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Global Climate Policy Durability Amid American Backtracking: Cooling Sector Chemicals in the Kigali Era

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This paper examines this understudied international climate policy regime, considering its key design features and future viability amid recent US policy shifts hostile to many global and domestic climate mitigation efforts. It concludes that any forthcoming American shocks to this global system are likely significant but not fatal, leaving considerable room for sustained implementation and expanding leadership roles for Canada and other nations.

INTRODUCTION

Global initiatives to reduce climate change risks have long struggled to secure broad national participation or deliver sustained greenhouse gas reductions. The Kyoto Protocol collapse in 2012 and the meager achievements of the succeeding 2015 Paris Agreement illustrate this challenge, as have fledgling efforts to form clubs of like-minded nations around carbon pricing and border adjustments.[1] In turn, many national climate mitigation policies have struggled to achieve significant emissions reductions, even when they prove durable politically.[2] This reflects the profound difficulties facing domestic and global climate policies, which often combine near-term costs with aspirations for long-term benefits.[3] One notable exception has involved transformation of cooling sector chemicals through unique and durable global governance lodged in a landmark treaty that has been frequently adapted to changing conditions. This paper examines this understudied international climate policy regime, considering its key design features and future viability amid recent US policy shifts hostile to many global and domestic climate mitigation efforts. It concludes that any forthcoming American shocks to this global system are likely significant but not fatal, leaving considerable room for sustained implementation and expanding leadership roles for Canada and other nations.

THE MONTREAL FOUNDATION

The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer and its five amendments between 1990 and 2016 remain the gold standard of global environmental governance.[4] It was designed principally to provide ozone protection benefits but has also generated significant climate co-benefits. Montreal features universal national participation in transitioning from chemicals used primarily in refrigeration and air conditioning systems that depleted the ozone layer and posed severe public health and environmental risks.[5] It did not embrace any single synthetic or natural chemical alternative, but specified phase-down timetables, encouraging a global search for environmentally friendlier cooling options. These were buttressed by formal trade sanctions for national non-compliance.[6] Montreal also developed a funding mechanism through national Multilateral Fund pledges that provided less-developed nations substantial support over multiple decades to acquire new chemicals and training to use them safely.[7]

One key factor supporting Montreal adoption and later expansion involved deep divides among private firms engaged in research and production of cooling sector chemicals. Some, including major American-based firms, were already developing expertise and securing patents in next-generation chemicals and thereby saw strategic advantage in accelerating their global use through Montreal's unique policy blend of trade restrictions and subsidies.[8] This contributed to the formation of coalitions that included firms that manufactured cooling equipment and sought clear rules for future production. A formidable and durable epistemic community ultimately emerged, involving industry, government and academic experts, including winners of the 1995 Nobel Prize in Chemistry, to guide adoption and provide long-term leadership and support for later adjustments.[9] All of this activity was motivated by robust and disturbing

empirical evidence of rapid ozone layer depletion that was directly attributable to the release of cooling sector chemicals.

Alongside considerable ozone benefits, Montreal also delivered major climate benefits by protecting vegetation from heightened ultraviolet radiation that threatened plant capacity to store carbon through photosynthesis. This side benefit has already reduced additional global warming by an estimated 0.5 to 1.0 degrees Celsius below levels anticipated without the chemicals shift, making Montreal the most impactful climate policy adopted to date.[10] However, Montreal's unique design features have proven difficult to replicate in other sectors linked to climate change, including those linked to substantial fossil fuel production and use, raising questions of whether it stands alone as a "fluke case" or could offer lessons to other sectors contributing to climate change.[11]

KIGALI EXPANSION

Montreal's cooling sector transformation included one adverse climate side-effect that offset about one-tenth of its climate benefits. The chemicals developed globally to reduce ozone depletion, a diverse suite of hydrofluorocarbons (HFCs), have short-term but intensive global warming impacts, like their predecessors.[12] HFC releases from production and operational leaks began soaring in the 2000s amid rapidly expanding cooling equipment demand and use. This prompted the question of whether further technological transformation could sustain ozone protection while heightening climate protection. An eight-year global negotiation process culminated in the 2016 Kigali Agreement, the fifth formal Montreal amendment, which has since been ratified by 163 nations and the European Union. Developed nations agreed to an 85 percent reduction in HFC production and use by the mid-2030s, with less-developed nations following a timetable extended into the 2040s. Full global participation in Kigali was expected to reduce global warming through 2100 by 0.4 degrees Celsius below projections under sustained HFC use.[13]

As under Montreal, unusually broad political support for Kigali endured, despite shifts among potential industrial winners and losers in cooling chemical production, contributing to rapid implementation. Many key Montreal provisions were extended or adapted to this new challenge, including national loss of market access under non-compliance.[14] North American leaders collectively endorsed major HFC reductions in a 2016 summit; Canada formally ratified Kigali in 2017 and moved quickly to develop domestic reduction policies, followed by Mexico in 2018. The United States failed to match this pace, following the 2017 federal court rejection of Obama Administration efforts to establish policy through executive actions.[15] However, numerous states began to fill this void with their own policies during the late 2010s. Despite deep partisan divides, a bipartisan Congress adopted the American Innovation and Manufacturing (AIM) Act, signed by President Donald Trump in 2020.[16] Overwhelming Senate approval of Kigali followed in 2022 and the United States moved rapidly into domestic implementation and coordination with allies to deter smuggling of illegal cooling chemicals.[17]

FACTORS THREATENING KIGALI DURABILITY

Could Kigali replicate Montreal's success, achieving a second major cooling sector chemical transformation in less than half a century? Kigali has demonstrated considerable momentum thus far, including major reductions ahead of schedule in Europe, Canada and some Asian nations, broad cross-national support that includes China and India, and shifting Multilateral Fund revenues toward next-generation technologies. American bipartisan support via legislation, treaty approval, and rapid regulatory development further demonstrated the high potential for sustained support, building on its Montreal precedent. The sheer scope of expanding cooling needs was a galvanizing force behind developing future cooling chemicals that are climate-friendly and linked to new equipment offering superior energy efficiency. Total global supply of cooling appliances is projected to increase from 3.6 billion in 2020 to 9.5 billion by 2050, and total cooling sector emissions (combining HFCs with electricity-related sources) constitute approximately 10 percent of total global releases.[18]

The second Trump presidency, however, imperils sustained American AIM and Kigali implementation. Given the vast American economy and its major global role in producing cooling sector chemicals and equipment, this pivot raises questions about American capacity to upend the Kigali process. Congress has halted US Multilateral Fund contributions, which have historically provided one-quarter of total revenue, and is phasing down some programs incentivizing domestic purchase of energy-efficient cooling equipment. Despite substantial industry support, some firms have challenged technical aspects of AIM interpretation in court, opposing QR tracking code use to deter smuggling and methodologies to allocate HFC use allowances.[19] Federal courts have generally rejected these challenges, but such cases add uncertainty and slow implementation. The Environmental Protection Agency (EPA) is expected, in 2026, to issue rules to delay implementation, possibly up to a decade beyond statutory requirements. These would alter timetables and provisions addressing HFC phase-down, next-generation leak detection systems, and leak repair protocols. They would also threaten expanded chemical recovery and reclamation programs intended to reduce costs by providing alternatives to virgin HFCs as replacements in existing equipment, which already lag behind such initiatives in Europe and Asia. The EPA has already dialled back border enforcement, given shifts in its philosophy, deep staff and budget reductions, and reduced engagement with other agency and national counterparts.

AIM Act opponents in industry and think tanks contend that the legislation is a primary driver behind significant cooling equipment inflation. Some inflationary contribution is likely, but these analyses downplay other contributing factors, including escalating raw material costs, unpredictable tariff shifts on aluminum and steel imports, supply chain disruptions (including semiconductors and skilled labour shortages), consumer demand for more sophisticated equipment, slow development of HFC recycling and reclamation, and increased average size of newly constructed homes.[20] Such critiques also tend to overlook cost benefits from improved energy efficiency linked to next-generation cooling technology and some chemical alternatives to HFCs, as well as advanced leak detection capacity to reduce coolant loss and replacement costs.

FACTORS SUGGESTING SUSTAINED AMERICAN ENGAGEMENT

Unlike other climate policy areas, however, full American disengagement from HFC transition is not a *fait accompli*. There has been no formal Congressional attempt to repeal the AIM Act, unlike numerous climate provisions of the 2022 Inflation Reduction Act that have been reversed. A Congressional Review Act resolution to reverse some EPA HFC rules was introduced but not adopted. President Trump could initiate Kigali withdrawal but has not done so. Even EPA plans to reverse the "endangerment finding" that has facilitated extensive Clean Air Act application to greenhouse gases would not necessarily eliminate continued AIM Act operation. The legislation is formally linked to the Clean Air Act but remains a standalone statute adopted with bipartisan support, thereby making it harder for the executive branch to ignore.[21] Two additional factors suggest some American policy continuity, albeit likely short of full AIM implementation.

Industry Backing. AIM and Kigali retain substantial industry support, including numerous firms leading in development of next-generation cooling sector chemicals, consistent with initial Montreal experience. Organizations such as the US Chamber of Commerce, the Air-Conditioning, Heating and Refrigeration Institute, and numerous individual firms have continued to support federal legislation during early AIM implementation, some offering positive commentary about initial EPA efforts to work constructively in standing up the legislation.[22] Avoiding potential loss of global market access through Kigali sanctions remains an industry priority and concerns have surfaced about Multilateral Fund cuts, given the fund's historic role in facilitating global access for American cooling sector products. Cooling chemical production is distributed across numerous states and legislative districts, cutting across party and regional lines, which likely contributes to strong support from legislators in both political parties.[23]

State Support. American HFC policy serves as a reminder that the United States maintains a federal system allowing states to frequently augment or influence federal policy. Many states played significant roles in shaping AIM Act adoption and are poised for potential encores in 2026 and thereafter. American environmental policy frequently allows states to pursue policy innovations so long as they do not encroach on federal jurisdiction. After federal courts in 2017 blocked EPA efforts to regulate HFCs, 13 states adopted their own laws between 2018 and 2020. These provided models for other states and incentivized Congress to avert imposition of varied state requirements upon national firms.

Federal legislation pre-empted states from adopting further policies for five years, with such restrictions ending in January 2026. Some states continued to develop policies that supplemented the AIM Act and thereby avoided pre-emption through 2025, while others have begun to consider further steps given their newfound latitude and possible federal backpedalling.[24] Washington, for example, adopted state purchase preferences for next-generation chemicals, established HFC leak inspection programs, and fined stores selling prohibited air conditioner replacement chemicals. It also adopted legislation in 2025 designed to expand HFC recovery and reclamation for use in servicing existing equipment and containing costs as virgin HFC production wanes, an issue of growing interest in other states. California has adopted a series

of HFC-related laws in the last decade, including use of cap-and-trade auction revenue to support the purchase of climate-friendly cooling systems and develop workforce training programs to expand next-generation chemical expertise. New York is providing financial support for food retail and serving facilities in low-income areas to purchase cooling equipment using natural chemicals. Such steps follow the pattern of earlier energy efficiency and chemical safety standards, whereby state policy proliferation prompted federal policy that maintained some latitude for later state policy expansion.[25] Numerous states would likely move aggressively to replace federal HFC legislation with their own versions if it was significantly weakened. In November 2025, a coalition of 19 state attorneys general stated opposition to EPA attempts to slow AIM Act implementation, contending that the agency failed to complete a comprehensive review of costs and benefits and is violating core statutory provisions.[26]

FACTORS SUPPORTING CONTINUED GLOBAL ENGAGEMENT REGARDLESS OF AMERICAN SHIFTS

Whether or not the US government remains active in cooling sector transition under Kigali, there is considerable reason to anticipate sustained global engagement. This reflects ongoing technological advances following Kigali initiation, rapid sectoral transition in many nations following early policy adoption, and global industry practice shifts. Collectively, these developments suggest an evolving global arena of science and policy that is likely considerably less dependent on the United States than it was during the decades immediately following Montreal Protocol adoption.

Technological Advances. Just as there was no uniform HFC blend used universally under Montreal, a diverse suite of synthetic and natural chemicals has emerged as next-generation cooling alternatives.[27] Various forms of cooling equipment, such as air conditioning for vehicles versus buildings, will require different chemical solutions. Synthetic chemicals with ultra-low ozone depleting and global warming qualities are increasingly emerging as major players. These include various hydrofluoroolefins (HFOs) and hydrochlorofluoroolefins (HCFOs). As with HFCs, some of these alternatives do not rapidly break down if released into the environment, requiring careful stewardship during production, use and disposal.[28] HFCs, along with most leading synthetic chemical alternatives, are derived from petrochemical feedstocks and thus linked to fossil fuels such as natural gas.

At the same time, natural (non-fluorinated and non-synthetic) chemicals such as ammonia, propane, isobutane, and even water and carbon dioxide, can also facilitate cooling and offer strong ozone and climate protection advantages.[29] Such chemicals are generally less costly than synthetic ones and offer dramatically lower recharging costs during maintenance or following leaks. Some may offer significant energy efficiency advantages as well. However, they can pose added safety risks during installation and maintenance and have thus far been used most frequently in large commercial cooling systems, including those found in cold storage warehouses, grocery stores, food processing plants, ice rinks and hotels, most notably in Europe but increasingly around the world. They are also receiving increasing consideration in

developing cooling systems for data centres, where major increases in demand for electricity and cooling capacity are widely anticipated.[30] As has long been true for cooling chemicals, a skilled workforce is necessary to ensure safe installation and maintenance of both synthetic and natural chemicals and will require ongoing training as chemical use and cooling equipment evolve. Collectively, this expansive menu of chemical coolants provides an array of options for facilitating Kigali compliance.[31]

Alongside rapid development of chemical alternatives has been intensifying efforts to refine measurement of HFCs and earlier cooling sector chemicals when they are released into the atmosphere during production or use, or when shipped across jurisdictional boundaries. Illegal chemical smuggling remains a significant concern, but has begun to be addressed through tightened border monitoring and advanced technologies to track shipments. Sophisticated methods linked to satellites are increasingly being used, potentially pinpointing major releases with unprecedented speed and precision.[32]

Lessons from National Leaders. Unlike the Montreal process where the United States helped lead global transition, it has lagged behind many other nations in the Kigali era in supporting development and deployment of cooling chemical alternatives. National policy steps were initiated by Nordic nations in the early 2000s, followed by a sequence of European Union initiatives. These utilized a mixture of policy tools, including HFC taxes and regulations to begin phasing down their use, long before Kigali was approved. Europe also operates programs to monitor leaks and initiate repairs upon discovery, as well as equipment labelling that specifies cooling chemical use and product energy efficiency. Collectively, these initiatives drove EU HFC reductions of more than 40 percent between 2015 and 2023, following significant reductions in prior years. This success triggered considerable continental research and development of both synthetic and natural chemical alternatives for internal use and export. The European Union appears to be on track to meet all Kigali commitments, with some nations especially far ahead of scheduled transitions. Costs have risen significantly for HFCs in recent years, given continuing demand for them in existing equipment as phase-down accelerates, one of many factors driving cooling sector inflation.

Europe's cooling sector today looks considerably different than the US sector. European refrigerators and freezers for domestic and commercial purposes remain far more likely to use natural chemicals than American ones; their lower costs and superior energy efficiency have proven increasingly attractive since the 2022 outbreak of war between Russia and Ukraine, and mounting concerns over energy availability and price.[33] Among commercial refrigerators, more than 26,000 European supermarkets had transitioned away from HFCs as of 2020, versus only 600 in the United States.[34] In turn, nearly all European ice rinks use ammonia for cooling, unlike American practice, with analyses indicating significant energy efficiency gains.[35] Similar differences exist for other commercial facilities. Denmark was a particularly early adopter of alternative chemicals, following a 2000 extension of its carbon tax to HFCs that was augmented by later regulations and fees to cover HFC disposal costs once they are no longer recyclable.[36] Denmark hosted the world's first restaurant entirely free of HFCs: a McDonald's affiliate that opened in 2003.

These examples indicate that HFC transition is not merely a theoretical possibility, but represents increasingly common practice outside the United States. Alongside Europe, other early national leaders

in this transition include Australia, Canada, Japan and New Zealand.[37] Nations such as Cameroon, Jordan and Malaysia, among others, have been working with Multilateral Fund support to achieve a technological "leapfrog."[38] The goal is to entirely bypass HFC use by utilizing next-generation chemicals (and achieving maximum possible energy efficiency) when households and businesses make their first-ever cooling equipment purchases.

WHITHER CANADA ON COOLING SECTOR TRANSITION?

Canada moved far more rapidly into full Kigali implementation than the United States and appears to be five or more years ahead of its neighbour in many aspects of this transition. This raises numerous questions, particularly given its outsized trade dependence on the United States and severe strains in its American trade relationship during the second Trump Administration. On the one hand, Canada could use any American backtracking to legitimize delaying or halting its own HFC transition. This could be a modest bargaining chip in attempts to appease an increasingly neo-mercantilist United States demanding trade concessions, following Canadian adjustments on retaliatory tariffs and digital service taxes. On the other hand, cooling sector chemicals may represent an expanding comparative economic advantage for Canada. Continued pursuit of Kigali transition could provide Canada an opportunity to expand its domestic production capacity for advanced cooling chemicals and equipment, establish a significant lead over America in global markets, and bolster sectoral trade ties with other nations that remain more amenable to free trade than the United States.

The United States may be increasingly less consequential in this sector globally, given the significant technology and policy advances well underway beyond its borders. Kigali provisions could also restrict its future global market access if AIM Act implementation and HFC transition were severely compromised. Canada has moved far more rapidly and consistently to honour its Kigali commitments, although it remains behind many European nations, given their earlier launch.[39] It surpassed its initial HFC reduction targets, achieving a 25 percent decline below baseline levels between 2019 and 2022, putting it on track to meet or exceed subsequent targets through the 2020s and 2030s. Some provinces, such as Quebec, have developed supplemental policies to accelerate transition, including regular leak testing, workforce training, and bans on HFC uses in non-cooling equipment such as fire extinguishers and plastic foams. There is no evidence to date that either federal or provincial governments are preparing to follow the American federal playbook and stall this transition.

Canada is not a major HFC chemical producer, having long relied heavily on American imports. This may be changing, in part due to new opportunities linked to Kigali. Mounting trade tensions with the United States also play a role, as they have spurred interest in expanding domestic cooling sector manufacturing capacity, including production of equipment utilizing cutting-edge technologies One such example is Ontario-based firm Due North, which has expanded its "EH! Fridge" program. Chief Commercial Officer Sean McGrann notes that this program seeks to markedly expand cooling equipment with "products made in Canada, by Canadians, for Canadians."[40] This initiative includes major emphases on natural

refrigerant use and product energy efficiency; Due North previously received American Energy Star Partner of the Year and Excellence in Product Design Awards. A review of Canadian cooling industry trends indicates that other firms are moving in similar directions, including increased use of natural refrigerants and other alternative cooling sector chemicals.[41] In turn, Canadian firms such as Pure Sphera in Quebec are expanding their capacity to safely dismantle and decontaminate used cooling equipment to minimize HFC releases and assure their safe recycling or destruction. American exports of cooling sector equipment to Canada and other nations declined significantly during 2025, suggesting expanding opportunities for greater domestic production.

Canada has also remained active in two other areas vital to Kigali effectiveness: sustained financial support for technology transfer through Multilateral Fund contributions; and research leadership to achieve more precise measurement of HFC production and use releases. Canada maintained its global fund financial support between 1991 and 2025, ranking fifth among nations in total contributions over that period. Sustaining such support will help bolster that program as the United States disengages, potentially positioning Canadian firms to expand exports of their cooling sector chemicals and equipment. Canada also plays a central role in sharpening HFC release measurement through its SCISAT-1 satellite, with engagement by the Canadian Space Agency and Environment and Climate Change Canada. This effort actively involves Canadian universities, including the University of Waterloo's Atmospheric Chemistry Experiment research group.[42]

CONCLUSIONS AND POTENTIAL EXPANSION TO NITROUS OXIDES

New American political and policy shifts add considerable uncertainty to the future of global climate governance. These may have significant impacts on Canadian and international efforts to sustain policies to reduce greenhouse gas emissions and support climate mitigation. However, global policy efforts to achieve climate-friendly advances in cooling chemical production and use may be on more secure ground than other sectors. The United States is exploring some consequential federal domestic policy changes while withdrawing financial support for global efforts. These American pivots are not yet, however, as far-reaching as those for addressing carbon dioxide, methane and other greenhouse gases. Moreover, the global effort to achieve cooling sector transformation is based on an unusually robust and durable international policy structure through the Kigali Amendment to the Montreal Protocol that would be difficult for any unilateral American actions to disrupt. Kigali includes binding emission reduction commitments, widespread international and industry support for transition, and considerable early-stage progress by nations and firms on multiple continents. This approach also incentivizes collaboration through unique trade provisions that can block chemical exports from non-compliant nations, presenting a potential risk to firms in the United States or any other nation that disengages.

This creates both challenges and opportunities for Canada in deciding whether to follow the American lead in backtracking or sustain initial steps and become a global leader in this area of technological

transformation designed to benefit both the climate and ozone layer. There is considerable early evidence that Canada intends to stay its course, reflecting potential domestic economic benefits alongside environmental ones. More broadly, this case represents a fundamental test of global climate policy durability and performance under conditions in which a major national player, the United States, after initial delays in making firm legislative and treaty commitments, begins to equivocate further.

The unique Montreal Protocol framework has never been fully replicated for other sectors of climate policy, likely reflecting unique factors that drove initial adoption and sustained it across multiple amendments. It was designed to address the salient issue of ozone layer depletion rather than climate change, and did not represent a major threat to fossil fuel production and use — factors that often complicate climate politics. However, it might prove useful to consider another way that the adaptable Montreal and Kigali frameworks combining ozone and climate protection could be further extended. Nitrous oxides constitute the third-largest global warming source after carbon dioxide and methane, reflecting their intensive warming capacity (273 times greater than carbon dioxide over a century) and longer duration in the atmosphere (114 years greater than methane and most HFCs). They also represent the most significant remaining source of ozone layer depletion after HFCs, offering a potentially large co-benefit from reduction that could fit under both the Montreal ozone and Kigali climate architecture. Nitrous oxides emanate from numerous sources, including industry, but more than three-quarters globally are produced through agricultural activity. The largest agriculture source involves releases from nitrogen-based fertilizers. These play a vital role in boosting crop yields and food output, but can be released as potent greenhouse gases if not taken up by plants. Overall, agriculture is responsible for about 25 percent of global greenhouse gases and remains the sector most impervious to mitigation efforts.

Policies to curb nitrous oxide releases from agriculture have proven extremely difficult to adopt at international, national or subnational levels, reflecting deep agriculture industry aversion to altering fertilizer production or application. Excessive or inefficient applications of synthetic nitrogen fertilizers remain leading sources of nitrous oxide releases, threatening water and air quality as well as ozone layer stability.[43] In theory, a large menu of policies might be employed to reduce releases, including fertilizer pricing, cover crop and plowing reforms, developing alternative fertilizers that release nitrogen more slowly, and farmer training on more efficient fertilizer use.[44] Nonetheless, these have generally struggled politically, leaving very few models of durable and effective best practices for diffusion. Potentially, the mixture of tools employed under Montreal and Kigali, including structured phase-downs in fertilizer use alongside funding support to assist transition in less-affluent nations, could be employed, making nitrous oxides the focus of a sixth round of Montreal Protocol amendments. Any such extensions to other contributors to ozone depletion and climate change, of course, will hinge on further developments in the cooling sector case, including whether its historic durability and performance can be sustained despite recent American political shifts.

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