THE KIGALI AMENDMENT 2016–2026

MONTREAL PROTOCOL
FACT SHEET
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Montreal Protocol Is Successfully Tackling Climate Threat After Saving Ozone Layer

10-year anniversary of Kigali Amendment celebrates avoiding up to 0.5ºC of warming

- The world has successfully phased out nearly 100 fluorinated gases—CFCs and their replacements—by nearly 100%.[1]
    - The phaseouts started in the 1970s with boycotts of spray cans using CFCs as propellants.
    - This was followed in 1987 with the binding 1987 Montreal Protocol on Substances that Deplete the Ozone Layer, now recognized as the world's most successful environmental treaty.[2]
- The success reducing "f-gases" will avoid 0.5–1ºC of warming by mid-century[3] and effectively delay warming up to 45 years.[4]
- The Montreal Protocol is on course to avoid a planet-saving 2.5°C of global warming by 2100.[5]
    - Of the 2.5°C of avoided warming, 1.7°C is from reducing the super f-gases.
    - Another 0.85°C (0.65°–1.0°C) is from repairing the ozone layer and keeping excess UVB radiation from destroying forests and other sinks.
    - By the end of the century, this will save 325 to 690 billion tonnes of CO_2 held in plants and soils—representing up to 17 years of avoided CO_2 emissions.
- Phasing down HFCs will, on its own, avoid up to 0.5ºC of warming by 2100,[6] equivalent to avoiding emissions of 420 $GtCO_2e$[7]—more than 10 years of CO_2 emissions—with 0.1ºC avoided by 2050.[8]
- The 2016 Kigali Amendment to the Montreal Protocol set an initial HFC phasedown schedule that will deliver most of this reduction.
- Adding improvements in energy efficiency can double the climate benefits of the Kigali Amendment[9] and increase the combined HFC and energy-related climate benefits—over just the next four decades—to 460 $GtCO_2e$.[10]
    - This number combines ambitious implementation of the Kigali Amendment HFC phasedown schedule with increased energy efficiency in cooling appliances, but does not include HFC-23, which the Montreal Protocol's Scientific Assessment Panel estimates at 15% of the total radiative forcing from HFCs in 2019.[11]
- Much of the 61 $GtCO_2e$ of f-gases that will enter the market and be embedded in products by 2050 (and the 91 $GtCO_2e$ that will enter by 2100) can be reduced with robust lifecycle refrigerant management that avoids leaks, promotes recovery, and increases reclamation.[12]
- In addition, the successful actions to phase out CFCs and their replacements put the protective ozone layer on the path to recovery by 2066.[13]
    - This is avoiding hundreds of millions of cases of skin cancer and cataracts in the US alone.[14]
    - It is delivering an estimated $2 to $9.5 trillion in savings to society,[15] depending on the social cost assigned to carbon.
- If all of the cost of phasing out f-gases through the Montreal Protocol's Multilateral Fund were assigned to climate protection—rather than ozone protection—the cost of climate mitigation would be less than $0.10 per tonne of CO_2e.[16]
- While some of the climate and ozone benefits have already been realized, it's a long road to 2100 to capture all of the potential benefits.
    - The next decade of action provides a critical opportunity to maximize the climate and ozone mitigation from the Montreal Protocol and related cooling strategies and thereby slow near-term warming and avoid fast-approaching tipping points, which is especially important as today's accelerating rate of warming appears to be more important for triggering tipping points, such as AMOC, than temperature increase.[17]
- There is no better climate investment than the Montreal Protocol, a proven regime that has delivered its promised mitigation for nearly four decades, and is ready to do even more in the next four decades honoring its "start and strengthen" culture, as noted in the KIGALI +10 DECLARATION TO ADVANCE GLOBAL ATMOSPHERIC PROTECTION: *Celebrating the past decade of success. Committing to the next decade of success.*

ENDNOTES

[1] Molina M. & Zaelke D. (2017) The Montreal Protocol: triumph by treaty, United Nations Environment Programme ("The Protocol, also agreed under UN Environment's auspices, aimed at starting, then strengthening, protective action. Initially its parties agreed to cut chlorofluorocarbons by 50 per cent over 12 years, but they swiftly accelerated the reduction to 75 per cent by 1998, and then 100 per cent by 1992. Success has continued to breed success. Over its 30-year history, the treaty has succeeded in reducing nearly 100 ozone-depleting chemicals by nearly 100 per cent.").

[2] Molina M. & Zaelke D. (25 September 2012) *A Climate Success Story to Build On*, THE NEW YORK TIMES ("A more fitting culmination of 25th year of the world's most successful environmental treaty would be an agreement to phase down the high-impact HFCs when the parties meet later this year, and again provide broader political momentum for additional action to address the accelerating impact of climate change.").

[3] Liang Q., Rigby M., Fang X., Godwin D., Mühle J., Saito T., Stanley K. M., Velders G. J. M., Bernath P., Derek N., Reimann S., Simpson I. J., & Western L. (2022) SCIENTIFIC ASSESSMENT OF OZONE DEPLETION: 2022, Global Ozone Research and Monitoring Project–Report No. 278, World Meteorological Organization, United Nations Environment Programme, National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration, & European Commission ("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.").

[4] Velders G. J. M., Andersen S. O., Daniel J. S., Fahey D. W., & McFarland M. (2007) The importance of the Montreal Protocol in protecting climate, PROC. NAT'L. ACAD. SCI. 104(12): 4814–4819 ("When using an averaged CO_2 RF growth rate, the MR74 delay is calculated to be 13–18 or 31–45 yr, corresponding to the 3% and 7% annual growth rates, respectively. [MR74 includes the early consumer boycotts and national measures leading up to the MP.] Similarly, the delay attributable to the Montreal Protocol (NMP87) is calculated to be 7–12 yr.").

[5] 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 ("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 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.").

[6] Xu Y., Zaelke D., Velders G. J. M., & Ramanathan V. (2013) The role of HFCs in mitigating 21st century climate change, ATMOS. CHEM. PHYS. 13(12): 6083–6089, 6083 ("Here we show that avoiding production and use of highGWP (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 ºC warming by the end of the century. This combined mitigation on SLCPs would cut the cumulative warming since 2005 by 50% at 2050 and by 60% at 2100 from the CO_2-only mitigation scenarios, significantly reducing the rate of warming and lowering the probability of exceeding the 2 ºC warming threshold during this century.").

[7] Salawitch R.J., McBride L.A., Thompson C.R., Fleming E.L., McKenzie R. L., Rosenlof K. H., Doherty S. J., & Fahey D. W. (2022) Twenty Questions and Answers About the Ozone Layer: 2022 Update, Scientific Assessment of Ozone Depletion, World Meteorological Organization ("The Kigali Amendment entered into force on 1 January 2019. Figure Q19-1 shows how the amendment provisions dramatically reduce projected emissions of HFCs in the coming decades. The emissions of HFCs that are avoided by 2100 total about 420 gigatonnes CO_2-equivalent, which is more than 10 years of present-day annual emissions of CO_2 due to human activities.").

[8] Zaelke, D., Picolotti, R., Campbell, K. & Dreyfus, G. (2025), Background Note: The Need for Fast Near-Term Climate Mitigation to Slow Feedbacks and Tipping Points, Working Paper. Institute for Governance & Sustainable Development and Center for Human Rights and Environment ("Reducing HFCs through the 2016 Kigali Amendment to the Montreal Protocol will account for nearly 0.1 °C of the avoided warming by 2050."), *citing* Liang Q., *et al.* (2022) Chapter 2: Hydrofluorocarbons (HFCs), in SCIENTIFIC ASSESSMENT OF OZONE DEPLETION: 2022, Global Ozone Research and Monitoring Project–Report No. 278, WMO, UNEP, NOAA, NASA, & European Commission, 145 (Figure 2-18); and Szopa 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.), 873. Improving energy efficiency of cooling equipment can double the climate benefits of reducing HFCs. *See* Dreyfus G., *et al.* (2020) ASSESSMENT OF CLIMATE AND DEVELOPMENT BENEFITS OF EFFICIENT AND CLIMATE-FRIENDLY COOLING; and note 9, below, where we cite energy efficiency.

[9] Liang Q., Rigby M., Fang X., Godwin D., Mühle J., Saito T., Stanley K. M., Velders G. J. M., Bernath P., Derek N., Reimann S., Simpson I. J., & Western L. (2022) *Chapter 2: Hydrofluorocarbons (HFCs)*, *in* SCIENTIFIC ASSESSMENT OF OZONE DEPLETION: 2022, Global Ozone Research and Monitoring Project–Report No. 278, WMO, UNEP, NOAA, NASA, & European Commission ("Concerted efforts to improve energy efficiency of refrigeration and air-conditioning equipment could lead to reductions in greenhouse gas emissions of the same order as those from global implementation of the Kigali Amendment.").

[10] United Nations Environment Programme & International Energy Agency (2020) COOLING EMISSIONS AND POLICY SYNTHESIS REPORT: BENEFITS OF COOLING EFFICIENCY AND THE KIGALI AMENDMENT ("According to these studies, the world can avoid the equivalent of up to 210-460 $GtCO_2e$ (roughly equal to 4-8 years of global emissions at 2018 levels) (UNEP 2019b) over the coming

four decades through efficiency improvements and the refrigerant transition (Shah et al. 2019), depending on future rates of decarbonization"). *See also* IEA Press Release (2020) Climate-friendly cooling could cut years of greenhouse gas emissions and save trillions of dollars ("Reductions of between 210 and 460 billion tonnes of carbon dioxide (CO_2) equivalent emissions can be delivered over the next four decades through actions to improve the cooling industry's energy efficiency together with the transition to climate-friendly refrigerants, according to the report.").

[11] Liang Q., Rigby M., Fang X., Godwin D., Mühle J., Saito T., Stanley K. M., Velders G. J. M., Bernath P., Derek N., Reimann S., Simpson I. J., & Western L. (2022) *Chapter 2: Hydrofluorocarbons (HFCs)*, *in* SCIENTIFIC ASSESSMENT OF OZONE DEPLETION: 2022, Global Ozone Research and Monitoring Project–Report No. 278, World Meteorological Organization, United Nations Environment Programme, National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration, & European Commission ("Global mean abundances of each of the major HFCs have increased since 2016. Radiative forcing due to the HFCs reached 44.1 ± 0.6 mW m–2 in 2020, an increase of around one-third since 2016. HFC-134a remained the largest contributor to the overall radiative forcing due to HFCs (44%), and HFC-125 (18%) overtook HFC-23 (15%) as the second-largest contributor.").

[12] Theodoridi C., Hillbrand A., Starr C., Mahapatra A., & Taddonio K. (2022) THE 90 BILLION TON OPPORTUNITY, Environmental Investigation Agency, Institute for Governance and Sustainable Development, and Natural Resources Defense Council ("A robust LRM regime would make it possible to prevent the release of a significant portion of the approximately 61 GtCO2e of ODSs and HFCs in use or expected to be produced by 2050. By 2100, the global total rises to approximately 91 GtCO2e – nearly equal to three full years of global energy-related carbon dioxide emissions today.").

[13] World Meteorological Organization, United Nations Environment Programme, National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration, & European Commission (2022) SCIENTIFIC ASSESSMENT OF OZONE DEPLETION: 2022, Global Ozone Research and Monitoring Project–Report No. 278, WMO, 3 ("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). The assessment of the depletion of TCO in regions around the globe from 1980–1996 remains essentially unchanged since the 2018 Assessment.").

[14] U.S. Environmental Protection Agency (2020) Updating the Atmospheric and Health Effects Framework Model: Stratospheric Ozone Protection and Human Health Benefits, EPA Publication No. 430R20005 ("With the current set of updates to the AHEF, the Montreal Protocol as amended and adjusted—compared with a scenario of no controls on ODS to reduce or avoid emissions—is now expected to prevent approximately 443 million cases of skin cancer, 2.3 million skin cancer deaths, and 63 million cataract cases for people in the United States born in the years 1890–2100."). *See also* Madronich S., Lee-Taylor J.M., Wagner M., Kyle J., Hu Z., & Landolfi R. (2021) Estimation of Skin and Ocular Damage Avoided in the United States through Implementation of the Montreal Protocol on Substances that Deplete the Ozone Layer, ACS EARTH SPACE CHEM., 1876–1888.

[15] Multilateral Fund for the Implementation of the Montreal Protocol, Pioneering Environmental Change: The Multilateral Fund's Impact ("At the rate of US$ 0.07 per tonne of CO_2-equivalent (CO_2-eq) removed from the atmosphere, MLF has contributed to the avoidance of billions of tonnes of CO_2-eq emissions at a fraction of the cost compared to other sectors. Between 1995 and 2021, the total avoided emissions from Article 5 countries are estimated at 51.1 gigatonnes of CO_2-eq, a US$ 2 trillion savings to society (based on a social price of carbon of US $40/$CO_2$-eq tonne)."). Using a more realistic social cost of carbon of $185/ton, the savings to society would be $9.5 trillion. *See* Rennert K., *et al.* (2022) Comprehensive evidence implies a higher social cost of CO_2, NATURE 687-692, 610 ("Our preferred mean SC-CO_2 estimate is $185 per tonne of CO_2 ($44–$413 per tCO_2: 5%–95% range, 2020 US dollars) at a near-term risk-free discount rate of 2%, a value 3.6 times higher than the US government's current value of $51 per t$CO_2$. … Our higher SC-$CO_2$ values, compared with estimates currently used in policy evaluation, substantially increase the estimated benefits of greenhouse gas mitigation and thereby increase the expected net benefits of more stringent climate policies.").

[16] Dreyfus G., Wei M., Shah N., & Taddonio K. (2023) Ambitious Replenishment of the Multilateral Fund for Implementation of the Montreal Protocol Delivers High Impact Climate Benefits at Low Cost ("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.").

[17] van Westen R.M., Börner R., & Dijkstra H.A. (2026) *Failure to track a stable AMOC state under rapid climate change*, NATURE CLIMATE CHANGE ("The Atlantic Meridional Overturning Circulation (AMOC) … currently has an estimated global warming threshold for collapse of +4.0 °C (uncertainty range 1.4–8 °C). However, such a threshold may not be meaningful because AMOC stability depends on the rate of radiative forcing change, not a set temperature. … [U]nder faster CO_2 ramps [such as today's 2.6 ppm yr^{-1} of CO_2], the AMOC collapses at substantially lower warming levels (+2 °C). Our findings demonstrate rate-induced AMOC tipping and imply that limiting the rate of emissions is critical for reducing the risk of an AMOC collapse.").