policymakers, Working Group I Contribution to the IPCC Fifth Assessment Report.

[2] Velders G. J. M *et al.* (2012) *Preserving Montreal Protocol Climate Benefits by Limiting HFCs*, Science 335.

[3] 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; *see also* Velders G. J. M. *et al.* (2009), *The large contribution of projected HFC emissions to future climate forcing*, Proc. Nat'l. Acad. Sci. USA 106:10949 ("[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, Berkeley, USA (in press) ("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]. Because of the factors mentioned in the previous section, we believe that the AC ownership in India is may witness a similar growth.")

[4] Velders G. J. M *et al.* (2012) *Preserving Montreal Protocol Climate Benefits by Limiting HFCs*, Science 335.

[5] 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.

[6] According to the World Resources Institute, Climate Analysis Indicators Tool (CAIT) CO_2-eq emissions of f-gases in China increased by 111% between 2000 and 2005, compared to a 68% increase in CO_2, 8% increase in methane, and 6% increase in N_2O. F-gas emissions increased by 78% in India over the same period, compared to 19% for CO_2, 10% for methane, and 6% for N_2O. F-gas emissions in the US increased by 30% between 2000 and 2005 compared to 1.5% for CO_2, and a 5% decrease in methane and N_2O. Note that f-gases include emissions of HFCs, SF_6, and PFCs. According to the US EPA (2013) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2011, emissions of HFCs increased by 5.48% between 2005 and 2010, emissions all other greenhouse gases decreased over that period (CO_2 -6.1%; methane -0.2%; N_2O -3.43%; PFC -4.8%; SF_6 -32.7%). EU CO_2-eq emissions of HFCs increased by 298% between 1990 and 2011, 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 Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (2011) Australian National

Greenhouse Accounts: National Inventory Report 2011, Vol. 1; *see also* European Environment Agency (2013) Annual European Union greenhouse gas inventory 1990 – 2011 and inventory report, No 8/213.

[7] UNEP (2011) HFCs: A Critical Link in Protecting Climate and the Ozone Layer – A UNEP Synthesis Report; *see also* Montzka S. A. (2012) HFCs in the Atmosphere: Concentrations, Emissions, Impacts, ASHRAE.

[8] 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.

[9] Proposed amendment to the Montreal Protocol submitted by the Federated States of Micronesia, UNEP/OzL.Pro.WG.1/33/4 (16 April 2013); *and* Proposed amendment to the Montreal Protocol submitted by Canada, Mexico and the United States of America, UNEP/OzL.Pro.WG.1/33/3 (16 April 2013). *See also* U.S. Envtl. Prot. Agency (2013) Benefits of Addressing HFCs under the Montreal Protocol (calculating the mitigation as almost 95 billion tonnes of CO_2 between 2016 and 2050).

[10] 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.

[11] 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 ("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.").

[12] Hu A., *et al.* (2013) *Mitigation of short-lived climate pollutants slows sea-level rise*, Nature Climate Change 3:730-734.

[13] Hu A., *et al.* (2013) *Mitigation of short-lived climate pollutants slows sea-level rise*, Nature Climate Change 3:730-734.

[14] Hu A., *et al.* (2013) *Mitigation of short-lived climate pollutants slows sea-level rise*, Nature Climate Change 3:730-734.

[15] De Larminat P. (2013) *Development of Climate-Friendly Alternatives for Chillers* (presentation at Bangkok Technology Conference, 29 June 2013).

[16] Speech, Shende R. *2009 USEPA'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. Envtl. Prot. Agency (2002) Building owners save money, save the earth: replace your CFC air-conditioning chiller, 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.").

[17] U.S. Envtl. Prot. Agency (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, 10 ("These CFC chillers serve an estimated3.4 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.").

[18] 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.").

[19] U.S. Envtl. Prot. Agency (2002) Building owners save money, save the earth: replace your CFC air-conditioning chiller, 7.

[20] Consumer Goods Forum (2009) Success Stories About HFC-Free Refrigeration and Energy Efficiency: Barriers and Solutions, 7.

[21] Consumer Goods Forum (2009) Success Stories About HFC-Free Refrigeration and Energy Efficiency: Barriers and Solutions, 7.

[22] Shah N., *et al*. (2013) Cooling the Planet: Opportunities for Deployment of Super-efficient Room Air Conditioners, 80 ("The metric used to report energy savings is Rosenfelds. One Rosenfeld is equivalent to annual energy savings of 3 Twh/year, i.e. about the energy generated by one medium-sized power plant… The total 2020 energy savings potential from standards that is cost effective from a consumer perspective is about 64 Rosenfelds, i.e. Equivalent to 64 medium sized power plants (or 192 TWh/year), while the total technical potential is about 123 Rosenfelds, i.e. about 123 medium sized power plants (or 369 TWh/year).").

[23] 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, Berkeley, USA (in press) ("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* Press Release, 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.").

[24] As of June 2013, Indian air conditioning companies reported annual sales growth of up to 30%. In China, companies report

air conditioning sales at a compounded annual growth rate of 13% over the past five years. 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.").

[25] For example, in the room air conditioning sector, a recent study concluded that significant energy savings are cost effective in most of the economies studied. Shah N., *et al*. (2013) Cooling the Planet: Opportunities for Deployment of Super-efficient Room Air Conditioners, 73, The Clean Energy Ministerial Super Efficiency Appliance and Equipment Deployment Initiative ("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.").

[26] Adapted from Table 5.3 *in* Shah N., *et al*. (2013) Cooling the Planet: Opportunities for Deployment of Super-efficient Room Air Conditioners, 79 (Economically justified energy savings per country calculate the maximum energy efficiency of room A/C achievable under current consumer energy tariffs in each individual country. Technically possible energy savings are calculated by assuming that the best available technologies are deployed in the climate and seasonal conditions of the respective economies are deployed irrespective of cost).

[27] According to the Carbon Trust, a tonne of diesel/gas contains approximately 12,683 kWh of energy, and according to bp, one tonne of diesel/gas is equivalent to 7.5 barrels. One kWh is equal to 0.00000001 TWh. *See* Carbon Trust (2013) Conversion factors: Energy and carbon conversions; *and* bp, *conversion factors* (2013).

[28] 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.

[29] Picolotti R. (2011) *An equitable arrangement*, *in* UNEP (2011) Our Planet: Powering Climate Solutions.

[30] 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.

[31] 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.

[32] 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) *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.

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

[34] 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) *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.

[35] 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.

[36] 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.

[37] 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.

[38] Proposed amendment to the Montreal Protocol submitted by the Federated States of Micronesia, UNEP/OzL.Pro.WG.1/33/4 (16 April 2013); *and* Proposed amendment to the Montreal Protocol submitted by Canada, Mexico and the United States of America, UNEP/OzL.Pro.WG.1/33/3 (16 April 2013).

[39] The U.S. Environmental Protection Agency calculates that the mitigation would be equivalent to almost 95 billion tonnes of CO_2 between 2016 and 2050. *See* U.S. Envtl. Prot. Agency (2013) Benefits of Addressing HFCs under the Montreal Protocol, Table ES-1 ("Adoption of the HFC amendment would produce environmental benefits of more than 90 gigatons of carbon dioxide equivalent (CO_2eq) by 2050. To provide some context, current global climate emissions from all sources are about 45 gigatons CO_2eq annually.").

[40] *See also* Velders G. J. M., *et al.* (2007) *The importance of the Montreal Protocol in protecting climate*, Proc. Nat'l. Acad. Sci. USA 104:4814.

[41] UNEP (2010) Declaration on the global transition away from hydrochlorofluorocarbons (HCFCs) and cholrofluorocarbons (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; *and* UNEP (2012) Report of the Twenty-Fourth Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer: Advance Copy.

[42] 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.").

[43] Climate and Clean Air Coalition to Reduce Short Lived Climate Pollutants (2013) *About* (One year after its launch, the CCAC has 72 Partners, including 34 State Partners, 8 IGOs, and 30 NGOs who have endorsed the Framework for the Coalition and agreed to meaningful action to reduce short-lived climate pollutants.)

[44] 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.").

[45] 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).

[46] 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…").

[47] 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).

[48] 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). Executive Office of the President (2013) The President's Climate Action Plan; *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, 3-4.

[49] 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).

[50] The BASIC countries include Brazil, South Africa, India, and China. Press Release, South Africa Dep't. of Envt'l. Aff., *Joint statement issued at the conclusion of the 15th BASIC Ministerial meeting on climate change, Cape Town, South Africa* (28 June 2013).

[51] 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.").

[52] *Nadi Outcome Document: Accelerating Integrated Approach to Sustainable Development* (Pacific SWIDS Regional Preparatory Meeting, Fiji, 10-12 July 2013).

[53] Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (2013) Communique of the Third Meeting of the High Level Assembly, Oslo, Norway.

[54] Press Release, White House Office of the Press Secretary, *United, China, and Leaders of G-20 Countries Announce Historic Progress Toward a Global Phase Down of HFCs* (6 September 2013).

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

[56] 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.

[57] Joint statement issued at the conclusion of the 16th BASIC Ministerial meeting on climate change (Press Release, Department of Environmental Affairs Republic of South Africa, 16 September 2013) ("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.")(The BASIC countries include: Brazil, South Africa, India, and China); *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 ("155. Several representatives raised concerns over the level of financial support that would need to be available [for an HFC phase down 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.").

[58] Press Release, White House Office of the Press Secretary, *U.S.-India Joint Statement* (27 September 2013).

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

[60] 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; *and* 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.

[61] Schwarz W., *et al.* (2011) Preparatory Study For A Review of Regulation (EC) No 842/2006 on Certain Fluorinated Greenhouse Gases: Final Report. (The information in this paragraph is from Schwarz W., *et al.* (2011)).

[62] Confederation Fiscale Europeenne (2013) Opportunite d'une taxation des frigorigenes' (in French); *see also* Everything R744 (April 2013) *HFCs to be Taxed in France?*.

[63] Congreso de los Diputados (2013) Boletin official de las cortes generals congreso do 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/tCO2eq*.

[64] Schwarz W., *et al.* (2011) Preparatory Study For A Review of Regulation (EC) No 842/2006 on Certain Fluorinated Greenhouse Gases: Final Report.

[65] Australian Government (2011) Ozone Protection and Synthetic Greenhouse Gas (Import Levy) Amendment Bill 2011, C2011B00170. Australia is proposing to replace the domestic carbon tax with an EU-type emissions-trading scheme as early as July 2014, instead of in 2015, as originally intended by the law. Hydrocarbon 21 (August 2013) Hydrocarbon 21 (August 2013) Hydrocarbon 21 (August 2013) *Australia's HFC levy one year on – part 1*.

[66] Australian Government, Ozone Protection and Synthetic Greenhouse Gas Management Act of 1989 *Import, Export and Manufacture of ODSs and SGGs*.

[67] Parliamentary Counsel Office New Zealand (2013) Climate Change (Synthetic Greenhouse Gas Levies) Regulations 2013, SR 2013/46; *see also* Ammonia 21 (July 2013) *Synthetic Greenhouse Gas Levy Enters into Force in New Zealand*.

[68] Ozone Secretariat Conference Portal, UNEP (2013) *Statement by the European Union and its Member States on the Proposed Amendments to the Montreal Protocol Submitted by Canada, Mexico and the United States of America and by the Federated States of Micronesia, Morocco and Maldives*. In November 2012 the European Commission published a proposal to strengthen their fluorinated greenhouse gas (f-gas) regulations, calling for an economy-wide phase-down of f-gases, managed by a quota system for importers and producers, along with use bans and better equipment seals. In March 2013, the European Parliament's rapporteur, Bas Eickhout, submitted a

report containing a number of amendments to the 2012 proposal, including: earlier and additional bans on new refrigeration and air conditioning equipment containing HFCs, mandatory destruction of by-product emissions from the manufacture of f-gases including production of feedstocks, and a faster phase-down schedule. The amendments also call for implementation of a fee system for import and production quotas as well as reporting requirements for the import, export, or production of more than 500 tonnes CO_2-eq of f-gases in a calendar year. On 19 June 2013, the European Parliament's Environment, Public Health & Food Safety Committee approved the proposal by a vote of 48 to19. The proposal still has to be approved by a plenary session of the Parliament and by Member States. The proposal in the European Commission (2012) is: Regulation of the European Parliament and of the Council on fluorinated greenhouse gases, COM(2012)0643 final. The amended proposal in the European Parliament, Committee on the Environment, Public Health and Food Safety (2013) is: Draft Report on The Proposal For A Regulation of The European Parliament And of The Council on Fluorinated Greenhouse Gases, 2012/0305(COD).

[69] See e.g. European Commission (2013) Implementation of Directive 2006/40/EC – State of Play.

[70] Schwarz W., *et al.* (2011) *Preparatory Study For A Review Of Regulation (EC) No 842/2006 On Certain Fluorinated Greenhouse Gases: Final Report*.

[71] Press Release, Consumer Goods Forum, *3rd Refrigeration Summit Warms Retailers to Uptake of Natural Refrigeration Systems* (5 June 2013) (Keynote speech by Gregory Barker, UK Minister for Climate Change, who stated: "Energy efficiency is not only vital for reducing the impact of global climate change, but will also boost the UK economy, stimulate growth and give our businesses a real competitive edge in the low carbon global race.… Refrigeration is a significant part of this and that is why I'm calling

on retailers to agree to freeze out costly HFC refrigeration. I'm also setting up a new Taskforce with the retail sector to help unlock the significant further potential for energy savings in this sector.").

[72] Swiss Federal Office for the Environment, Ordonnance sur la reduction des risqué lies a l'utilization de substances, de preparations et d'objets particulierement dangereux, 2012-2708 (2012) (in French); *see also* Hydrocarbons 21 (November 2012) *Switzerland to Introduce HFC Bans in Several AC and Refrigeration Applications*.

[73] Ministry of Economy, Trade and Industry of Japan (April 2013) *Cabinet Decision on the Bill for the Act for Partial Revision of the Act on Ensuring the Implementation of Recovery and Destruction of Fluorocarbons concerning Designated Products*.

[74] The President's Climate Action Plan (Executive Office of the President 2013) (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 Remarks by the President on Climate Change* (The White House Office of the Press Secretary, 25 June 2013) (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)). *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, 3-4.

[75] H.R. 1943 (2013) SUPER Act of 2013, 113th Congress 1st Session (introduced).

[76] U.S. Envtl. Prot. Agency (2011) *EPA and NHTSA Finalize Historic National Program to Reduce Greenhouse Gases and Improve Fuel Economy for Cars and Trucks*.

[77] California Air Resources Board, Small Containers of Automotive Refrigerant, 17 CA ADC T. 7, 17, Div 3, Chap 1(1)10.5; *see also* Ammonia 21 (December 2009) *California Adopts Refrigerant Management Program*.

[78] European Commission (2013) Fluorinated greenhouse gases; *see also* California Air Resources Board (2013) Refrigerant Management Program Regulation for Non-Residential Refrigeration Systems; Environment Canada (2013) Consultations on Proposed Extended Producer Responsibility Regulations for Managing End-of-Life-Ozone-Depleting Substances (ODSs) and their Halocarbon Alternatives; *and* Ammonia 21 (January 2012) *2012 Brings Regulatory Requirements and Opportunities for Ammonia in the EU and N. America*.

[79] European Commission (2013) Fluorinated greenhouse gases; *see also* California Air Resources Board (2013) Refrigerant Management Program Regulation for Non-Residential Refrigeration Systems; Environment Canada (2013) Consultations on Proposed Extended Producer Responsibility Regulations for Managing End-of-Life-Ozone-Depleting Substances (ODSs) and their Halocarbon Alternatives; *and* Ammonia 21 (January 2012) *2012 Brings Regulatory Requirements and Opportunities for Ammonia in the EU and N. America*.

[80] Schwarz W., *et al.* (2011) Preparatory Study For A Review of Regulation (EC) No 842/2006 on Certain Fluorinated Greenhouse Gases: Final Report.

[81] Danish Ministry for Climate and Energy (2009) Denmark's Fifth National Communication on Climate Change Under the United Nations Framework Convention on Climate Change and the Kyoto Protocol 150.

[82] Government of the Republic of Slovenia (2008) Regulation on Changes and Amendments to the Regulation on the Environmental Tax for Polluting the Air with Carbon Dioxide Emissions, *Official Gazette of the Republic of Slovenia* 78/08.

[83] Schwarz W., *et al.* (2011) Preparatory Study For A Review of Regulation (EC) No 842/2006 on Certain Fluorinated Greenhouse Gases: Final Report.

[84] Congreso de los Diputados (2013) Boletin official de las cortes generals congreso do 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/tCO2eq*.

[85] Confederation Fiscale Europeenne (2013) Opportunite d'une taxation des frigorigenes' (in French); *see also* Everything R744 (April 2013) *HFCs to be Taxed in France?*

[86] Australian Government (last visited July 29, 2013) *Import, Export and Manufacture of ODSs and SGGs*.

[87] Australian Government (2011) Ozone Protection and Synthetic Greenhouse Gas (Import Levy) Amendment Bill 2011, C2011B00170; *see also* Ammonia 21 (September 2011) *Australia HFC Carbon Charge to Start at €17 per tonne of CO2eq*.

[88] Parliamentary Counsel Office New Zealand (2013) Climate Change (Synthetic Greenhouse Gas Levies) Regulations 2013, SR 2013/46; *see also* Ammonia 21 (July 2013) *Synthetic Greenhouse Gas Levy Enters into Force in New Zealand*.

[89] European Commission (2013) Fluorinated greenhouse gases; *see also* California Air Resources Board (2013) Refrigerant Management Program Regulation for Non-Residential Refrigeration Systems; Environment Canada (2013) Consultations on Proposed Extended Producer Responsibility Regulations for Managing End-of-Life-Ozone-Depleting Substances (ODSs) and their Halocarbon Alternatives; *and* Ammonia 21 (January 2012) *2012 Brings Regulatory Requirements and Opportunities for Ammonia in the EU and N. America*.

[90] Schwarz W., *et al.* (2011) Preparatory Study For A Review of Regulation (EC) No 842/2006 on Certain Fluorinated Greenhouse Gases: Final Report.

[91] Schwarz W., *et al.* (2011) Preparatory Study For A Review of Regulation (EC) No 842/2006 on Certain Fluorinated Greenhouse Gases: Final Report.

[92] Ministry of Economy, Trade and Industry of Japan (April 2013) *Cabinet Decision on the Bill for the Act for Partial Revision of the Act on Ensuring the Implementation of Recovery and Destruction of Fluorocarbons concerning Designated Products*.

[93] Ammonia 21 (December 2009) *California Adopts Refrigerant Management Program*.

[94] Schwarz W., *et al.* (2011) Preparatory Study For A Review of Regulation (EC) No 842/2006 on Certain Fluorinated Greenhouse Gases: Final Report.

[95] Schwarz W., *et al.* (2011) Preparatory Study For A Review of Regulation (EC) No 842/2006 on Certain Fluorinated Greenhouse Gases: Final Report.

[96] Ministry of Economy, Trade and Industry of Japan (April 2013) *Cabinet Decision on the Bill for the Act for Partial Revision of the Act on Ensuring the Implementation of Recovery and Destruction of Fluorocarbons concerning Designated Products*, *see also* Environmental Investigation Agency (May 2013) *Landmark Revision of Japanese Fluorocarbon Regulations: Make It Count*.

[97] California Air Resources Board, 17 CA ADC T. 7, 17, Div 3, Chap 1(1)10.5, Small Containers of Automotive Refrigerant; *see also* Ammonia 21 (December 2009) *California Adopts Refrigerant Management Program*.

[98] Ammonia 21 (July 2012) *China Will Release the First Safety Standards for Cold Stores*.

[99] Australian Government (last visited July 29, 2013) *Import, Export and Manufacture of ODSs and SGGs*.

[100] Schwarz W., *et al.* (2011) Preparatory Study For A Review of Regulation (EC) No 842/2006 on Certain Fluorinated Greenhouse Gases: Final Report.

[101] European Commission (2013) Implementation of Directive 2006/40/EC – State of Play; *see also* The Telegraph (July 2013) *Ban on Selling New Mercedes in EU Moves Closer*.

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[110] Air-Conditioning, Heating, and Refrigeration Institute (2013) *AHRI Responds to President Obama's Climate Change Plan* (25 June 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…").

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[112] 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." *Refrigerants, Naturally! calls for an immediate HFC phase-down under the Montreal Protocol* (June 2013).

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Natural Refrigerants based technology at Carrefour, presentation at ATMOsphere Europe 2011, Brussels, 11-12 October 2011; *see also* U.S. Envtl. Prot. Agency (2013) Benefits of Addressing HFCs under the Montreal Protocol, 20 ("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.")

[119] The Consumer Goods Forum (2011) *The CGF Good Practices About HFC-Refrigeration and Energy Efficiency*; and U.S. Envtl. Prot. Agency (2013) Benefits of Addressing HFCs under the Montreal Protocol, 21 ("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.").

[120] Refrigerants Naurally! (2013) *PepsiCo*.

[121] Coca-Cola (2013) *Cooling Equipment: Pushing Forward with HFC-Free*.

[122] Red Bull (2013) *Efficient Cooling*.

[123] Unilever (2013) *Climate-Friendly Refrigeration*.

[124] Hydrocarbons21 (2012) *McDonalds Europe installs over 3,300 pieces of HFC-free refrigeration equipment* (18 May 2012).

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[126] The Consumer Goods Forum (2011) *The CGF Good Practices About HFC-Refrigeration and Energy Efficiency*.

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[134] Hodnebrog O. *et al.* (2013) *Efficiencies Of Halocarbons And Related Compounds: A Comprehensive Review*, Rev. Geophys, 333.

[135] Montreal Protocol Technology and Economic Assessment Panel (May 2013) TEAP 2010 Progress Report, Vol. I, 50-51.

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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.").

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