HOW THE MONTREAL PROTOCOL SAVED THE WORLD TWICE AND COULD DO IT AGAIN

by Durwood Zaelke

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I. Introduction: Temperature, Time, and Tipping Points

Solving a problem starts with defining it, and the climate emergency is no exception. Three concepts do the job: temperature, time, and tipping points. It's too hot, and we have too little time before passing tipping points that are likely to be catastrophic and irreversible.

The average temperature of the last three years exceeded 1.5º Celsius (ºC) above its pre-industrial level for the first time in 125,000 years. It will be locked in within five years, if it isn't already in the rearview mirror as climate scientist Jim Hansen believes. And tomorrow's temperature of 2ºC will be breached as early as 2045.[1]

In this narrowing window, the planet faces the first five irreversible tipping points—including the loss of the Amazon forest, the loss of the Greenland Ice Sheet, and the halting of the Atlantic Meridional Overturning Circulation (AMOC)—all with catastrophic impacts. Losing the Amazon will cost us a significant sink that is already starting to give up some of the carbon dioxide (CO_2) it has absorbed. It will also dry up the atmospheric rivers that carry the moisture needed to support agriculture and biodiversity throughout much of South America.

Losing the Greenland Ice Sheet will result in several meters of sea-level rise, drowning coastal cities, and will intensify the loss of the AMOC. Losing the AMOC will strand the heat this vital Atlantic current carries north to warm much of Europe, causing it to face freezing temperatures. Instead, that heat will remain in the tropics and accelerate melting in Antarctica.

It's a dark future, getting darker from the continuing emissions of climate pollutants and the destruction of our ocean and land sinks, and increasingly from self-amplifying feedback loops where the planet is starting to warm itself. The reduction of Arctic Sea ice illustrates such feedbacks. As the white ice shield melts, it is replaced by darker water that absorbs solar radiation formerly reflected to space, causing still more warming and more ice loss. This in turn accelerates the thawing of permafrost, which releases its ancient stores of CO_2 and methane, setting off a similar loop. Scientists have identified 27 such self-amplifying feedback loops to worry about.[2]

II. The Current Landscape

Given this precarious state of affairs, it is increasingly obvious that we will not solve the fast-moving climate emergency with current slow-moving solutions. Success will require speed, and the need for speed must become a key metric. How fast can various solutions slow warming? That's the question policymakers need to answer.

Keeping this in mind, we can seek out possible solutions. Let us start with efforts to cut CO_2 emissions from the fossil fuel sector, responsible for a bit more than half of climate emissions, and then go on to the non-CO_2 pollutants responsible for the other half. Despite more than three decades of negotiations in the 1992 United Nations Framework Convention on Climate Change (UNFCCC),[3] and the voluntary measures of the 2015 Paris Agreement,[4] emissions of climate pollutants continue to increase.

Of course, it is surely true that the planet would warm even more without the UNFCCC and its Paris Agreement: the early scenarios of warming reaching 4 to 7ºC above pre-industrial levels by the end of the century have now been revised downward to an expectation of "only" 2.7 to 3.2ºC.[5] Yet, fossil CO_2 emissions increased by nearly 75%

1. *See* James E. Hansen et al., *Global Warming Has Accelerated: Are the United Nations and the Public Well-Informed?*, 67 Env't: Sci. & Pol'y for Sustainable Dev. 6 (Jan./Feb. 2025), https://doi.org/10.1080/00139157.2025.2434494. *See also* Damian Carrington, *Climate Change Target of 2C Is "Dead," Says Renowned Climate Scientist*, The Guardian, Feb. 2025, https://www.theguardian.com/environment/2025/feb/04/climate-change-target-of-2c-is-dead-says-renowned-climate-scientist.
2. William J. Ripple et al., *Many Risky Feedback Loops Amplify the Need for Climate Action*, 6 One Earth 86 (Feb. 2023), https://doi.org/10.1016/j.oneear.2023.01.004.
3. United Nations Framework Convention on Climate Change, May 9, 1992, S. Treaty Doc No. 102-38, 1771 U.N.T.S. 107. On January 27, 2026, the U.S. withdrawal from the Paris Agreement went into effect. *See* UN, *Paris Agreement: United States of America—Withdrawal*, depositary notification C.N.71.2025. TREATIES-XXVII.7.d, January 27, 2025, https://treaties.un.org/doc/Publication/CN/2025/CN.71.2025-Eng.pdf.
4. Paris Agreement to the United Nations Framework Convention on Climate Change, Dec. 12, 2015, T.I.A.S. No. 16-1104.
5. William J. Ripple et al., *The 2024 State of the Climate Report: Perilous Times on Planet Earth*, 74 BioScience 812 (Dec. 2024), https://doi.org/10.1093/biosci/biae087.

and methane by 30% between 1990 and 2024.[6] The growth rate for the concentration of CO_2 in the atmosphere has tripled, with a record annual jump last year to 3.5 parts per million (ppm).[7]

Thanks to its lower price tag, clean renewable energy is faring well and is the preferred choice for most of the world's new energy demand, with China leading the way. However, renewables are largely satisfying new energy demand rather than reducing the continuing demand for fossil fuels. As a result, the fossil fuel majors are confidently telling their shareholders that demand for their product will be strong through 2050. For example, Exxon's 2050 report notes that they expect oil and natural gas to still make up more than half of the global energy mix at mid-century.[8]

The European Union (EU) is having more success with its mandatory climate policy, aiming to cut climate emissions by 55% by 2030 and achieve net zero by 2050.[9] In December 2025, after months of intense political battle in the European Council, the EU co-legislators reached an agreement on a legally binding 2040 climate target of a 90% reduction below 1990 greenhouse gas emission levels, up to 5% of which may be achieved through international carbon credits.[10] While Europeans are setting the pace for what the world should do, too few countries so far are following their example.

III. The Need for Speed in Climate Policy

Even in these difficult political times, the demand for stronger climate governance will continue to grow and find new channels to flow through, including at the state and local levels. But we must expand beyond just reducing CO_2. Even if climate policy does succeed in imposing and observing binding targets for fossil fuels so as to achieve net-zero emissions by 2050, warming will slow very little in the near term: it will avoid only one-tenth of a degree Celsius over the next 25 years.

This is because shutting down fossil fuel facilities, especially coal-powered ones, reduces emissions not just of CO_2 but also of cooling sulfates that limit the amount of sunlight reaching the planet, thus masking up to one-half degree Celsius of existing warming. When these cooling sulfate aerosols fall out—which they do within weeks after facilities are shut down—more near-term warming is quickly unmasked. Meanwhile, the accumulated CO_2 remains in the atmosphere, where it will cause warming for centuries.

Reducing sulfates through decarbonization and by cleaning up local air pollution saves lives today but imposes a climate penalty tomorrow—a "Faustian bargain" in Hansen's words.[11] Whatever name it goes by, it's important to understand that because of the sulfate unmasking, *decarbonization cannot do much to limit temperatures in the near term*, although it starts to kick in more significantly in the 2060s.

The United Nations' Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) made this clear: "The projected reduction of cooling and warming aerosol emissions over time leads to net warming in the near- to mid-term . . . mostly due to reduced fossil fuel combustion that was not equipped with effective air pollution controls."[12] In race terms, decarbonization is a marathon; essential, yes, but not the tool to slow near-term warming.

But all is not lost. If we cut the non-CO_2 climate pollutants responsible for the other half of the problem, we can slow near-term warming by 0.4 ºC[13] to up to 0.6 ºC by 2050.[14] This is primarily achieved by cutting short-lived climate pollutants (SLCPs), including methane, tropospheric ozone, black carbon soot (an aerosol), and hydrofluorocarbon (HFC) refrigerants.

These SLCPs are known as climate super pollutants because reducing them is the best and—so far—the only strategy that can slow near-term warming. Cutting them is also the best strategy for slowing self-amplifying feedback loops and avoiding, or at least delaying, the impending irreversible tipping points. If reducing CO_2 is a necessary marathon, slashing the SLCPs is a sprint. The achievements of the Montreal Protocol and its 2016 Kigali Amendment demonstrate how quick and effective action is possible over some of these climate super pollutants.

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6. Monica Crippa et al., GHG Emissions of All World Countries—2025 Report (Publications Office of the European Union 2025), https://data.europa.eu/doi/10.2760/9816914 ("Global fossil CO_2 emissions increased by 74.9% since 1990. The increases in CH_4 and N_2O emissions have followed a somewhat slower pace: CH_4 increased by nearly 30% and N_2O by 34% between 1990 and 2024, while F-gases have seen a four-fold increase (+310%) in the same period.").
7. World Meteorological Organization & Global Atmosphere Watch, WMO Greenhouse Gas Bulletin: The State of Greenhouse Gases in the Atmosphere Based on Global Observation Through 2024, Report No. 21 (Oct. 16, 2025), https://public.wmo.int/sites/default/files/2025-10/GHG-21_en.pdf:
   > Atmospheric CO_2 continued to increase in 2024, with no sign of slowing down. Globally averaged CO_2 at the Earth's surface reached 423.9 ppm in 2024. CO_2 growth rates accelerated significantly from an average of 0.8 ppm per year in the 1960s to 2.4 ppm per year in the decade from 2011 to 2020 (Figure 1), a direct response to increasing human emissions. From 2023 to 2024, CO_2 in the global surface atmosphere increased by 3.5 ppm; this was the largest one-year increase in the modern measurement record, exceeding the previous record of 3.3 ppm from 2015 to 2016 and surpassing the increase of 2.4 ppm from 2022 to 2023 by a large margin.
8. ExxonMobil, *Advancing Climate Solutions Progress Report—Executive Summary* (2025), https://corporate.exxonmobil.com/-/media/global/files/advancing-climate-solutions/2025/acs-report-executive-summary.pdf.
9. Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999.
10. *See* https://www.europarl.europa.eu/news/en/press-room/20251208IPR32091/2040-climate-target-deal-on-a-90-emissions-reduction-in-eu-climate-law.
11. James Hansen et al., *Climate Forcing Growth Rates: Doubling Down on Our Faustian Bargain*, 8 Env't Rsch. Letters 1 (2013), https://iopscience.iop.org/article/10.1088/1748-9326/8/1/011006.
12. Intergovernmental Panel on Climate Change, Summary for Policymakers 24 (2022), https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_SummaryForPolicymakers.pdf.
13. Gabrielle B. Dreyfus et al., *Mitigating Climate Disruption in Time: A Self-Consistent Approach for Avoiding Both Near-Term and Long-Term Global Warming*, 119 Proc. Nat'l. Acad. Sci. 22 (2022), https://www.pnas.org/doi/10.1073/pnas.2123536119.
14. Climate & Clean Air Coalition, *Short-Lived Climate Pollutants* (n.d.), https://www.ccacoalition.org/content/short-lived-climate-pollutants.

IV. Backbone of Success

The Montreal Protocol, widely regarded as the world's most successful environmental agreement, has solved the first great threat to the global atmosphere—the ozone hole. By mandating the phaseout of nearly 100 chemicals that were destroying protective stratospheric ozone—and achieving nearly 100% compliance—the Protocol has put the ozone layer on the path to recovery by 2066. In the United States alone, approximately 443 million cases of cancer and 2.3 million skin cancer deaths will be avoided as a result.[15] And it was agreed remarkably rapidly, in only nine months, after the discovery of the Antarctic ozone hole shocked the world.

The treaty also has done more to solve the second great atmospheric threat—climate change—than any other agreement, since the chemicals it has phased out are also powerful causes of global warming. Without it and earlier consumer boycotts and national measures, climate-forcing from controlled chemicals would have equaled or surpassed that from CO_2 by 2010, reaching the equivalent of 24-76 gigatons of CO_2 per year (compared to annual emissions of 29-35 gigatons of CO_2).[16] It has therefore delayed warming by 31 to 45 years, slowed self-amplifying feedbacks, avoided tipping points, and demonstrated the benefits of taking early action.

The most recent calculation of the climate benefits of the Montreal Protocol show that it is on track to avoid more than 2.5ºC of warming by 2100: 1.7 ºC from the reduction of ozone-depleting fluorinated gases that are also powerful climate forcers, and 0.85 ºC from protection of the land-based carbon sinks that otherwise would have been degraded by the harmful effects of ultraviolet radiation penetrating the thinning ozone layer.[17] And it will save the world $2 trillion to $9.5 trillion (depending on the social cost assigned to carbon) in damages.[18]

The Montreal Protocol is an example of a positive social tipping point, and it is important to understand why it works so well. Some of its success stems from the remarkable people who have worked on it over the past several decades, mostly in governments but also in industry, academia, think-tanks, and a few NGOs. Naming them would leave unnamed too many who deserve to be mentioned: The Montreal Protocol's Who's Who describes many.[19] But one person deserves the spotlight: Mostafa Tolba, an Egyptian scientist who was a key architect of the Protocol during his tenure as head of the UN Environment Program.

In 2006, in preparation for the campaign designed to accelerate the phaseout of hydrochlorofluorocarbons (HCFCs), I went to Cairo to visit Dr. Tolba. After a gracious and very long lunch, he said he'd leave me with two takeaway messages. He held up his hand showing little distance between his thumb and forefinger and said the first message was that "science mattered this much," which I interpreted to mean that it was the foundation but could never on its own solve the problem. Tolba's second takeaway was that the Montreal Protocol is "a start and strengthen treaty." The Protocol started modestly, learned by doing the difficult work, gained confidence through its initial successes, and was repeatedly strengthened.

When the Montreal Protocol was agreed on September 16, 1987, it was signed by only 24 countries and the EU. Only 46 nations had signed by the time it entered into force on January 1, 1989. Initially, the parties agreed to cut chlorofluorocarbons (CFCs)—fluorinated gases used primarily as refrigerants and foam-blowing agents—by 50% over 12 years. But they later amended the Protocol five times to add new chemicals and adjusted it six times to accelerate chemical phaseout schedules. Every country on earth has now joined; it has reduced nearly 100 dangerous chemicals by nearly 100% and is expanding to focus explicitly on protecting the climate.

Its success also is based on a governance approach that pioneered the precautionary principle, established dedicated expert bodies to conduct real-time assessments of the relevant science and technological solutions, and implemented common but differentiated responsibilities and respective capabilities—including the Multilateral Fund,[20] a mechanism by which developed-country Parties provide financing for developing countries to phase out dangerous chemicals. The Montreal Protocol is the first multilateral agreement to achieve universal ratification, and it has been ratified five times, including the framework agreement and the first four amendments.

The 2016 Kigali Amendment to phase down HFCs, whose 10th anniversary will be marked this fall, is well on its way to universal ratification, with 172 nations as of January 2026. The United States ratified it in September 2022, with support from more than 20 Republican senators, following legislation President Trump signed to implement it, demonstrating the consistent support from both Republican and Democratic presidents.[21] The story of how it was achieved is also encouraging and instructive.

15. U.S. Environmental Protection Agency, Updating the Atmospheric and Health Effects Framework Model: Stratospheric Ozone Protection and Human Health Benefits, EPA Publication No. 430R20005 (May 2020), https://www.epa.gov/sites/default/files/2020-04/documents/2020_ahef_report.pdf.
16. Guus J.M. Velders et al., *The Importance of the Montreal Protocol in Protecting Climate*, 104 Proc. Natl. Acad. Sci. 4 (2007), https://doi.org/10.1073/pnas.0610328104.
17. Paul J. Young et al., *The Montreal Protocol Protects the Terrestrial Carbon Sink*, 596 Nature 7872 (2021), http://www.nature.com/articles/s41586-021-03737-3.
18. Multilateral Fund for the Implementation of the Montreal Protocol, *Pioneering Environmental Change: The Multilateral Fund's Impact* (n.d.), https://www.multilateralfund.org/our-impact.
19. *See* https://www.theozonehole.org/whowho.htm.
20. For more, see https://www.multilateralfund.org/.
21. Republican President Ronald Reagan oversaw the creation of the Montreal Protocol and called it "a model of cooperation." National Security Archive, *Ronald Reagan: Climate Hero*, https://nsarchive.gwu.edu/briefing-book/climate-change-transparency-project/2024-08-01/ronald-reagan-climate-hero. And of course, Republican President George W. Bush strengthened the Montreal Protocol in 2007 with a campaign to accelerate an HCFC phaseout.

V. Start and Strengthen: The Kigali Amendment

Back in 2007, the Federated States of Micronesia was among the first countries to initiate an international campaign to reduce HCFCs. These had been brought in as refrigerants, foam-blowing agents, and chemical solvents to replace the very damaging CFCs being phased out under the Montreal Protocol. But, though both are far less destructive to ozone and far less effective at warming the atmosphere than CFCs, they still attacked the earth's protective ozone shield and were up to around 2,000 times more potent greenhouse gases than CO_2.

The small island nation recruited many powerful allies—including Argentina, Brazil, the EU, and the United States (under the Administration of George W. Bush)—in a campaign to accelerate an HCFC phaseout. It succeeded within six months. In September 2007, on the 20th anniversary of the Montreal Protocol, its parties agreed by consensus to the acceleration, thus avoiding emissions that would total up to five times more than the UNFCCC's Kyoto Protocol.

In his remarks the following week at the Major Economies Meeting on Energy Security and Climate Change, President Bush stated that:

> developed and developing nations reached consensus on speeding up the recovery of the ozone layer by accelerating the phase-out of these harmful [HCFC] substances. This accelerated phaseout will bring larger benefits because they'll dramatically reduce greenhouse gas emissions. We have seen what happens when we come together to work for a common cause, and we can do it again.[22]

In 2009, the Federated States of Micronesia started a new campaign. Together with Mauritius, it was the first to propose amending the Montreal Protocol to phase down HFCs, which were being used as replacements for HCFCs.[23] While not destroying stratospheric ozone—since, unlike HCFCs, they lack chlorine—they were at the time the fastest-growing climate pollutants, up more than 290% since 1990. Extending the Montreal Protocol's control measures to cover HFCs seemed a logical choice: the goal was to amend it to phase down their upstream production.

Surprisingly, the proposal—which was soon joined by many more parties and backed by many scientists and international organizations—provoked an objection from the UNFCCC, which was addressing downstream HFC emissions with voluntary measures. Its legal experts basically said, "wait a minute, you can't steal our gas!"—even though the Montreal Protocol would only be regulating the upstream production of HFCs and not the UNFCCC's downstream emissions.

Proponents of the HFC phasedown explained that mandatory measures under the Montreal Protocol would complement the UNFCCC's voluntary mitigation of emissions. They explained the science, including calculations showing that phasing down production of HFCs could avoid nearly 150 gigatons of CO_2 equivalent (CO_2-eq), representing nearly five years of CO_2 emissions.

Since few policymakers could appreciate the metric of gigatons, the scientific community and others stepped in to help put things into context. For example, the Institute for Governance & Sustainable Development (IGSD) put together a team of scientists to calculate how much phasing out HFCs would reduce future warming. The peer-reviewed results were clear and powerful: reducing HFCs could avoid up to a half degree Celsius of warming by the end of the century,[24] making it one of the biggest and fastest bites out of the climate emergency.

That "half degree Celsius" number became a key rallying cry, one that policymakers—from heads of State and ministers to rank-and-file staff—could remember and repeat. (One environmental group complained that the calculations were exaggerated, and another encouraged us to drop the campaign because it might detract from the parallel UNFCCC negotiations on the Paris Agreement.)

Indeed, IGSD helped develop the science showing the power of super climate pollutants as well as the policy for tackling them. Working with pioneering scientists such as Veerabhadran Ramanathan, Mario Molina, Drew Shindell, and Guus Velders, its team initiated and co-authored a series of peer-reviewed papers and climate assessments. This included co-authoring eight of the "Distinguished Dozen" papers that laid the foundation for the Kigali Amendment,[25] five of which are ranked in the top 99th

22. Press Release, *U.S. Department of State, President Bush Participates in Major Economies Meeting on Energy Security and Climate Change* (Sept. 28, 2007), at https://georgewbush-whitehouse.archives.gov/news/releases/2007/09/20070928-2.html.

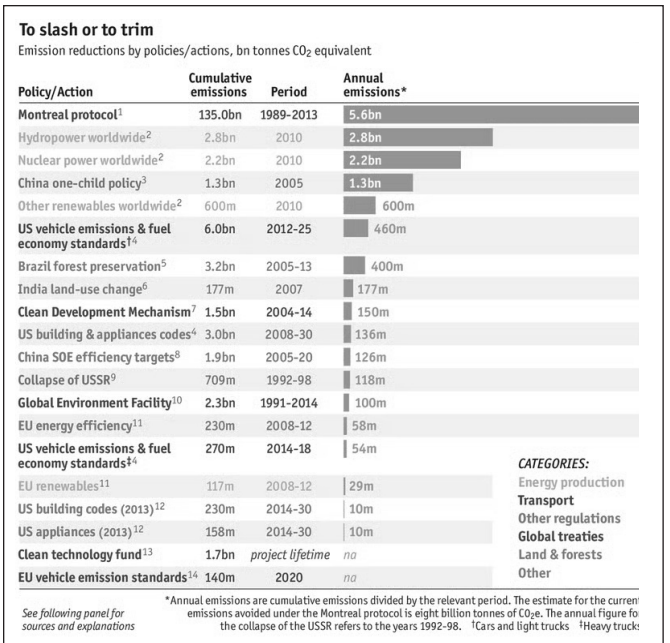
23. Proposed amendment to the Montreal Protocol (Submitted jointly by the Federated States of Micronesia and Mauritius), UNEP/OzL.Pro.WG.1/29/8 (18 July 2009).

24. Yangyang Xu et al., *The Role of HFCs in Mitigating 21st Century Climate Change*, 13 Atmos. Chem. Phys. 12 (2013), http://www.atmos-chem-phys.net/13/6083/2013/.

25. *See* Stephen O. Andersen et al., *Setting the Stage for Climate Action Under the Montreal Protocol*, Eos (Oct. 18, 2022), https://eos.org/features/setting-the-stage-for-climate-action-under-the-montreal-protocol. In addition to these papers, IGSD supported several other assessments analyzing the climate benefits of super pollutant policies. In 2020, IGSD served as lead author along with UNEP and the International Energy Agency in an assessment that analyzed how much climate mitigation was possible from the Kigali Amendment when combined with improving the energy efficiency of cooling equipment—and it was a very big number, double the mitigation from reducing HFCs alone. *See* Gabrielle Dreyfus et al., *Assessment of Climate and Development Benefits of Efficient and Climate-Friendly Cooling* (2020), https://www.ccacoalition.org/en/resources/assessment-climate-and-development-benefits-efficient-and-climate-friendly-cooling (Nobel Laurate Molina and I co-chaired the steering committee.) Another IGSD assessment analyzed methane science and mitigation opportunities, weighing in with 1,401 endnotes; *see* Institute for Governance & Sustainable Development, A Primer on Cutting Methane: The Best Strategy for Slowing Warming in the Decade to 2030 (Oct. 2024), https://www.igsd.org/wp-content/uploads/2024/01/IGSD-Methane-Primer.pdf. Earlier, IGSD worked with Lawrence Berkeley National Laboratory (LBNL) to analyze the climate benefits of improving energy efficiency of room air conditioners in parallel with replacing HFC refrigerants. LBNL calculated that a 30% improvement in energy efficiency could avoid as much energy by 2050 as 2,500 medium-size peak power plants. *See* Nihar Shah et al., Benefits of Leapfrogging to Superefficiency and Low Global Warming Potential Refrigerants in Room Air Conditioning, LBNL-

percentile of the nearly 30 million outputs tracked by one or more metrics scored by Altmetric,[26] with another ranked in the top 98th percentile of the outputs.[27]

Significantly, the HFC campaign included strong support from industry, including in Europe from the Consumer Goods Forum,[28] and in the United States, where the U.S. Alliance for Responsible Atmospheric Policy, under the leadership of Kevin J. Fay, was the "leading industry voice in support of the successful negotiation in October 2016 of the Kigali Amendment."[29] The U.S. Chamber of Commerce,[30] the American Chemistry Council, the National Association of Manufacturers, and the Air Conditioning, Heating, and Refrigeration Institute, among others, supported ratification of the Kigali Amendment.[31] There is also compelling evidence that, since its inception, the Montreal Protocol has "spurred scientific research and technological advancements in the development of CFC substitutes" by industry.[32] Further support came from the military, including in the United States.[33]



The Economist reported that it "made a stab at a global comparison of carbon-mitigation efforts. Chart 1 is the result. It ranks 20 policies and courses of action according to how much they have done to reduce the atmosphere's stock of greenhouse gases. We have used figures from governments, the EU and UN agencies. As far as we know, this exercise has not been carried out before." Source: *The Deepest Cuts*, THE ECONOMIST (Sept. 20, 2014), at https://www.economist.com/briefing/2014/09/20/the-deepest-cuts . Reprinted with permission. © The Economist Newspaper Limited, London, 2014).

The HFC campaign also included a robust media effort, including *The Economist*, *The New York Times*, *The Financial Times*, *The Guardian*, and *Nature*, among many other publications. *The New York Times* and *Nature* published a series of editorials on the importance of HFC mitigation, and *The Economist* did several stories. One story in *The Economist* used a powerful graph (above) to compare the climate benefits of the Montreal Protocol (through 2014 when the story was published) to a series of mitigation strategies, including hydropower and renewables worldwide, the fall of the Soviet Union, and China's one child policy. The Montreal Protocol earned the top spot, providing nearly as much mitigation as all the other strategies combined, including the UNFCCC.

1003671 (Oct. 2015), https://eta-publications.lbl.gov/sites/default/files/lbnl-1003671.pdf.

26. *See* Mario Molina et al., *Reducing Abrupt Climate Change Risk Using the Montreal Protocol and Other Regulatory Actions to Complement Cuts in CO_2 Emissions*, 106 PROC. NATL. ACAD. SCI. 20 (2009), https://doi.org/10.1073/pnas.0902568106; Stephen A. Montzka et al., *Recent Trends in Global Emissions of Hydrochlorofluorocarbons and Hydrofluorocarbons—Reflecting on the 2007 Adjustments to the Montreal Protocol*, 119 J. PHYS. CHEM. A 4 (2015), https://doi.org/10.1021/jp5097376; Guus J.M. Velders et al., *The Importance of the Montreal Protocol in Protecting Climate*, 104 PROC. NATL. ACAD. SCI. 4 (2007), https://doi.org/10.1073/pnas.0610328104; Guus J.M. Velders et al., *The Large Contribution of Projected HFC Emissions to Future Climate Forcing*, 106 PROC. NATL. ACAD. SCI. 10 (2009), https://doi.org/10.1073/pnas.0902817106; Yangyang Xu et al., *The Role of HFCs in Mitigating 21st Century Climate Change*, 13 ATMOS. CHEM. PHYS. 12 (2013), http://www.atmos-chem-phys.net/13/6083/2013/.
27. Guus J.M. Velders et al., *Future Atmospheric Abundances and Climate Forcings From Scenarios of Global and Regional Hydrofluorocarbon (HFC) Emissions*, 123A ATMOS. ENV'T (2015), https://doi.org/10.1016/j.atmosenv.2015.10.071. The remaining two papers were published in peer-reviewed interdisciplinary outlets rather than scientific journals, which limits their visibility in Altmetric rankings. *See* Mario Molina & Durwood Zaelke, *A Comprehensive Approach for Reducing Anthropogenic Climate Impacts Including Risk of Abrupt Climate Changes* (2013), *in* FATE OF MOUNTAIN GLACIERS IN THE ANTHROPOCENE (Paul J. Crutzen et al. eds., Pontifical Academy of Sciences 2011), https://doi.org/10.5167/uzh-50863; *and* Durwood Zaelke et al., *Strengthening Ambition for Climate Mitigation: The Role of the Montreal Protocol in Reducing Short-Lived Climate Pollutants*, 21 REV. EUR. COMPLIANCE INT. ENV'T L. 3 (2012), https://doi.org/10.1111/reel.12010. [Note that the Molina & Zaelke 2013 paper is in the 93rd percentile compared to outputs of similar age and from the same source.]
28. Durwood Zaelke et al., *Primer on HFCs: Fast Action Under the Montreal Protocol Can Limit Growth of Hydrofluorocarbons (HFCs), Prevent 100 to 200 Billion Tonnes of CO_2-eq by 2050, and Avoid Up to 0.5°C of Warming by 2100,* Working Paper, Institute for Governance & Sustainable Development (2018), https://www.igsd.org/wp-content/uploads/2018/01/HFC-Primer-v11Jan18.pdf; *citing* Consumer Goods Forum, *Better Lives Through Better Business* (2013), *and* Press Release, Consumer Goods Forum, *3rd Refrigeration Summit Warms Retailers to Uptake of Natural Refrigeration Systems* (June 5, 2013). The *Consumer Goods Forum* is a global network of over 400 retailers, manufacturers, and service providers from over 70 countries; they pledged to begin phasing down HFCs by 2015.
29. *See Kevin J. Fay*, Champions 123 (n.d.), https://champions123.org/person/kevin-j-fay.
30. U.S. Chamber of Commerce, U.S. Chamber Key Vote Letter on the Ratification of the Kigali Amendment to the Montreal Protocol, Sept. 19, 2022, https://www.uschamber.com/environment/u-s-chamber-key-vote-letter-on-the-ratification-of-the-kigali-amendment-to-the-montreal-protocol.
31. Holly Rooper, *The Kigali Amendment Is a Win for Climate and U.S. Industry*, Climate Leadership Council, Nov. 2, 2022, https://clcouncil.org/blog/the-kigali-amendment-is-a-win-for-climate-and-u-s-industry/.
32. Eugenie Dugoua, *Induced Innovation and International Environmental Agreements: Evidence From the Ozone Regime*, 107 REV. ECON. STAT. 6 (2023), https://doi.org/10.1162/rest_a_01398; *discussed in* Eugenie Dugoua, *Global Environmental Cooperation and Innovation*, CEPR, Sept. 12, 2024, https://cepr.org/voxeu/columns/global-environmental-cooperation-and-innovation.
33. Stephen O. Andersen et al., *The Military's Role in Protection of the Ozone Layer*, 28 ENV'T SCI. TECH. 13 (1994), https://doi.org/10.1021/es00062a719; *see also* Tariq Waseem Ghazi & Ajay Kumar Singh, *Climate Security*, THE DAWN, Oct. 30, 2015, https://www.dawn.com/news/1216266.

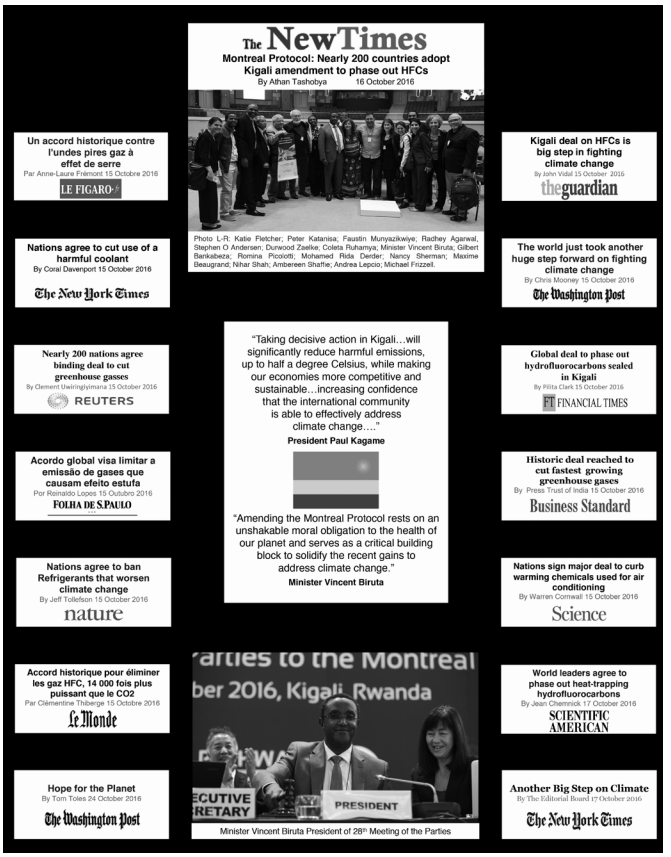
The campaign also included working with the G7, G20, African Environmental Ministerial Council, and many other international, regional, and bilateral forums to explain the importance of putting mandatory controls on the production of HFCs. In the United States, first John Kerry and then-President Barack Obama made the HFC phasedown a priority, assigning Rick Duke as the White House lead for the endgame. After discussions with Norway, IGSD proposed that a special fast-start fund be created to help reluctant parties across the finish line. Duke led the charge with governments and key foundations and assembled an 80 million-dollar fund that was launched in September 2016 by Secretary of State Kerry,[34] joined by senior government officials representing over 100 governments.

The next month, the Kigali Amendment to phase down HFCs was agreed in Rwanda's capital in the early morning of Saturday, October 15, after an all-night negotiating session,[35] along with a parallel decision to start focusing on improving energy efficiency of cooling equipment. The initial schedule of the Kigali Amendment will avoid 90% of the half degree Celsius available from phasing down HFC production. And the energy-efficiency efforts, which formally started with the parallel decision, can potentially double the climate benefits.[36]

According to Lawrence Berkeley National Laboratory (LBNL), a combined transition to higher efficiency in the room air conditioning sector, along with the transition out of HFCs, could avoid (or free up for other uses) an amount of electricity equal to the production of between 676 and 1,576 medium sized peak-load coal power plants by 2030, and between 1,090 and 2,540 by 2050.[37] These efficiency gains lower the cost of operating the air conditioning, save money for consumers including businesses, and ease pressure on overloaded electricity grids.

As the single biggest bite out of the climate problem to date, and through a binding treaty, the Kigali Amendment made the front page of many newspapers around the world.

To their credit, many of these publications helped spur the very action they were reporting. And I humbly note that the Montreal Protocol Secretariat selected two members of IGSD's team (myself and Dr. Stephen O. Andersen) for two awards each celebrating the Kigali Amendment, one for scientific leadership and the other for policy leadership, making IGSD the only nongovernmental organization to receive such awards.



VI. What Can We Do Next?

The Montreal Protocol and its Kigali Amendment also provide inspiration and a model to address the climate emergency, including methane, via future sectoral agreements. Cutting methane emissions can avoid nearly 0.3°C by the 2040s,[38] making this the best way to reduce near-term warming, slow self-amplifying feedbacks, and avoid, or at least delay, irreversible climate tipping points.

The United States and the EU launched the Global Methane Pledge at COP26 in 2021: 159 countries plus the EU now participate in it. While the pledge was a useful step for educating countries about the importance of cutting methane emissions, it is time to move to binding measures, including through an international Methane Agreement to cut emissions from the fossil fuel sector.[39] Such a binding agreement for the oil and gas sector is "a no-brainer," according to Barbados Prime Minister Mia Mottley.[40] She has made it a top priority for her presidency

34. *See* https://www.highambitioncoalition.org/.
35. Amendment to the Montreal Protocol agreed by the Twenty-Eighth Meeting of the Parties (Kigali, 10-15 October 2016), https://ozone.unep.org/treaties/montreal-protocol/amendments/kigali-amendment-2016-amendment-montreal-protocol-agreed.
36. Gabrielle Dreyfus et al., *Assessment of Climate and Development Benefits of Efficient and Climate-Friendly Cooling*, (2020), https://www.ccacoalition.org/en/resources/assessment-climate-and-development-benefits-efficient-and-climate-friendly-cooling.
37. Nihar Shah et al., Benefits of Leapfrogging to Superefficiency and Low Global Warming Potential Refrigerants in Room Air Conditioning, LBNL-1003671 (Oct. 2015), https://eta-publications.lbl.gov/sites/default/files/lbnl-1003671.pdf.
38. United Nations Environment Programme & Climate and Clean Air Coalition, Global Methane Assessment: Benefits and Costs of Mitigating Methan Emissions (2021), http://www.ccacoalition.org/resources/global-methane-assessment-full-report.
39. The waste sector and especially the agriculture sector would require a different approach that helps farmers continue to feed the world even as their job becomes more difficult in a warming climate.
40. Mia Amor Mottley & Wale Edun, *What Climate-Vulnerable Developing Countries Need Right Now*, Project Syndicate, June 21, 2024, https://www.project-syndicate.org/commentary/unlocking-climate-finance-for-vulnerable-developing-countries-green-development-by-mia-amor-mottley-and-wale-edun-2024-06.

of the Climate Vulnerable Forum, which includes more than 70 of the most imperiled countries.

A binding agreement to limit methane emissions from fossil fuels could start with the European Methane Regulation,[41] which comprises: strict standards for the EU market, including prohibitions on routine venting and flaring; extensive requirements on measuring, reporting, and verification; mandatory leak detection and repair; and robust performance standards. It also will set rigorous standards for imported oil and gas, which has global significance because the EU is their single biggest importer, with the United States as the biggest exporter into the EU.

The next step would be to "multilateralize" the European standard to Japan and South Korea. These three jurisdictions represent over half of global natural gas imports.[42] Once buyers align their methane gas import standards, such as reporting, data accuracy, and low methane intensity performance standards, they will have the market muscle to require sellers to meet them. A key advantage is that such a "Natural Gas Buyers Club" can exclude traditional blockers that might otherwise slow progress. At the same time, energy-hungry data centers like Microsoft and Meta wishing to grow their AI businesses should agree to resort to gas as a last resort and then only use gas with the lowest methane leak profile.

Another step would be to link the Natural Gas Buyers Club to the Oil and Gas Decarbonization Charter.[43] Launched at COP28 by 56 oil and gas companies, including 34 national companies, this included promises to cut routine gas flaring by 2030 and to reduce upstream methane leaks to near zero, defined as 0.2% or less methane intensity. These promises by producers representing nearly 40% of the market would match up well with the European Methane Regulation.

To turn these promises into binding measures, islands and other vulnerable countries have been inspired to call for negotiations on "a legally binding framework at the international level" to reduce methane, something the European Commission and European Parliament first called for in 2020.

The Montreal Protocol provides the inspiration and the blueprint for much of the architecture for a future binding international Methane Agreement for the oil and gas sector. Its governance elements to mirror are: the Scientific Assessment Panel; the Technological and Economic Assessment Panel; clear reduction targets and phasedown schedules; a dedicated funding mechanism akin to the Protocol's Multilateral Fund; a legally binding decisionmaking authority to accelerate mitigation commitments; support for national technical offices in 147 developing countries to manage implementation; effective compliance controls; continued country oversight and decisionmaking that evolves with the times; as well as other aspects that robustly implement the principle of common but differentiated responsibility and respective capabilities.

Recent Advisory Opinions on the climate emergency from three of the highest courts in the world—the International Court of Justice (ICJ),[44] the International Tribunal for the Law of the Sea,[45] and the Inter-American Court of Human Rights[46]—also provide support for fast cuts to methane, both through contentious legal cases that implement them and through an international Methane Agreement. The ICJ and Inter-American opinions both single out the Montreal Protocol, offering it as a model for international diplomacy.

VII. Conclusion

The Montreal Protocol should be lauded not just for what it has done, including slowing warming enough to avoid irreversible tipping points and the resource conflicts and wars this would lead to. It also should be lauded for what it can do tomorrow. It should be celebrated for the confidence and inspiration it provides to guide others to further protect the environment via a binding international Methane Agreement for the oil and gas sector. If solving the climate emergency is like scaling Mt. Everest, it is reassuring to know that we've climbed this mountain before, and have a route pioneered by the Montreal Protocol that can take us to the summit again.

The Protocol would be a good candidate to receive the Nobel Peace Prize.[47] In 2007, the Prize was awarded to the IPCC and Al Gore "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change." An earlier Nobel Prize, this one in chemistry, was awarded in 1995 to Mario Molina, Sherry Rowland, and Paul Crutzen for their work identifying the threats to the stratospheric ozone layer. But none has yet been awarded for successful efforts to slow climate change and prevent future conflicts. It's time to change that.

41. Regulation (EU) 2024/1787 of the European Parliament and of the Council of 13 June 2024 on the reduction of methane emissions in the energy sector and amendment Regulation (EU) 2019/942.
42. Institute for Energy Economics and Financial Analysis, Global LNG Outlook 2024-2028 (April 2024), https://eefa.org/resources/global-lng-outlook-2024-2028.
43. *See* https://www.ogdc.org/.
44. *Obligations of States in Respect of Climate Change*, Advisory Opinion No. 187, I.C.J., ¶ 254 (July 23, 2025).
45. *Request for Advisory Opinion Submitted by the Commission of Small Island States on Climate Change and International Law*, Advisory Opinion, ITLOS Rep., 21 May 2024.
46. *Climate Emergency and Human Rights, Advisory Opinion OC-32/25*, Inter-Am. Ct. H.R. (ser. A) (May 29, 2025).
47. There are many things omitted from this brief story. I did not include the chance meeting with Secretary Hillary Clinton that helped our campaign create the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants; nor the strategy to encourage President Obama to make phasing down HFCs a key part of his first meeting with President Xi Jinping in China at Sunnylands, California; nor the fun of bowling in the White House or attending Christmas parties there; nor our work with senior military officials in Pakistan and in India who agreed to cooperate with Kigali Amendment negotiations; nor our efforts with the Vatican; nor working with Prof. Perry Wallace, who was a gifted law professor and a celebrated college basketball player who integrated the Southeastern Conference in the 1960s, or Tony Oposa, who taught Montreal Protocol negotiators how to tell a memorable story, both of whom assisted the Federated States of Micronesia; nor presenting our work to the heads of State at the G7 Summit in Biarritz at the invitation of President Emmanuel Macron; nor watching key climate negotiations behind a two-way mirror; nor working with many great climate scientists, including Mario Molina, Professor Ramanathan, Guus Velders, Dave Fahey, Steve Montzka, Paul Newman, and Walter Munk; nor the many other things IGSD has been able to contribute to strengthening the Montreal Protocol and the broader effort to cut SLCPs.