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Ambitious Replenishment of the Multilateral Fund for Implementation of the Montreal Protocol Delivers High Impact Climate Benefits at Low Cost

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Executive Summary

The Earth is rapidly warming with extreme heatwaves already threatening the lives and livelihoods of millions across the planet. Access to affordable, energy-efficient and climate-friendly air conditioning and refrigeration is becoming increasingly essential. Meeting this need requires transforming the air conditioning and refrigeration sectors.

The Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol) has been shaping the cooling industry for over three decades while it put the stratospheric ozone layer on the path to recovery and protected the climate. UN Secretary General Kofi Annan described the Montreal Protocol as "the most successful environmental treaty in history" and "perhaps the most successful international agreement to date". The Montreal Protocol has also been a low-cost and highly effective source of climate mitigation, already preventing 1°C of warming to date at a cost of less than ten cents per tonne of CO_2-equivalent (CO_2e) and as much as 2.5°C by 2100.

Since first agreed in 1987 to protect the ozone layer by phasing out chlorofluorocarbons (CFCs) and freeze halon production, the Parties to the Montreal Protocol have continued to expand the list of controlled substances and accelerate the phaseouts, putting the stratospheric ozone layer on the path to recovery by mid-century, while also avoiding as much as 2.5°C by 2100 as a collateral benefit. A key success of the Montreal Protocol's "start and strengthen" history is the 2016 Kigali Amendment to phase down hydrofluorocarbons (HFCs) undertaken explicitly to protect the climate. HFCs and related substances used as refrigerants in cooling equipment are less damaging than the CFCs used before them, but can still be hundreds to thousands of times more potent than carbon dioxide at warming the planet. As a result, efficient implementation of the Kigali Amendment could avoid nearly 0.1°C of additional warming by 2050, and an accelerated phasedown of HFCs could avoid up to 0.5°C by 2100. The Kigali Amendment and subsequent decisions further recognize the need to pair improved energy efficiency of cooling equipment with the HFC phasedown. Improved cooling equipment efficiency could double the climate benefit of the Kigali Amendment while also lowering energy bills, supporting energy security, and enabling the energy transition to renewable and low-carbon electricity essential for meeting climate goals.

The success of the Montreal Protocol derives in large part from the efficacy of the Multilateral Fund (MLF) for the Implementation of the Montreal Protocol, which supports activities in Article 5 Parties[i] to ensure compliance with the Protocol and is replenished every three years by donor governments.

The replenishment for the 2024–2026 triennium will be decided October 23–27, 2023 at the 35th Meeting of the Parties to the Montreal Protocol. Previous replenishments have averaged about US$ 500 million for each three-year triennium to fulfill compliance obligations and cover costs for additional decisions. However, the upcoming triennium is unique as it will need to cover both

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[i] An Article 5 Party "is a developing country … whose annual calculated level of consumption of the controlled substances in Annex A is less than 0.3 kilograms per capita on the date of the entry into force of the Protocol for it, or any time thereafter until 1 January 1999." https://ozone.unep.org/treaties/montreal-protocol/articles/article-5-special-situation-developing-countries

the continued phaseout of ozone-depleting and climate-warming substances (primarily HCFCs) and the first step in phasing down HFCs required by the Kigali Amendment, including additional measures to improve energy efficiency in this transition. The combination of these activities means that the minimum funding levels required to support Article 5 Parties in meeting their compliance obligations is now at least US$ 1 billion as assessed by the Technology and Economic Assessment Panel (TEAP) Replenishment Task Force. (This does not count the funding needed to support parties that want to take accelerated action or the funding needed to capture the significant climate benefits of improving energy efficiency of cooling equipment.) Although larger than recent replenishments, the 2024-2026 funding requirement is comparable to previous allocations when adjusted for inflation: for example, in 1994, Parties approved US$ 455 million for the Multilateral Fund, a figure that is worth close to US$ 1 billion today when adjusted for inflation.

This paper reviews MLF accomplishments, summarizes the TEAP assessment of the funding required to replenish the MLF, and offers additional analyses of the potential climate benefits and energy savings that could be achieved with even more funding.

Major findings and recommendations are:

- The MLF is an extremely efficient and successful finance mechanism that has a proven track record of delivering climate benefits and transformation in the cooling sector at an unparalleled cost-effectiveness of US$ 0.07 per tonne of CO_2e. For comparison, the Intergovernmental Panel on Climate Change (IPCC) identifies lower cost mitigation options as those costing less than US$ 20 per tonne of CO_2e.[ii]
    - The MLF has disbursed US$ 3.6 billion in grant funding and assisted 144 Article 5 Parties in avoiding over 51 billion tonnes of carbon dioxide equivalent ($GtCO_2e$) greenhouse gas emissions since 1991.[1] For comparison, global annual emissions in 2020 reached 46.1 $GtCO_2e$ (excluding land use).[2]
    - The MLF supports technology demonstration and conversion projects, capacity building, enabling activities, sector transformation and national transition plans.
    - The Executive Committee is made up of seven Article 5 and seven non-Article 5 members and provides thoughtful and careful governance of the fund in an effective forum for negotiating remedies when issues arise.[iii]
- The replenishment for the 2021–2023 triennium was US$ 540 million (including US$ 475 million in new contributions and US$ 65 million in roll-over). The anticipated roll-over available for the 2024–2026 triennium is approximately US$ 300 million, including US$ 246 million from the 2018–2020 triennium[iv] due to a revised funding agreement with

[ii] IPCC AR6 WGIII finds that 76% of abatement potential in 2030 for fluorinated gases is less than US$ 20 per tonne CO_2e (Table 12.3). The assessed studies consider HFC, SF_6 and PFCs mitigation globally, and do not consider historical experience from Multilateral Fund projects for CFCs and HCFCs specific to Article 5 Parties.
[iii] These remedies can involve instances of unexpected and unreported controlled-substance emissions from Montreal Protocol Parties. For example, when atmospheric monitoring detected unexpected and persistent emissions of CFC-11, the Executive Committee took decisions 83/41 and 84/69 to remedy the situation, including financial penalties in the form of a reduction in agreed funding of US$252.7 million.
[iv] Decision Ex.V/1 paragraph 4 notes “that $246 million in remaining funds that were due to the Multilateral Fund during the triennium 2018–2020 will be used after 2023 to support the implementation of the Montreal Protocol”.

China (see note *iii*) and COVID-related implementation delays, and remaining roll-over from the 2021–2023 triennium.[v] The value of this roll-over funding could be maximized by allocating it to support additional ambitious activities beyond minimum compliance requirements.

- The assessment by the TEAP Replenishment Task Force for a replenishment amount of US$ 1 billion for 2024–2026 is fully justified based on the funding needed to support compliance in Article 5 with both the continued phaseout of ozone-depleting substances and the first HFC phasedown step.
    - This funding level will support activities over three years to phase out over 202 million tonnes CO_2e in ozone-depleting substances and 568–781 million metric tonnes CO_2e ($MMTCO_2e$) of HFCs.
    - Compared to a baseline "without controls" scenario assuming 4% annual growth in HFC consumption, the mitigation value is a remarkable US$ 0.17 per tonne CO_2e. Achieving the 85% phasedown in HFC production and consumption by 2050 would avoid 34.2 billion tonnes of CO_2e at an average cost of US$ 654 million per triennium.
- Additional funding to support accelerated action and to improve energy efficiency of cooling equipment has the potential to save governments and consumers trillions of dollars in electricity costs while avoiding emissions from the power sector at a mitigation value of US$ 0.30–10.00 per tonne CO_2e depending on cooling equipment type and other assumptions (***Table 1***).

[v] Amount will be determined at the conclusion of the 93rd Meeting of the Executive Committee of the MLF in December 2023.

Table 1. Energy & climate benefits from ambitious MLF replenishment with additional funding for accelerated action, energy efficiency and lifecycle refrigerant management

Activity		Emissions reductions ($MMTCO_2e$)	Cost estimate (US$ million)	US$ per tonne CO_2e
HCFC Phaseout, 2024-2026		202	$ 205.4	$ 1.02
HFC Phasedown				
2024–2026		568–781	$ 384.5	$ 0.49–0.68
2024–2050		34,200	$ 5,888	$0.17
Accelerated Action		10	$ 4.9	$0.49
Lifecycle Refrigerant Management, 2024–2050 [5]		10,000	$1,000	$0.10
Energy Efficiency Incentive [1]	Energy savings (TWh per US$ 1M) [2]	Emissions reductions ($MMTCO_2$ per US$ 1M) [2]	Cost estimate (US$ million) [3]	US$ per tonne CO_2 [2]
Split AC (23% EE improvement; 19% incentive)	1.7–4.9	0.5–3.4	$6–220 25 million units 82 lines @ 300k units/line	$2.00 - $0.30
Domestic Refrigerators (16% EE improvement; 18% incentive)	0.35–0.39	0.10–0.28	$17–130 21 million units 112 lines @ 188k units/line	$10.00 - $3.60
Self-Contained Commercial Refrigerators (20% EE improvement; 22% incentive)	2.55	0.7–1.8	$9–34 2.2 million units 56 lines @ 39k units/line	$1.40 - $0.60

[1] We assume 15 years of production for each factory and 15-year operating lifetime for all three product types when calculating lifetime energy savings per dollar invested in enhanced energy efficiency.
[2] Includes factory upgrade costs and 2 yrs. support for additional unit production costs.
[3] Assumes a constant electricity grid emission factor of 0.7 $kgCO_2/kWh$ to 0.29 $kgCO_2/kWh$.
[4] Lower number in the range is for factory upgrades only; high number in range includes factory upgrade cost and two years of support for additional manufacturing production costs. [5] Support to implement LRM best practices described in NRDC, EIA & IGSD (2022) *The 90 Billion Ton Opportunity*: How Minimizing Leaks and Maximizing Reclaim Can Avoid up to 91 Billion Tons of CO_2-equivalent Emissions.

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Part I – The Multilateral Fund of the Montreal Protocol: Over 30 Years of Success

The Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol) was agreed in 1987 to control ozone-depleting substances, which are primarily used as refrigerants, as propellants in cosmetic and convenience aerosol products, as foam blowing agents, as solvents, and as fire suppressants. Almost all air conditioning and refrigeration equipment works by evaporating and condensing working fluids, called refrigerants, to move heat and provide cooling and dehumidification. Since the 1930s until the Montreal Protocol phaseout, refrigerants have primarily been synthetic gases, initially chlorofluorocarbons (CFCs) and hydrochlorofluorocarbon (HCFCs). CFCs were found to be powerful ozone-depleting substances responsible for the destruction of the stratospheric ozone layer, first observed over Antarctica in 1985. CFCs are also potent greenhouse gases, often many thousands of times more potent than CO_2. Starting in the 1990s, manufacturers started to switch from CFCs to existing and newly-invented HCFCs, which are less ozone depleting, and hydrofluorocarbons (HFCs), which do not deplete the ozone layer. While HFCs are not ozone-depleting and are generally less damaging to the climate than CFCs, they are still greenhouse gases that are hundreds to thousands of times more powerful at trapping heat than carbon dioxide.

The Montreal Protocol is the world's most successful environmental treaty, responsible for putting the stratospheric ozone layer on the path to full recovery by the late 2060s and avoiding circa 1°C warming by mid-century.[3]

The Montreal Protocol is regarded as the most successful global environmental treaty.[4] It successfully saved our planet's protective stratospheric ozone layer—avoiding crop loss, ecosystem devastation, millions of cancer deaths, and countless cases of skin cancer. The ozone-depleting substance phaseout also reduced anthropogenic contributions to climate change by an estimated 135 $GtCO_2e$ from 1990 to 2010.[5] Scientists have calculated that without the Montreal Protocol, ozone-depleting substances would have caused 1°C warming by mid-century.[3]

In 2016 the international community celebrated a major climate victory with the agreement of the Kigali Amendment to the Montreal Protocol to phase down high-global warming potential (GWP) HFCs. This agreement officially converted the Montreal Protocol from an ozone protection treaty to an ozone and climate protection treaty. The Kigali Amendment, which entered into force in 2019, will avoid 80 billion tonnes of CO_2-equivalent by 2050[6] and 0.3–0.5°C of warming by 2100 (not counting the benefits of phasing down HFC-23, the by-product of producing HCFC-22, which is 14,700 more potent than CO_2).[7] Scientists have recently calculated that thanks to the Montreal Protocol's ozone-depleting substance phaseout and HFC phasedown, the world will avoid 2.5°C of global warming by the end of this century.[8]

The Multilateral Fund of the Montreal Protocol is a proven and yet under-appreciated tool to combat climate change while building resilience by increasing access to efficient and climate-friendly cooling.

The Multilateral Fund (MLF) for Implementation of the Montreal Protocol is a central pillar of the success of this treaty. The MLF is a dedicated funding mechanism with democratic governance and over three decades of experience delivering on projects enabling the success of the Montreal Protocol. Since the decision to create the MLF at the 1990 London Meeting of the Parties, the MLF has disbursed US$ 3.6 billion in grant funding and assisted 144 countries in avoiding over 51 $GtCO_2e$, achieving a remarkable cost-effectiveness of US$ 0.07 per tonne CO_2e.[9]

The MLF is carefully governed by an Executive Committee made up of seven Article 5 and seven non-Article 5 members, elected on a yearly basis in most cases. The MLF Secretariat and Implementing Agencies assist the Executive Committee in developing, implementing, managing, and providing oversight to projects (***Figure 1***). The MLF works closely with National Ozone Units and Implementation Agencies in the development, implementation, and assessment of projects. The implementation agencies are the World Bank, United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP), and the United Nations Industrial Development Organization (UNIDO). Projects can also be developed and implemented by bilateral development agencies of donor governments, such as Germany's Deutsche Gesellschaft für Internationale Zusammerarbeit (GIZ), Japan International Cooperation Agency (JICA), and others constituting up to 20 percent of donor government contribution to the MLF.[10]

The MLF supports technology demonstration and conversion projects, capacity building, enabling activities, sector transformation and national transition plans such as:

- **Technology demonstration and conversion projects:** The MLF has provided assistance to over 4,500 eligible enterprises to demonstrate and convert their production, manufacturing, or use of products to environmentally superior technologies and transition away from ozone-depleting and high global warming potential substances.[11]

- **Capacity building:** A key to the successful implementation of the Montreal Protocol is the National Ozone Units in every Article 5 Party, staffed by professional National Ozone Officers, and supported by the MLF as part of its "country-driven approach." The National Ozone Units and regional networks supported by the MLF through UNEP's Compliance Assistance Program have enabled consistent coordination of the technical and financial support as well as the continuous presence of ozone protection activities in all A5 parties necessary to the success of the Treaty. In addition, MLF projects have trained:

    - Over 64,000 customs officials to assist with implementing provisions relating to trade in controlled substances;
    - Over 230 technical institutions implementing training programs;
    - More than 260,000 technicians critical to the proper installation, maintenance, and end-of-life treatment of equipment containing controlled substances;
    - Over 130 certification systems for technicians; and
    - More than 230 recovery and recycling programs.[12]

  These types of projects have been critical to ensuring that the people who service equipment have the right knowledge and tools to do so safely and in compliance with regulations that limit refrigerant leakage.

- **Enabling activities:** The MLF also supports enabling activities such as establishing policies and programs in support of refrigerant transition, putting in place the data reporting and licensing systems for tracking production and consumption of controlled substances, supporting the institutional arrangements needed for compliance, preparations for ratification of amendments, awareness raising and related activities to facilitate implementation and compliance with Montreal Protocol requirements.

- **Sector transformation and national plans:** Coordination and sectoral transformation are hallmarks of the MLF and its partners. For example, in 2004 the implementing agencies UNDP, World Bank, and UNIDO collaborated and coordinated with the Government of Indonesia to develop a national ozone-depleting substance phaseout strategy that built on sector transformation plans for aerosols and solvents, as well as previously agreed sectors plans, including for the foams and mobile air conditioning sector.[13] Implementing Agencies are currently working with Article 5 Parties to develop national plans to implement the Kigali Amendment HFC Phasedown (Kigali Implementation Plans, or KIPs).

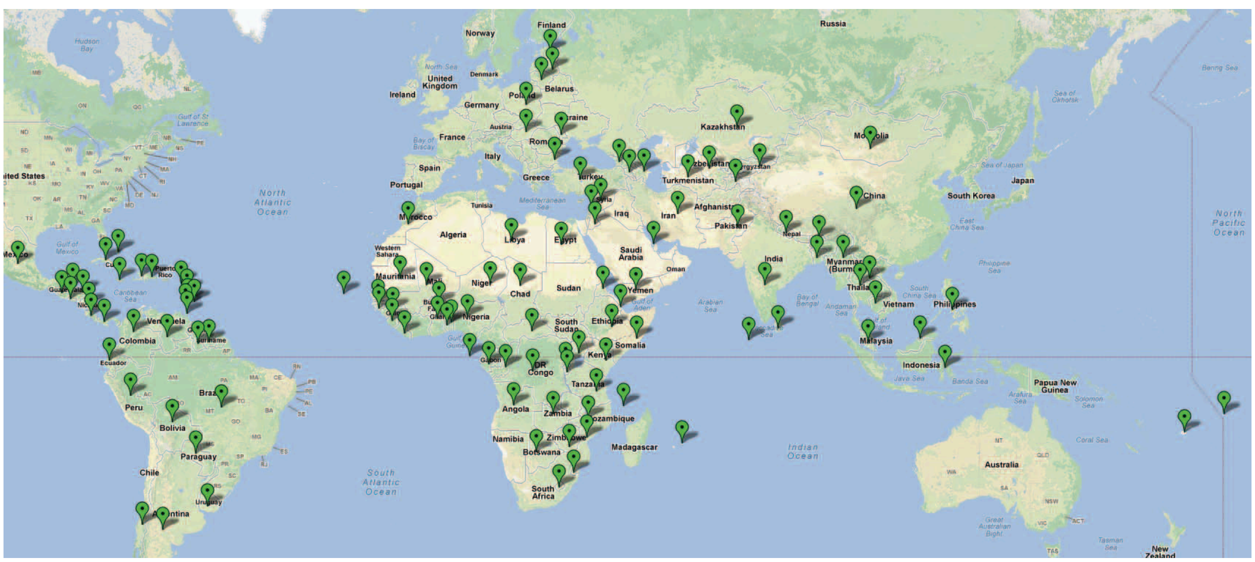

Figure 1. Illustrative map showing the 118 countries where UNDP implemented Montreal Protocol projects supported by the MLF between 1991 and 2012 (includes 13 countries financed by the Global Environment Facility).[14]

Sustainable cooling sits at the intersection of mitigation, adaptation and resilience. The Multilateral Fund for Implementation of the Montreal Protocol (MLF) has a proven track record of delivering cost-effective transformation in the cooling sector, reducing emissions for as low as $0.07 per tonne of CO_2e.

Parties to the Montreal Protocol achieved impressive greenhouse gas emissions abatement for a remarkably low cost: from the Treaty's finalization in 1987 through May 2023, contributions to the Multilateral Fund (MLF) for the Implementation of the Montreal Protocol totaled US$ 4.4 billion.[15] In that time MLF projects supporting technology conversions, capacity building, and enabling activities have avoided emissions equal to 51 billion tonnes of CO_2e. That amounts to mere pennies per tonne of CO_2-equivalent emissions reduced: only \$0.07 per tonne of CO_2e. As a comparison, the price of permits for the European Union's carbon market reached over 100 euros per tonne for the first time in February 2023.[16] **If the 51 billion tonnes of CO_2e emissions reduced by the Montreal Protocol's MLF were valued at 100 euro per tonne, the emissions reductions would have a value of over 5 *trillion* euro.** That is more than the gross domestic product (GDP) of Germany. Using a lower price of US\$ 40 per tonne of CO_2e, the Montreal Protocol Secretariat calculated that the Montreal Protocol's MLF projects provided US \$2 trillion savings to society.[17]

These avoided emissions only account for the phaseout of ozone-depleting and super climate polluting substances. The climate and economic benefits would be even greater if the reduction in indirect emissions from improvements in the energy efficiency of cooling equipment that accompanied previous refrigerant transitions were included. Previous amendments to the Montreal Protocol spurred major efficiency upgrades to cooling equipment and appliances, setting a strong precedent for similar progress under the Kigali Amendment. In the original transition away from chlorofluorocarbons (CFCs), many manufacturers took the opportunity to redesign their systems to improve energy efficiency in the new CFC-free designs. New CFC-free chillers marketed worldwide were up to 50% more energy efficient than the equipment those chillers replaced.[18]

The Kigali Amendment and subsequent decisions recognize the need to phase down high-GWP HFCs while maintaining and/or enhancing energy efficiency.[19] A full phaseout of HFCs has the potential to avoid up to 0.5 °C of warming by 2100.[20] The initial phasedown schedule of the Kigali Amendment would lock in reductions limiting warming from HFCs in 2100 to about 0.04 °C, avoiding about 90% of the potential, or up to 0.44 °C.[21] Most HFCs are used in cooling products, hence the HFC phasedown provides a key opportunity and driver for maximizing cost-effective energy efficiency gains, against the backdrop of growing demand for cooling and increasing urgency to mitigate climate change. Improving energy efficiency of cooling equipment during the HFC phasedown could double the climate benefits in CO_2e terms by reducing emissions from the power plants that provide the electricity to run the equipment.[22] In the extreme scenario where all cooling equipment is replaced in 2030 with the best available efficiency and climate-friendly alternative refrigerants, it would avoid cumulative emissions of 210–460 $GtCO_2e$ by 2060, equivalent to 8 years of current anthropogenic emissions.[23]

Part II assesses the TEAP Replenishment Task Force estimates and anticipated benefits as well as opportunities for additional funding to accelerate and deliver expanded climate and energy benefits.

Part II – High Impact Climate Benefits at Low Cost

The MLF replenishment for the 2024–2026 triennium will be decided in October at the 35th Meeting of the Parties. Compared to recent replenishments on the order of US$ 500 million, the TEAP Replenishment Task Force (RTF) report estimates a replenishment on the order of US$ 1 billion to cover the simultaneous HCFC and HFC compliance requirements for this 3-year period (**Table *2***).[24] These estimates include US$ 20 million for energy efficiency pilots approved by the MLF Executive Committee in decision 91/65, but they do not consider additional funding for integrating support for maintaining and/or enhancing energy efficiency as part of HFC phasedown plans (called Kigali HFC Implementation Plans, or KIPs). They also exclude consideration of funding for accelerated action. While the US$ 1 billion figure appears large, this amount is comparable to past replenishments when adjusted for inflation: for example, in 1994, Parties approved US$ 455 million for the Multilateral Fund, a figure that is worth over US$ 938 million in 2023 dollars when adjusted for inflation.[25]

Summary of TEAP Replenishment Task Force Reports

The TEAP RTF assesses the funding required for meeting HCFC phaseout and HFC phasedown obligations, as well as support for institutional strengthening and a potential funding window for end-of-life activities (***Table 2***). The "high-end" and "Sep 2023 update" scenarios assume all Parties ratify the Kigali Amendment by 2026.

Table 2. Range of Total Funding Requirement for Replenishment of the MLF 2024-2026 Based on Different Scenarios (US$) from TEAP RTF May 2023 Report Table ES-2 and TEAP RTF September 2023 Report Table ES-1.

2024-2026 TRIENNIUM	LOW-END	HIGH-END (MAY 2023)	SEP 2023 UPDATE
SUBTOTAL - HCFC Activities (including US$100k per Low Volume Consuming (LVC) country for energy efficiency enabling activities)	$ 363,911,000	$ 363,911,000	$ 362,323,000
SUBTOTAL - HFC Activities (including gender mainstreaming activities, project preparation, enabling activities and $20M energy efficiency funding window)	$ 475,491,000	$ 519,142,000	$ 643,908,000
SUBTOTAL - Funding Window on End of Life/Disposal	$ 13,590,000	$ 13,590,000	$ 13,590,000
SUBTOTAL – Institutional Strengthening & Standard Activities	$ 121,581,000	$ 121,581,000	$ 121,581,000
GRAND TOTAL	**$ 974,573,000**	**$ 1,018,224,000**	**$ 1,140,721,000**

The HCFC phaseout primarily includes US$116.7 million in approved HCFC phaseout management plans and US$205.4 million in estimated phaseout plans for the 2024–2026 triennium to meet the 80.5% phaseout obligation for this period. **Converting the remaining eligible HCFC to be phased out into CO_2-equivalents results in an estimated value of US$ 1.02 per tonne CO_2e** (**Table *3***), based on 100-year global warming potentials.

Table 3. Remaining eligible HCFC to be phased out (TEAP RTF May 2023 Table 2-5).

	ODP tonnes	ODP value (Annex C)	Tonnes of substance	GWP_{100} (Annex C)	$MMtCO_2e$
HCFC-22	7,054	0.055	128255	1810	232.14
HCFC-141b	93	0.110	845	725	0.61
HCFC-142b	496	0.065	7631	2310	17.63
Other HCFCs*	28	0.020	1400	350	0.49
HCFC-141bPolyol	54	0.110	491	725	0.36
Total					**251.23**
Total x 80.5%					202.24
Estimated HCFC phaseout plans cost (US$ million)					$205.4
US$ per tonne CO_2e					$1.02

* Taken as 50/50 HCFC-123 and HFC-124 and using a GWP_{100} average of 91 for HFC-123 from WMO (2022) and 609 for HFC-124 from Annex C. Based on TEAP RTF May 2023 breakdown of "other HCFCs" into HCFC-123 (32 ODPt), HCFC-124 (26 ODPt), HCFC-141 (1 ODPt), HCFC-21 (1 ODPt), HCFC-225 (3 ODPt), and HCFC-225cb (1 ODPt).

We estimate HFC savings by calculating the difference between HFC allowed to be consumed under the Kigali Amendment Phasedown (Kigali Amendment phasedown scenario) versus a business-as-usual scenario where HFC consumption and emissions continue to grow (the "counterfactual scenario"):

Business-as-usual HFC emissions – Kigali Amendment HFC consumption = HFC savings

For the **Kigali Amendment phasedown scenario,** this report starts with the HFC baselines[vi] from ***Table 4*** grouped by "Bracket A (China)" and all other Article 5 Parties eligible for MLF assistance ("Other A5 Group 1"), excepting Article 5 Parties with a delayed HFC phasedown ("Group 2"),

[vi] The Kigali Amendment defines the HFC baseline as having two components: an HFC component based on the average annual consumption drawing on reported consumption over the period for 2020–2022, and an HCFC component equal to 65% of the predetermined HCFC baseline. Countries are divided into brackets based on their historic HCFC consumption levels (***Table 4***). These brackets provide a basis for distributing the consumption across sectors (*i.e.*, manufacturing sectors for domestic refrigeration, industrial and commercial refrigeration, stationary air conditioning, mobile air conditioning, servicing, foams, aerosols, fire suppression, and solvents). The TEAP RTF then estimates costs for phasedown over the 2024–2026 period for each sector using cost-effectiveness factors in terms of US$ per quantity of substance reduced for each sector agreed by the MLF Executive Committee (because the HFC cost guidelines are not finalized for all sectors, the TEAP RTF used the values in the working text discussed at the 91st Executive Committee meeting and values for sectors agreed at the 92nd Executive Committee meeting).

as shown in ***Table 5A***. The Kigali Amendment Scenario takes the HFC baselines for these groupings and projects consumption for 2024–2026 assuming a 2% annual reduction in consumption, which is a linear decrease to meet the 10% phasedown step in 2029.

Table 4. HFC Baseline (including HCFC component) from TEAP RTF May 2023 Report.[vii]

	% of HCFC Total GWP	HFC Portion of Baseline Calculation	HCFC Portion of Baseline Calculation		HFC BASELINE (MMTCO2e)
			HCFC Baseline	*HCFC Baseline x 65%*	
Bracket A	59.28%	**570**	481	**313**	**883**
Bracket B	9.23%	**139**	75	**49**	**188**
B Group 2	8.62%	**105**	70	**45**	**150**
Bracket C	11.77%	**112**	96	**62**	**174**
C Group 2	2.88%	**32**	23	**15**	**47**
Bracket D	4.53%	**85**	37	**24**	**109**
D Group 2	1.13%	**21**	9	**6**	**27**
Bracket E	2.56%	**52**	21	**14**	**65**
Total All	100.00%	**1,115**	812	**528**	**1,643**

Business-as-usual HFC emissions scenarios (the Counterfactual Scenarios) are based on the HFC emission trends under the "current policy Kigali-Independent" scenario in Velders *et al.* (2022),[26] as seen in ***Table 5B***. We note that the 6–7% annual growth in HFC emissions for China and other non-OECD countries derived from Velders *et al.* (2022) for the period 2020–2030 is not equivalent to consumption (emissions lag consumption) but can be used as an approximation. We also calculate a second counterfactual assuming a larger 9.9% growth rate in business-as-usual HFC consumption.[27]

Tables 5 A & B: Kigali Amendment HFC Consumption Scenario and Business-as-Usual Counterfactual Scenarios.

Table 5A	% of HCFC Total GWP	HFC Portion of Baseline Calculation	HCFC Portion of Baseline Calculation		HFC BASELINE (MMTCO2e)
			HCFC Baseline	*HCFC Baseline x 65%*	
Bracket A (China)	59.28%	**570**	481	**313**	**883**
Other A5 Group 1	28.09%	**388**	229	**149**	**536**

Table 5B	With Kigali HFC Baseline (including HCFC) Assuming 2% per year reduction for Group 1 (MMTCO2e)			Counterfactual using current policy Kigali-Independent scenario (MMTCO2e)			Counterfactual using 9.9% HFC growth rate from TEAP reports (MMTCO2e)		
	2024	*2025*	*2026*	*2024*	*2025*	*2026*	*2024*	*2025*	*2026*
Bracket A (China)	**865**	**848**	**830**	**925**	**968**	**1010**	**939**	**1001**	**1070**
Other A5 Group 1	**525**	**515**	**504**	**560**	**584**	**608**	**575**	**618**	**664**

[vii] TEAP RTF September 2023 report provides minor updates to baselines based on additional reporting in Table 2-3.

HFC Mitigation and Cost Effectiveness, 2024-2026: US$0.49–0.68 per tonne CO_2e avoided

The difference between these scenarios gives the avoided HFC consumption of 568–781 million metric tonnes of CO_2e just from 2024–2026. The estimated Kigali HFC phasedown cost for the 2024–2026 triennium from TEAP RTF May 2023 report Table 3-15 is US$ 384.5 million. The resulting mitigation value for the first step of the Kigali HFC phasedown is US$ 0.49–0.68 per tonne CO_2e avoided (***Table 5C***). As the difference between allowed HFC consumption and business-as-usual emissions gets larger over time due to the lifetime of equipment using alternatives to high-GWP HFCs, the dollar per tonne of avoided emissions decreases as the avoided emissions are projected forward in time.

Table 5C: Avoided HFC in MMTCO_2e and cost effectiveness, 2024-2026.

Table 5C	Avoided Consumption Counterfactual minus Kigali Baseline (MMTCO2e)				Total cost for HFC Consumption for 2024–2026 (US$M)	Average US$ per tonne CO_2e avoided
	2024	*2025*	*2026*	*SUM*		
Bracket A (China)	**60**	**120**	**180**	**360**	**$ 273.4**	**$0.76**
Other A5 Group 1	**35**	**69**	**104**	**208**	**$ 111.0**	**$0.53**
Total	**95**	**189**	**284**	**568**	**$ 384.5**	**$0.68**
	Avoided 9.9% HFC Consumption Growth Counterfactual minus Kigali Baseline (MMTCO2e)				Total cost for HFC Consumption for 2024–2026 (US$M)	Average US$ per tonne CO_2e avoided
	2024	*2025*	*2026*	*SUM*		
Bracket A (China)	**74**	**154**	**240**	**467**	**$ 273.4**	**$ 0.58**
Other A5 Group 1	**50**	**103**	**160**	**313**	**$ 111.0**	**$ 0.35**
Total	**124**	**257**	**400**	**781**	**$ 384.5**	**$ 0.49**

We can further estimate the mitigation value of the HFC phasedown through mid-century based on the estimated costs in TEAP RTF May 2023 report Table 3-13 (**Error! Reference source not found.**).

Table 6. Estimated cost of Multilateral Fund HFC Phasedown Assistance through 2050.

Table 3-13 Estimated Total Cost of a full HFC Phase-down Under the MLF (by groups)

	HFC Cost 100% Phaseout	HFC Cost 100% Phaseout minus 15% Exports, Foreign Ownership, & Cutoff Date	HFC BASELINE	HFC Cost Phasedown (80% or 85%)
Group 1 Countries	**$ 7,439,216,336**	**$ 6,407,504,049**	**1,418**	**80%** **$ 5,126,003,240**
Group 2 Countries	**$ 1,037,401,451**	**$ 896,004,605**	**225**	**85%** **$ 761,603,915**

We compare consumption under the Kigali Amendment phasedown schedule with a counterfactual assuming a conservative 4% annual growth rate in the HFC component of the baseline, which reaches a level of 3.1 $GtCO_2e$ consumption for Article 5 Parties in 2050, consistent with the level reached in 2050 under the current policy Kigali-independent scenario. **The cumulative avoided consumption for 2024–2050 between the Kigali Amendment scenario and this counterfactual is 34.2 $GtCO_2e$. Taking the estimated cost for the full HFC phasedown of US$ 5.888 billion yields a mitigation value of US$ 0.17 per tonne CO_2e (Table *7*).**

Table 7. The incredible cost-effectiveness of Multilateral Fund Assisted HFC Phasedown.

Cumulative HFC avoided, 2024-2050 (billion tonnes CO_2e)	34.2 $GtCO_2e$
Cost per tonne* of CO_2e avoided	US$ 0.17

*assumes MLF replenishments totaling $US5.888 billion through and 2050

Building in margin for accelerated HFC action

The TEAP RTF September 2023 Supplement report includes a scenario in which some countries submit projects to phase down HFCs in advance of applicable compliance targets. Based on current baselines and assuming a 3% growth rate through 2028, the TEAP RTF finds 14 countries that could take advantage of accelerated action and that additional funding on the order of US$ 5 million could be invested over the 2024–2026 triennium to reduce HFC consumption by an additional 10 $MMTCO_2e$ over this period.

Larger projects and benefits could be envisaged if Group 2 countries with large manufacturing sectors such as India also were considered for potential action in advance of applicable compliance targets.

Further, front-loading funding for Article 5 Parties that depend on imports of equipment presents a valuable opportunity to prevent the proliferation of high-GWP and low efficiency equipment in these markets that would result in a longer "servicing tail" and emissions as these products continue to require high-GWP refrigerants and waste energy over their 10-20 year lifetimes. Support for adoption of policies to more rapidly shift imported equipment to low-GWP and high efficiency would not only reduce emissions by reducing the consumption needed to service legacy equipment, but also directly reduce emissions from the banks of equipment and indirectly reduce emissions as a result of lower energy consumption.

Expanding climate benefits (beyond compliance)

Improving energy efficiency of cooling equipment during the HFC phasedown can more than double the climate benefits by reducing emissions from the power plants that provide the electricity to run the equipment.[28] Adopting the best available efficiency and climate-friendly alternative refrigerants by 2030 has the potential to avoid cumulative emissions of 210–460 billion tonnes of CO_2e by 2060, equivalent to 8 years of current anthropogenic emissions.[29]

Additionally, Parties would realize trillions of US dollars in savings from reduced investment in electrical infrastructure and operating costs. The International Energy Agency has estimated that investing in more efficient cooling technologies can cut 2050 energy demand in half, from over 6,000 terawatt hours to less than 3,500 terawatt hours, which will reduce electricity infrastructure investment and running costs by US$ 3 trillion through 2050. Additionally, average cooling energy costs would be almost halved.[30] **Stated another way, *failure* to enable access to the energy efficient and climate-friendly cooling equipment will cause electricity prices for consumers to rise, potentially doubling electricity prices by 2050.**

These trillions of dollars in electricity savings are in addition to the avoided social costs of carbon emissions. If cooling efficiency is accelerated under the Montreal Protocol in combination with the HFC phasedown, it may prove to be the single best investment in affordable electricity and climate change mitigation ever coordinated globally.

Table 8. Scenario of potential energy efficiency pilot projects and costs (reproduced from TEAP RTF Supplemental Report September 2023).

Pilot project sector	Cost per project (excluding project preparation and support costs)	Total Cost, US$
1. Residential and commercial air conditioning and heat pump (ACHP) sector conversions from HFCs that enhance EE by 5–10% (assumes conversion to A3)	Up to 3 large ACHP enterprises with project cost of up to \$2,000,000 including additional capital and operating cost for product development, factory upgrades, and operating cost support. Up to 6 small and medium ACHP enterprises with project cost of less than \$1,000,000 including additional capital and operating cost for product development and operating cost.	\$9.0 M (5 projects)
2.1. Domestic refrigeration and/or stand-alone commercial refrigeration sector conversions from HFCs that enhance EE by 5–10% (assumes conversion to A3)	Up to 2 large enterprises with project cost of up to \$1,500,000 including additional capital and operating cost for product development, factory upgrades, and operating cost support.	\$5.0 M (3 projects)
2.2 Stand-alone commercial refrigeration sector conversions from HFCs that enhance EE by 5–10%	Up to 2 SME and large enterprises with project cost of up to \$1,000,000 including additional capital and operating cost for product development, factory upgrades, and operating cost support.	
3.1 [racks -- distributed systems and condensing units] Technical assistance for assembly and installation of large commercial and industrial refrigeration and/or ACHP	~\$50k per country for policy & awareness ~\$45k-150k for study tours ~\$200-800k (for non-LVC with multiple enterprises) for consultants to provide technical assistance to upgrade capacity to develop higher EE systems and install properly	\$2.0 M (3 regional projects)
3.2 [industrial refrigeration] Technical assistance for assembly and installation of large industrial refrigeration and/or ACHP	Training costs related to maintaining EE, e.g., ~\$50k per country for policy & awareness ~\$50k-150k for study tours	\$1.0 M (2 regional projects)
4. Servicing sector	Technology demonstrations \$10,000 - \$75,000 per demo retro-commission pilot \$100,000+	\$1.0 M (2 regional projects)
5. MEPS, labels and supporting framework for implementation capacity	~\$535k development per country (importing, assumes enabling legislation is in place) [align with U4E/trading partner] Market assessment: ~\$70,000+ MEPS and labelling analyses, design and vetting: ~\$200,000+ (with additional complexity/cost in case of domestic manufacturing/assembly) Communications and awareness raising: ~\$90,000+ Market monitoring, verification and enforcement (MVE) protocols, software and training: ~\$175,000+ Collection, recycling, and disposal: \$170,000+	\$2.0 M (2 projects)

The TEAP RTF Supplement report includes a scenario for funding 10 to 15 energy efficiency pilot projects in the context of the funding window created by ExCom decision 91/65 and initially set at US$ 20 million with the possibility of augmentation. ***Table 8*** provides an illustrative set of potential pilot projects and costs for energy efficiency improvements generally on the order of 5–10% improvement. The next section provides a more detailed analysis of the costs and benefits from energy efficiency improvements in air conditioning and refrigeration equipment.

The TEAP Energy Efficiency Working Group (EEWG) proposed a novel energy efficiency improvement-linked incentive approach in Chapter 9 of the 2023 report.[31] The incentive is calculated as a percentage of the costs associated with the energy efficiency improvement (additional capital costs for factory upgrades and addition operating costs on a per product basis). The approach uses an index to adjust the level of incentive provided as a function of the starting energy efficiency level of an enterprise and the improvement in energy efficiency level for the product being converted. The TEAP EEWG notes that a "key feature of the incentive index is that it focuses resources on those enterprises with the greatest need for capacity building and access to knowledge for designing and integrating lower-cost components into their products to improve from minimum to medium and better energy performance." Further, "the overall capacity of an enterprise based on the energy performance of its portfolio of products is considered in this approach." In this case, large enterprises that produce both very efficient and very inefficient products would receive a lower incentive given that they are not R&D capacity-limited and in many cases own the intellectual property for the high-efficiency components. A recent study shows how low-efficiency equipment and technologies that would not meet the energy efficiency performance requirements in their country of manufacture or brand ownership are exported from China and Japan, respectively, into Southeast Asia.[32]

Here we apply the concept of an improvement-linked incentive approach to three illustrative product types: domestic refrigerators, self-contained commercial refrigeration equipment, and mini-split room air conditioner units (split AC). These products match priority sectors identified by the MLF Executive Committee in decision 91/65. ***Table 9*** summarizes the range of energy savings, EE-linked incentive amounts, and the range of funding support corresponding to these levels for upgrading eligible factories.

The analysis consists of first estimating the costs to upgrade factories and the products by accounting for additional capital costs for equipment manufacturing factories and additional product costs (research, development, testing, marketing and other costs). These costs are based on a review of U.S. Department of Energy rulemakings, LBNL data, and other literature sources. The split AC assumes a shift from R-410A to R-454B,[viii] while the two refrigeration products assume a shift from baseline refrigerant (e.g., R-134a) to R-600a (isobutane). The efficiency improvement uses the Cooling Season Performance Factor (CSPF) metric for split ACs and a percentage reduction in annual electricity use for the domestic and commercial refrigeration cases. Full methodological details are available in Wei and Shah (2023).[33]

[viii] There is less than a 5% difference in cost estimate for a shift to R-32 or R-290 in the context of EE improvement. *See* Wei, Max, Greg Rosenquist, Katie Coughlin, Ed Cubero, Chao Ding, Tom Burke, Omar Abdelaziz, *Benefits and Challenges in Deployment of Low GWP A3 Refrigerants in Residential Air Conditioning Equipment*, 2023, Draft Report for California Energy Commission.

Table 9. Summary of support using energy-efficiency improvement-link incentive approach for energy efficiency upgrades for three types of refrigeration and air conditioning equipment (bolded cases are those treated in detail in the analysis below).

Product	EE improvement	Incentive	Range [1]	Units/Lines
Split AC	**23% (CSPF 3.4 to 4.4)** 30% (CSPF 3.1 to 4.4) [2]	19% 43%	$6-220M [2] $14-582M [2]	25 million units 82 lines @ 300k units/line
Domestic Refrigerators	**16% savings** 21% savings	18% 47%	$17-130M $44-340M	21 million units 112 lines @ 188k units/line
Self-contained commercial refrigeration equipment	**20% savings** 23% savings	22% 47%	$9-34M $19-72M	2.2 million units 56 lines @ 39k units/line

[1] Lower number in the range is for factory upgrades only; high number in range includes factory upgrade cost and two years of support for higher addition operational costs.

[2] The 23% and 30% EE improvement cases assume that all factories are starting at CSPF 3.4 or 4.4, respectively. If half of the factories start at 3.4 and half at 3.1, each of the ranges would be reduced by 50%.

We also assess the lifetime electricity savings in billion kilowatt-hours (TWh) compared to the reference case of no efficiency improvement per US$ 1 million invested in energy efficiency (***Table 10***). The energy savings assumes 15 years of factory production and a 15-year lifetime of each product. The range in electricity savings per US$ 1 million invested reflects ranges in the additional costs (in the case of domestic refrigerators) and hours of use (in the case of split AC). While domestic and commercial refrigeration equipment are assumed to operate 24 hours a day every day, the number of hours of air conditioner usage depends on the climate condition where the equipment is used. This analysis assumes hours of use for split AC for two conditions: 1817 hours and 3630 hours per ISO standard 16358-1 (2013).

The range in CO_2 saved per US$ 1 million invested takes into account the range in electricity saving and two electricity grid emissions factors: a high-end estimate of 0.7 kgCO_2/kWh (based on recent values[34]) and 0.29 kgCO_2/kWh (based on Figure 7-6 in TEAP EEWG (2023)[35], which reaches this level in the early 2030s in the low carbon intensity scenario and in 2050 in the high carbon intensity scenario). These ranges could be larger or smaller based on the assumptions regarding the efficiency and incentive levels used, as well as other factors such as the share of upgrade costs manufacturers pass on to consumers through increased retail price.

In the case presented here, the resulting value ranges from US$ 0.30 to US$ 10.00 per tonne of CO_2 saved in the power sector.

Table 10. Summary of funding scenario for three priority sectors considered wherein an incentive is provided as part of the funding for KIPs to enhance EE while phasing down HFCs.

Metric	Domestic Refrigerator	Self-contained Commercial Refrigeration Equipment	Split AC
TWh savings per $1M invested [1]	0.35-0.39	2.55	1.7-4.9
CO_2 saved in MMt per $1M invested [2]	0.10-0.28	0.7-1.8	0.5-3.4
Ratio of $ invested to metric tons CO_2 saved in the power sector [2]	$10.00 - $3.60	$1.40 - $0.60	$2.00 - $0.30

[1] Includes factory upgrade costs and 2 yrs. support for increased unit production costs.
[2] Assuming a static electricity grid emission factor of 0.7 $kgCO_2/kWh$ to 0.29 $kgCO_2/kWh$. At an electricity grid emission factor of 0.7$kgCO_2/kWh$, 1TWh of savings is equivalent to 0.7MMt CO_2 savings.

A key factor in this analysis is the development of the efficiency improvement-linked incentive. In the case of split AC equipment, the energy efficiency is normalized from 1.0 for the lowest starting efficiency level in a given market, for example, to a given high efficiency level, which is normalized to a value of 10.0 ***(Table 11***).

Table 11. Values of CSPF, normalized EE level on a scale of 1 to 10, and Incentive Index Support Percentage as a function of the factory's starting CSPF and normalized EE level for 1-ton mini split AC units.

CSPF	EE_normalized	Incentive Index Support Pct.
2.80	**1.0**	**100%**
3.00	**2.1**	**57%**
3.10	**2.7**	**43%**
3.20	**3.3**	**32%**
3.40	**4.4**	**19%**
3.60	**5.5**	**11%**
3.80	**6.6**	**6%**
4.00	**7.8**	**3%**
4.20	**8.9**	**2%**
4.40	**10.0**	**0%**

In this illustrative case, the high efficiency level is chosen to balance least lifecycle cost (criterion used by the European Commission as part of the Ecodesign Directive to consider electricity savings over the lifetime of the equipment) with estimated possible increase in retail price resulting from the higher energy efficiency performance. The level of incentive in percentage terms is then computed with this index using a function that starts at 100% for level 1.0 and decreases steeply to 0% at level 10.0. The rationale for this shape is to focus resources on those enterprises that have the least capability to improve the energy efficiency of their products, for example due to lack of R&D capacity and access to the know-how for sourcing and integrating lower-cost components.

As the TEAP EEWG 2023 report noted, "previous TEAP EETF reports have identified MEPS as a major enabling policy for access to higher EE equipment. However, in manufacturing countries, the ability of small and medium domestic enterprises to access the capital, capacity and knowledge to improve the EE of their products can act as a limitation on the MEPS level for that country. When MEPS levels are low, there is no disincentive for higher capacity manufacturers to continue producing and exporting inefficient RACHP equipment into that market. The adage 'a rising tide raises all boats' applies here, as 'raising the floor' on manufacturing EE capacity would address a key barrier to access to higher energy efficient equipment in manufacturing and importing countries."

Lifecycle Refrigerant Management: The 90 Billion Tonne Opportunity

The term "lifecycle refrigerant management" (LRM) refers to cradle-to-cradle best practices to minimalize refrigerant emissions from equipment design, installation, and operation to end-of-life.

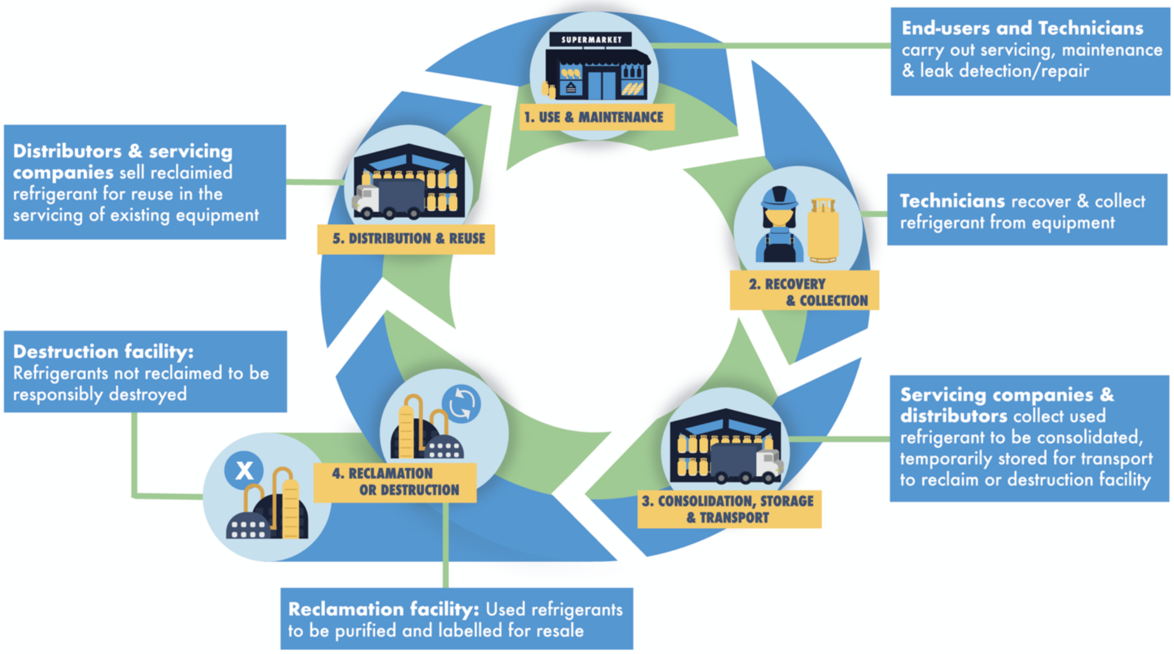

Figure 2. Illustration showing the best practices in the refrigerant lifecycle. Image credit: https://www.climatefriendlysupermarkets.org/refrigerant-management, 2023

The greenhouse gas emissions reduction potential from LRM is huge. The Montreal Protocol and its Kigali Amendment "turn off the tap" by gradually phasing down new *production and consumption* of ozone-depleting and HFC refrigerants, but there are no compliance requirements around emissions. Today, billions of tonnes of CO_2-equivalents of ozone-depleting and HFC refrigerants are contained within existing equipment, and in the future HFCs will continue to be produced and consumed. An analysis by NRDC, IGSD, and EIA found that under the current Kigali Amendment phasedown schedule, over 91 billion tonnes of CO_2e from refrigerant will still be produced, consumed, and emitted, through the end of this century. The majority of this—61 billion tonnes—will occur by 2050 (***Table 12***). The best hope to avoid these emissions, other than accelerating the HFC phasedown schedule under the Montreal Protocol, is action on the "six pillars" of lifecycle refrigerant management (Box 1).

Table 12. Cumulative ODS and HFC emissions that could be mitigated through proper lifecycle refrigerant management (above and beyond climate benefits of the Kigali Amendment).[36]

ODS and HFC Refrigerants ($GtC_{O2}e$)	Through 2050	Through 2100
Global	61	91
United States	6.9	9.2

Box 1. The Six Pillars of Lifecycle Refrigerant Management. From NRDC, EIA, and IGSD (2022) The 90 Billion Ton Opportunity: How Minimizing Leaks and Maximizing Reclaim Can Avoid up to 91 Billion Tons of CO_2-equivalent Emissions.

1 ENHANCE PRODUCT STEWARDSHIP. Most LRM best practices – leak repair, refrigerant recovery and proper disposal – must be ultimately carried out by the entity least responsible for introducing those materials into the economy: service professionals. Government or private entities can set up programs to help increase the responsibility of those higher up the supply chain, such as chemical producers and equipment manufacturers, to provide for economically and technically feasible LRM. This may be arranged voluntarily at first, or mandatorily, and is a good candidate for a pilot state program.

2 INCREASE REFRIGERANT RECOVERY, RECLAMATION AND REUSE. At the end of an appliance's life, the refrigerant should be recovered and sent to a company that cleans and resells it, a process called reclamation. Reclamation relies on refrigerant recovery for a steady supply of refrigerant so emphasis must be placed on making recovery of old refrigerant at end of life economical and enforceable. The reclamation industry itself needs investment and expansion to meet growing demand. Companies and regulators should require that certain equipment use only reclaimed refrigerant, whether by voluntary commitment or mandate, to increase demand for reclaimed refrigerant.

3 LEAK REDUCTION. If they are not well maintained, cooling appliances leak refrigerant slowly but continuously. Targeting low leak rates is an extremely high priority for LRM because they can lead to large climate benefits at low cost. Companies should pursue operational emission reductions as voluntary targets, and regulatory requirements should ensure that systems meet minimum standards. In some cases, leak reduction incentives by electric utilities may be appropriate. Operators and technicians should also adopt best practice leak monitoring and repair practices.

4 REPORTING AND ENFORCEMENT. Stakeholders frequently report that a lack of enforcement aids and abets improper LRM practices in the field, including violations of existing law regarding refrigerant management. Redoubled effort to monitor and enforce LRM provisions, with modernized technologies and approaches, is needed to ensure fair play and an even playing field for all.

5 WORKFORCE DEVELOPMENT. A well-trained, specialized workforce is the bedrock of LRM. Technicians that handle refrigerants should be recertified by EPA based on the latest standards of practice, with ongoing learning and development opportunities to follow. LRM is also a critical cornerstone of efforts to reduce the emissions footprint of buildings, an opportunity that calls for a concerted approach to recruiting and retaining talent.

6 INSTALLATION AND SERVICING. Installation is the starting point of HVACR equipment's life, and LRM cannot be achieved without proper installation and verification. Servicing practices, such as the widespread technique of topping up leaky systems without repairing the underlying leaks, should be discouraged and avoided whenever possible.

Montreal Protocol Parties have addressed the questions of management, collection, destruction, and disposal of controlled substances on numerous occasions, encouraging parties to reduce leaks and dispose of refrigerants in an environmentally sound manner at equipment end-of-life, as well as asking TEAP to study various scenarios to improve end-of-life refrigerant management.[37] Parties have yet to clarify the scope and funding criteria for these topics. This presents an opportunity for parties to maximize the mitigation potential of the Montreal Protocol by requesting MLF Implementing Agencies to prioritize lifecycle refrigerant management as part of the implementation of the Kigali Amendment. Examples of measures Parties could direct MLF Implementing Agencies to take include:

- **Enabling activities and national plans:** From a donor perspective, providing support for enabling activities and national plans that address LRM is one of the most cost-effective options available. The MLF already supports enabling activities, such as activities establishing policies and programs in support of refrigerant transition to facilitate implementation and compliance with Montreal Protocol requirements. Parties could ask the MLF to support enabling activities that help countries establish policies and programs to encourage lifecycle refrigerant management, such as extended producer responsibility requirements. Implementing agencies have experience helping countries establish such policies. Additional expert resources exist outlining policy best practices for lifecycle refrigerant management are available, such as the Resource Book for Life Cycle Management of Fluorocarbons, published by Climate and Clean Air Coalition and the Government of Japan, which showcases examples of policy measures relevant to the life cycle management of fluorocarbons.[38] Parties to the Montreal Protocol could further direct the MLF Implementing Agencies to explicitly integrate lifecycle refrigerant management into the national KIPs and sectoral plans that they are currently working with countries to develop. National policies and programs can potentially leverage much more funding to supplement resources made available under the MLF. As the TEAP replenishment task force noted on page 67 of the September 2023 update to its Replenishment Supplementary Report, refrigerant management can be *"supported by other market-based financing mechanisms, including extended producer responsibility and carbon finance mechanisms. With respect to the latter, a key role that MLF could play is supporting A5 countries…. The ideal system would be based on the equitable distribution throughout the system of the revenues generated, extending back to the national level commercial refrigeration servicing and waste managers."* The same report also identifies some of the indicative needs and costs associated with refrigerant end-of-life management.

- **Capacity building:** Capacity building is a core competency of the MLF and its national partners. Fortunately, 3 out of 6 of the lifecycle refrigerant management pillars revolve around capacity building: these include workforce development, installation and servicing best practices, and reporting and enforcement (Box 1). Parties could encourage MLF and its implementing agencies to integrate LRM best practices into capacity building projects. Specifically:

- *Workforce development, installation and servicing.* Through their experience with the ozone-depleting substance phaseout, MLF Implementing Agencies have already helped countries establish over 130 certification systems for technicians with more than 230 technical institutions implementing training programs; these programs provided training critical to the proper installation, maintenance, and end-of-life treatment of equipment containing controlled substances to over 260,000 technicians. They also helped countries establish more than 230 recovery and recycling programs. This experience is directly translatable to the HFC phasedown, and crucial for the successful implementation of the Kigali Amendment. Training and tools to help technicians minimize leaks when installing and servicing equipment and recover refrigerant at end-of-life is important for lifecycle refrigerant management, but also for technician and public safety (especially in the case of flammable refrigerants). Providing training and tools for the servicing sectors will be most effective when coupled with supportive national policy frameworks supporting LRM, such as requirements around extended producer responsibility, refrigerant leak rate limits and reporting, and/or mandatory technician training and certification to handle refrigerants.

- *Reporting and enforcement.* The MLF has helped parties improve their legal, reporting, and enforcement capacities around refrigerants. For instance, MLF implementing agencies have helped countries in the quantification and reporting of consumption of controlled substances and helped countries train over 64,000 customs officials to better monitor trade in controlled substances (including preventing illegal trade) and enforce controls. If directed to expand this expert assistance, the MLF could not only help countries establish LRM policies, but also help them assure they are robust and enforceable.

- **Technology demonstration and conversion projects:** The MLF has already helped over 4,500 eligible enterprises to demonstrate and convert their production, manufacturing or use of products away from CFCs and HCFCs. Technology conversion projects will also be crucial to the HFC phasedown. The decisions that manufacturers make have repercussions for refrigerant emissions downstream. Implementing Agencies may wish to consider working with eligible manufacturers to integrate LRM best practices from the very start to enhance product stewardship, reduce leaks, and improve ease of refrigerant recovery for reclamation. Examples include:

  - Design of equipment with lower-GWP refrigerants and reduced refrigerant charge;
  - Design and manufacture equipment to minimize leaks, such as selection of improved valves, fittings, hoses, connections, and components;
  - Design and manufacture with refrigerant recovery in mind: for example, features and fittings that allow technicians to quickly and effectively recover refrigerant in the field; features that allow technicians to pump down and retain refrigerant in split AC unit condensers for centralized recovery at a recycling center;
  - Automatic leak detection and diagnostic features to reduce refrigerant loss and limit likelihood of compressor failure in the event of a refrigerant leak; and

- Allowance for use of certified reclaimed refrigerant in existing and/or newly manufactured equipment (instead of specifying only virgin refrigerant can be used).

Many manufacturers will undoubtedly opt for ultra-low GWP refrigerant alternatives, but some may select medium-GWP HFCs due to cost, availability, or safety reasons. In these cases, integrating the LRM best practices from the outset such as those outlined above can be particularly helpful in reducing downstream emissions. Country policies, such as refrigerant GWP and leak rate limits and/or extended producer responsibility, can create the necessary incentives for manufacturers not eligible for MLF funding to integrate such best practices, too.

Funding for LRM could take different forms, such as:

- A separate, added financial incentive for Article 5 Parties to increase refrigerant *reclamation and destruction quantities* above baseline levels, with reporting to confirm increased reclamation and/or destruction rates;
- A simple improvement on the status quo: The MLF is already assisting many Article 5 Parties with LRM best practices, but may not be identifying them as such. Explicit guidance from Parties that the LRM should be integrated into capacity building, enabling activities, national planning, and technology demonstration and conversion projects could help empower implementing agencies to take the lead on these initiatives.
- A supplemental allocation tied to achieving a quantifiable LRM emissions mitigation goal.

If Parties' LRM efforts mitigate just 1/6th of the expected 60 billion tonnes of CO_2e emissions from refrigerants by 2050, it would represent global savings of an additional 10 GtCO_2e by mid-century (***Table 13***).

Table 13. Cumulative emissions reduction opportunity if 1/3 of expected ODS and HFC emissions are mitigated through improved LRM.

ODS and HFC Refrigerants: mitigation potential if just 1/6 of potential LRM emissions reductions are achieved (billion tonnes CO_2 equivalent)	Through 2050	Through 2100
Global	10 GtCO_2e	15 GtCO_2e

If Parties were to set a goal to reduce 10 GtCO_2e through 2050 through improved LRM and allocate an additional US$ 0.10 per tonne of CO_2e, this could unlock up to US$ 1 billion through 2050; or approximately US$ 111 million per triennium over the next 9 replenishments. This funding would be more than sufficient to help Parties implement core LRM best practices, especially if the policy frameworks established with this support lead to supplemental revenue sources LRM identified by the TEAP Replenishment Task Force (market-based financing mechanisms, extended producer responsibility and/or carbon finance mechanisms).

Part III – Recommendations and Conclusions

The MLF has a proven track record of efficient, cost-effective management of funds that can be built upon to deliver additional mitigation, adaptation, and resilience. Investing in the MLF will deliver significant climate and energy benefits that stand out as among the very best investment for planetary protection.

The legacy of cost-effective emissions reductions under the Montreal Protocol continues. Parties will meet in Nairobi the week of 23-27 October 2023 to decide on the replenishment of the MLF for the 2024-2026 triennium. This replenishment is historic as it will cover two simultaneous compliance requirements: the continuing phaseout of ozone-depleting hydrochlorofluorocarbons (HCFCs) and the first stage of hydrofluorocarbon (HFC) phasedown under the Kigali Amendment. Compared to past replenishments on the order of US$ 500 million, the Montreal Protocol's Replenishment Task Force (RTF) report estimates a replenishment on the order of US$ 1 billion to cover the HCFC and HFC compliance requirements for this three-year period.[39] This is comparable to past replenishments when adjusted for inflation: for example, in 1994, Parties voted to approve US$ 455 million for the Multilateral Fund, a figure that is worth over US$ 938 million in 2023 dollars when adjusted for inflation.[40] Importantly, the RTF estimate for 2024-2026 only includes US$ 20 million for energy efficiency pilots. Further it does not consider funding needs to support accelerated action, such as projects that "reduced HFC consumption in advance of Montreal Protocol targets […] for countries that had a strong national level of commitment in place to support such reductions,"[41] such as India.

The objective of report is to quantify the climate, energy and cost implications of accelerated sustainable cooling action under the Montreal Protocol to phase down super climate polluting hydrofluorocarbons (HFCs) while enhancing the energy efficiency of cooling equipment. It considers additional and accelerated activities building on the cost-effectiveness and demonstrated success of the MLF and complements the report prepared by the Technology and Economic Assessment Panel (TEAP) Replenishment Task Force (RTF).[42]

Under the current controlled substance phasedown schedule established by the Kigali Amendment, the treaty will reduce emissions by 80 billion tonnes of CO_2e from 2016-2050 if compliance is achieved.[43] The majority of these savings will come from Article 5 Parties eligible for MLF assistance with the incremental costs of transitioning to new technologies. Most of these emissions could be avoided through investment in the MLF at the low cost of US$ 1 per tonne CO_2e or less (***Table 1***).

This stands out as one of the best investments in planetary protection and resilience building.

Acronyms

A5 Party	Developing country as defined by Article 5 of the Montreal Protocol on Substances that Deplete the Stratospheric Ozone Layer
AC	air conditioning
ACHP	air conditioning and heat pumps
CFCs	chlorofluorocarbons
CO_2e	carbon dioxide equivalent
EE	energy efficiency
EEWG	Energy Efficiency Working Group of the Montreal Protocol Technology and Economic Assessment Panel
GIZ	Deutsche Gesellschaft für Internationale Zusammerarbeit
Gt	Gigatonne (billion metric tonnes)
GWP	Global warming potential of a substance relative to CO_2 over a defined period, such as 20 or 100 years
HCFCs	hydrochlorofluorocarbons
HFCs	hydrofluorocarbons
HPMP	HCFC Phaseout Management Plan
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
kWh	kilowatt-hours of electricity, a standard unit of measurement for electricity consumption equal to one kilowatt of electricity used for one hour
KIP	Kigali Amendment Implementation Plan
LRM	Lifecycle Refrigerant Management
LVC	Low volume consuming country (of Montreal Protocol controlled substances)
MEPS	Minimum energy performance standards
MLF	Multilateral Fund for the Implementation of the Montreal Protocol, which helps A5 Parties with incremental cost of transition away from controlled substances
MWh	Megawatt hour, equal to one thousand kilowatt hours of electricity
MMT	million metric tonne
ODS	ozone depleting substance
OECD	Organization for Economic Cooperation and Development
RACHP	Refrigeration, air conditioning and heat pumps
RTF	Replenishment Task Force
TEAP	Technology and Economic Assessment Panel of the Montreal Protocol
TWh	Terawatt hour, equal to one billion kilowatt hours or one million megawatt hours
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
UNDP	United Nations Development Programme

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[1] Multilateral Fund (2023) *A global challenge, universal solidarity*.

[2] World Resources Institute (*last visited* 5 September 2023) *Climate Watch Historical GHG Emissions (1990-2020)* Washington, DC.

[3] World Meteorological Organization (2022) SCIENTIFIC ASSESSMENT OF OZONE DEPLETION: 2022, Global Ozone Research and Monitoring Project–Report No. 278, WMO, 3 ("New studies support previous Assessments in that the decline in ODS emissions due to compliance with the Montreal Protocol avoids global warming of approximately 0.5–1 °C by mid-century compared to an extreme scenario with an uncontrolled increase in ODSs of 3–3.5% per year…. TCO [total column ozone] is expected to return to 1980 values around 2066 in the Antarctic, around 2045 in the Arctic, and around 2040 for the near-global average (60°N–60°S)…. Compliance with the 2016 Kigali Amendment to the Montreal Protocol, which requires phase down of production and consumption of some hydrofluorocarbons (HFCs), is estimated to avoid 0.3–0.5 °C of warming by 2100. This estimate does not include contributions from HFC-23 emissions."). *See also* Young P. J., Harper A. B., Huntingford C., Paul N. D., Morgenstern O., Newman P. A., Oman L. D., Madronich S., & Garcia R. R. (2021) *The Montreal Protocol protects the terrestrial carbon sink*, Nature 596(7872): 384–388, 384 ("Overall, at the end of the century, worldAvd warms by an additional 2.5 K (2.4–2.7 K) above the RCP 6.0 baseline in worldProj. Of this warming, 1.7 K comes from the previously explored[19] additional radiative forcing due to the higher CFC concentrations in worldProj. Newly quantified here is the additional warming of global-mean air temperature of 0.85 K (0.65–1.0 K)—half as much again—that arises from the higher atmospheric CO_2 concentrations due to the damaging effect of UV radiation on terrestrial carbon stores.").

[4] Gillis J. (9 December 2013) *The Montreal Protocol, a Little Treaty That Could*, THE NEW YORK TIMES ("Here is a remarkable fact about global warming: It might be twice as bad right now were it not for a treaty negotiated by a conservative American president, for an entirely different purpose, based on motives no one has ever quite understood…. The Montreal Protocol is widely seen as the most successful global environmental treaty. It incorporates pragmatic, business-friendly principles that have allowed it to operate smoothly for more than two decades, achieving its goals — and then some — with little controversy.").

[5] The Economist (20 September 2014) *Curbing Climate Change: The Deepest Cuts* ("The net effect is equivalent to that of a whopping 135 billion tonnes of carbon dioxide. That is more than twice today's total annual greenhouse-gas emissions, which are equivalent to about 50 billion tonnes of carbon dioxide (carbon dioxide itself makes up about three-quarters of that, with methane, nitrous oxide and some gases used in industry making up the rest).").

[6] US Environmental Protection Agency (2016) *Update on Kigali Amendment to the Montreal Protocol*, 4. ("Avoids over 80 billion metric tons of carbon dioxide equivalent cumulatively through 2050."). Several studies before and after the Kigali Amendment estimated the potential impact from phasing down HFCs compared to baseline: Velders and colleagues (Velders G. J. M., *et al.* (2015) *Future atmospheric abundances and climate forcings from scenarios of global and regional hydrofluorocarbon (HFC) emissions*, ATMOSPHERIC ENV'T. 123:200–209) calculated that, compared to business-as-usual, phasing down HFCs will avoid 4.0–5.3 GtCO_2-eq per year by 2050. With updated policies and a revised baseline (Höglund-Isaksson et al., 2017), full compliance with the Kigali Amendment under the Montreal Protocol could reduce global HFC emissions by 3.7 GtCO_2-eq per year by 2050 and avoid cumulative emissions of 39 GtCO_2-eq between 2018 and 2050. Because the Montreal Protocol has previously achieved near 100% compliance (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), the Kigali Amendment will ensure compliance with both the policies in the revised baseline and the additional potential from the requirements of the Amendment.

[7] World Meteorological Organization, United Nations Environment Programme, National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration, & European Commission (2022) *Executive Summary*, *in* SCIENTIFIC ASSESSMENT OF OZONE DEPLETION: 2022, Geneva, Switzerland ("Compliance with the 2016 Kigali Amendment to the Montreal Protocol, which requires phase down of production and consumption of some hydrofluorocarbons (HFCs), is estimated to avoid 0.3-0.5°C of warming by 2100. This estimate does not include contributions from HFC-23 emissions."). *See also* Xu Y., Zaelke D., Velders G. J. M., & Ramanathan V. (2013) *The role of HFCs in mitigating 21st century climate change*, ATOM. CHEM. PHYS. 13:6083–6089, 6083 ("Here we show that avoiding production and use of high-GWP (global warming potential) HFCs by using technologically feasible low-GWP substitutes to meet the increasing global demand can avoid as much as another 0.5 C warming by the end

of the century."). *HFC-23 100-year GWP value from* Burkholder J. B., Hodnebrog Ø., McDonald B. C., Orkin V., Papadimitriou V. C., & Van Hoomissen D. (2022) *Annex: Summary of Abundances*, *in* SCIENTIFIC ASSESSMENT OF OZONE DEPLETION: 2022, World Meteorological Organization: Geneva.

[8] Paul J. Young, Anna B. Harper, Chris Huntingford, Nigel D. Paul, Olaf Morgenstern, Paul A. Newman, Luke D. Oman, Sasha Madronich, Rolando R. Garcia. The Montreal Protocol protects the terrestrial carbon sink**.** *Nature*, 2021; 596 (7872): 384 DOI: 10.1038/s41586-021-03737-3

[9] Multilateral Fund (2023) *A global challenge, universal solidarity*.

[10] Multilateral Fund (2023) *Chapter IV: Bilateral Cooperation* in POLICIES, PROCEDURES, GUIDELINES AND CRITERIA (*as of* July 2023).

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[15] Multilateral Fund for the Implementation of the Montreal Protocol (last visited 15 August 2023) *Welcome to the Multilateral Fund for the Implementation of the Montreal Protocol*, ("As at [sic] 29 May 2023, the contributions received by the Multilateral Fund from developed countries, or non-Article 5 countries, totalled over US$ 4.4 billion. The Fund has also received additional voluntary contributions amounting to US $25.5 million from a group of donor countries to finance fast-start activities for the implementation of the HFC phase-down.").

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[17] Multilateral Fund (5 May 2023) *Scorecard for the Multilateral Fund*, 2–3 ("Social cost savings: To estimate the social cost savings associated with the avoided climate emissions (i.e., averting potential storms, heatwaves, wildfires, droughts, and other climate related natural disasters), the Secretariat used the social price of carbon of US $40/$CO_2$-eq tonne[4] resulting in US $2 trillion savings to society.") *Citing* World Bank (2017) *Shadow price of carbon in economic analysis*.

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

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lead-up to the Kigali Amendment and locked-in with the entry into force of the Kigali Amendment, *see* Velders G. J. M., Daniel J. S., Montzka S. A., Vimont I., Rigby M., Krummel P. B., Muhle J., O'Doherty S., Prinn R. G., Weiss R. F., & Young D. (2022) *Projections of hydrofluorocarbon (HFC) emissions and the resulting global warming based on recent trends in observed abundances and current policies*, ATMOS. CHEM. PHYS. 22(9): 6087–6101, 6099 ("Projected mixing ratios, radiative forcing, and globally averaged temperature changes are calculated from the projected HFC emissions. The 2050 radiative forcing is 0.13–0.18 Wm^{-2} in the current policies K-I scenario and drops to 0.08–0.09 Wm^{-2} when the additional Kigali Amendment controls are considered (in KA-2022). In the current policies K-I scenario, the HFCs are projected to contribute 0.14–0.31 °C to the global surface warming in 2100, compared to 0.28–0.44 °C without policies. Following the Kigali Amendment, the surface warming of HFCs is reduced to about 0.05 °C in 2050 and 0.04 °C in 2100 (KA-2022. In a hypothetical scenario with a full phaseout of HFCs production and consumption in 2023, the contribution is reduced to about 0.01 °C in 2100.").

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[22] World Meteorological Organization (WMO), United Nations Environment Programme (UNEP), National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA), and European Commission (2018). *Scientific Assessment of Ozone Depletion: 2018*. Geneva. Global Ozone Research and Monitoring Project-Report No. 58. ES.31 ("A faster phasedown of HFCs than required by the Kigali Amendment would further limit climate change from HFCs. One way to achieve this phasedown would be more extensive replacement of high-GWP HFCs with commercially available low-GWP alternatives in refrigeration and air-conditioning equipment. Figure ES-9 shows the impact of a complete elimination of production of HFCs starting in 2020, and their substitution with low-GWP HFCs, which would avoid an estimated cumulative 53 $GtCO_2$-eq emission during 2020–2060. Improvements in energy efficiency in refrigeration and air-conditioner equipment during the transition to low-GWP alternative refrigerants can potentially double the climate benefits of the HFC phasedown of the Kigali Amendment."). *See also* Spoza S., *et al.* (2021) *Chapter 6: Short-lived climate forcers*, *in* CLIMATE CHANGE 2021: THE PHYSICAL SCIENCE BASIS, *Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, Masson-Delmotte V., *et al.* (eds.), 6-71 ("Efficient implementation of the Kigali Amendment and national and regional regulations has been projected to reduce global average warming in 2050 by 0.05°–0.07°C (Klimont et al., 2017c; WMO, 2018) and by 0.2–0.4°C in 2100 compared with the baseline (see Figure 2.20 of WMO, 2018). Analysis of SSP scenarios based on an emulator (Section 6.7.3) shows a comparable mitigation potential of about 0.02–0.07°C in 2050 and about 0.1–0.3°C in 2100 (Figure 6.22, SSP5-8.5 versus SSP1-2.6). Furthermore, the energy efficiency improvements of cooling equipment alongside the transition to low global warming potential alternative refrigerants for refrigeration and air-conditioning equipment could potentially increase the climate benefits from the HFC phasedown under the Kigali Amendment (Shah et al., 2015; Höglund-Isaksson et al., 2017; Purohit and Höglund-Isaksson, 2017; WMO, 2018). Purohit et al (2020) estimated that depending on the expected rate of technological development, improving energy efficiency of stationary cooling technologies, and compliance with Kigali Amendment could bring future global electricity-savings of more than 20% of expected world's electricity consumption beyond 2050 or cumulative reduction of about 75-275 Gt CO_2eq over the period 2018-2100 (*medium confidence*). This could potentially double the climate benefits of the HFC phase-down of the Kigali Amendment as well as result in small air quality improvements due to reduced air pollutant emissions from power sector, i.e., 8-16% reduction of $PM_{2.5}$, SO_2, NO_x (Purohit et al., 2020)."); *and* Purohit P., Höglund-Isaksson L., Dulac J., Shah N., Wei M., Rafaj P., & Schöpp W. (2020) *Electricity savings and greenhouse gas emission reductions from global phase-down of hydrofluorocarbons*, ATMOS. CHEM. PHYS. 20(19): 11305–11327, 11305 ("The combined effect of HFC phase-down, energy efficiency improvement of the stationary cooling technologies, and future changes in the electricity generation fuel mix would prevent between 411 and 631 $PgCO_2$ equivalent of GHG emissions between 2018 and 2100, thereby making a significant contribution towards keeping the global temperature rise below 2 °C.").

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T., Picolotti R., Shah N., & Xu Y. (2020) ASSESSMENT OF CLIMATE AND DEVELOPMENT BENEFITS OF EFFICIENT AND CLIMATE-FRIENDLY COOLING, Molina M. & Zaelke D., Steering Committee Co-Chairs, xii ("Transitioning to high efficiency cooling equipment can more than double the climate benefits of the HFC phasedown in the near-term by reducing emissions of carbon dioxide (CO_2) and black carbon from the electricity and diesel used to run air conditioners and other cooling equipment. This also will provide significant economic, health, and development co-benefits. … Robust policies to promote the use of best technologies currently available for efficient and climate-friendly cooling have the potential to reduce climate emissions from the stationary air conditioning and refrigeration sectors by 130–260 $GtCO_2e$ by 2050, and 210–460 $GtCO_2e$ by 2060. A quarter of this mitigation is from phasing down HFCs and switching to alternatives with low global warming potential (GWP), while three-quarters is from improving energy efficiency of cooling equipment and reducing electricity demand, which helps achieve a more rapid transition to carbon free electricity worldwide. The mobile air conditioning sector, where energy consumption is expected to nearly triple by 2050, offers significantly more mitigation potential.").

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