



# **CHEMICAL NIGHTMARE**

**ENDING EMISSIONS  
OF FLUOROCHEMICAL  
GREENHOUSE GASES**

**eia**

**EIA briefing to the 34th Meeting of the  
Parties to the Montreal Protocol (MoP34)**



## ABOUT EIA

We investigate and campaign against environmental crime and abuse. Our undercover investigations expose transnational wildlife crime, with a focus on elephants, pangolins and tigers, and forest crimes such as illegal logging and deforestation for cash crops such as palm oil. We work to safeguard global marine ecosystems by addressing the threats posed by plastic pollution, bycatch and commercial exploitation of whales, dolphins and porpoises. Finally, we reduce the impact of climate change by campaigning to eliminate powerful refrigerant greenhouse gases, exposing related illicit trade and improving energy efficiency in the cooling sector.

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EIA has almost three decades of experience working with international bodies, governments and enforcement agencies and industry to reduce the environmental impacts of harmful refrigerant gases. Our pioneering investigations have shone a light on illegal trade in ozone-depleting substances (ODS) and hydrofluorocarbons (HFCs) across the globe. Our exposés and advocacy help increase awareness of illegal trade in ODS and HFCs and spur action to curtail it. Our work also focuses on promoting rapid greenhouse gas mitigation opportunities through the uptake of climate-friendly HFC-free cooling solutions.

## EIA UK

62-63 Upper Street,  
London N1 0NY UK  
**T:** +44 (0) 20 7354 7960  
**E:** [ukinfo@eia-international.org](mailto:ukinfo@eia-international.org)  
[eia-international.org](http://eia-international.org)

## EIA US

PO Box 53343  
Washington DC 20009 USA  
**T:** +1 202 483 6621  
**E:** [info@eia-global.org](mailto:info@eia-global.org)  
[eia-global.org](http://eia-global.org)

**Environmental Investigation Agency UK**  
UK Charity Number: 1182208  
Company Number: 07752350  
Registered in England and Wales

October 2022

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## Introduction

In 2018, scientists revealed alarming, unexpected emissions of CFC-11, a potent ozone-depleting substance (ODS) which had been banned for nearly a decade.<sup>1</sup>

EIA investigations traced the source of CFC-11 to illegal production and use in the polyurethane foam sector in China, which had gone undetected for years by the Montreal Protocol's existing monitoring and compliance mechanism.<sup>2</sup>

A nationwide enforcement effort by China in response to the findings appears to have had immediate impact, with atmospheric data indicating that CFC-11 emissions significantly decreased in 2019.<sup>3</sup> The change in emissions trajectory has continued through 2020 and the early part of 2021.<sup>4</sup>

The CFC revelation acted as a wake-up call for the Montreal Protocol, setting in motion a series of

discussions on institutional processes that could be enhanced to strengthen its effective implementation and enforcement.<sup>5</sup> Parties have begun to consider possible ways of dealing with illegal production of, and illegal trade in, controlled substances, identifying potential gaps in the non-compliance procedure, challenges, tools, ideas and suggestions for improvement.

The Parties also discussed gaps in the atmospheric monitoring of controlled substances, agreeing Decision XXXIII/4 at the 33rd Meeting of the Parties in 2021

**Above:** Raw materials including illegal CFC-11 for the production of foam blowing agent in Dacheng Aoyang Chemical Co Ltd, Hebei Province.

which tasked the Ozone Secretariat, in consultation with relevant experts, to explore options for enhancing the global and regional atmospheric monitoring of substances controlled by the Montreal Protocol.<sup>6</sup>

A review of the latest scientific findings suggest that CFC-11 is just the tip of the iceberg. A shocking array of new chemical emissions looms large over the Montreal Protocol, challenging its reputation as the most successful environmental treaty. The 2022 Scientific Assessment of Ozone Depletion draws attention to unexplained emissions of CFCs-13, 112a, 113a, 114a, 115, carbon tetrachloride (CCl<sub>4</sub>, CTC) and HFC-23, attributing emissions to feedstocks, by-products or unknown sources.<sup>7</sup>

Faced with the additional challenge of new hydrofluorocarbon (HFC) controls, there is a clear imperative for the Montreal Protocol community to develop more robust practices for monitoring and

addressing illegal production, use, trade and emissions of controlled substances. As part of this, the Parties to the Montreal Protocol must reexamine the premise of "insignificant" emissions which exempts feedstock and process agent uses from controls.

The Parties must also take concrete steps to avoid creating new environmental problems through the substitution of controlled substances with other potent greenhouse gases or fourth generation fluorochemicals such as hydrofluoroolefins (HFOs), which create new by-product and feedstock emissions and have other significant environmental impacts.

We cannot take for granted the continued success in healing the ozone layer and curbing climate change that the Montreal Protocol has seen since its adoption. Industrial emissions of man-made fluorochemicals represent an avoidable nightmare that the Montreal Protocol is well placed to address.





# Science points to industrial emissions haunting the Montreal Protocol

A growing number of scientific studies are sounding the alarm about a throng of synthetic chemicals linked to industrial sources being emitted into the atmosphere at levels that are unexpected, unexplained or poorly understood, with implications for climate and ozone protection under the Montreal Protocol.

These emissions all appear to originate from industrial sources of various fluorochemical production. Some, such as by-product HFC-23 emissions, are already covered by compliance obligations under the Montreal Protocol, while others such as emissions of carbon tetrachloride (CTC) and CFC-113 are likely attributable to sources exempted from its controls based on the premise of “insignificant” emissions. Others, such as industrial sources of nitrous oxide and PFC-318, have major implications for ozone and climate protection that the treaty is well-positioned to address, but are not currently within its scope.

## HFC-23: All-time-high emissions when there should be none

With a Global Warming Potential (GWP) of 14,600, HFC-23 is the strongest climate warmer of all HFCs and one of the most potent man-made greenhouse gases.<sup>8</sup>

HFC-23 is a by-product of HCFC-22 production, which is primarily produced as a feedstock to make HFCs and their replacements, hydrofluoroolefins (HFOs).<sup>9</sup> Under the Kigali Amendment, countries with production of hydrochlorofluorocarbons (HCFCs) or HFCs are required to ensure any by-product emissions of HFC-23 are “destroyed to the extent practicable”.<sup>10</sup>

**Above:** Growing emissions of synthetic chemicals from industrial sources are causing concern.

Recent atmospheric trends from 2012-18 suggest that promised control measures put in place by major HCFC-22 producing countries have not been fully implemented, while the possibility of substantial unreported production of HCFC-22 or other sources of HFC-23 cannot be ruled out.<sup>11</sup>

HFC-23 emissions reached their highest levels in history in 2018 at 15,900 ± 900 tonnes/yr. Based on reported data and pledged reductions from China and India (which together dominate global HCFC-22 production). During the period 2015-17, an estimated 24,400 tonnes of HFC-23 were unnecessarily emitted, equivalent to around 309 million tonnes carbon dioxide (MtCO<sub>2</sub>e).

The Scientific Assessment Panel (SAP) estimate global emissions in 2019 to be 17,200 ± 800 tonnes/yr, compared to 2,200 tonnes/yr expected based on reported activities, some eight times larger than expected.<sup>12</sup>

## CFC-11, CTC and HCFC-141b: Unanswered questions

Following the unexpected increase in emissions of CFC-11 after 2012, recent scientific studies show a sharp decline in global CFC-11 emissions between 2018-19 to 52,000 tonnes/yr, similar to average emissions over the 2008-12 period.<sup>13</sup> Regional emissions from eastern China show a similar decline to pre-2013 levels, as well

**Figure 1:** Annual Emissions of Greenhouse Gases and ODS Linked to Fluorochemical Production. Emissions of HFC-23, CTC, CFC-11, CFC-12 and CFC-113 are ‘unexpected emissions’ according to the scientific studies referenced.





as slightly earlier declines in emissions of carbon tetrachloride (CTC), which is a feedstock for CFC-11, and CFC-12, which is co-produced with CFC-11.<sup>14</sup> However, unexplained emissions of CTC continue in the wake of the CFC-11 decline. CTC is an ozone-depleting substance still widely used as a feedstock in the production of HFCs and HFOs, with a GWP of 2,200. Global CTC emissions were on average 44,000 ± 15,000 tonnes/yr in both 2016 and 2020,<sup>15</sup> while the most recent bottom-up estimates were 25,000 tonnes/yr.<sup>16</sup> The emissions regionally attributed to eastern China remain orders of magnitude above official bottom-up estimates from the region.<sup>17</sup> Feedstock use of CTC in China is reported to have grown by 70 per cent between 2015-19 and reported conversion rates for the same feedstock uses have differed considerably across years and facilities, suggesting uncertainty about emission factors.<sup>18</sup>

Rising global emissions of HCFC-141b between 2017-21 have also been reported, despite a fall in global reported production and consumption from a peak in 2012.<sup>19</sup> HCFC-141b is a product with several applications, an intermediate/by-product and a feedstock, demonstrating the complexities of unravelling atmospheric emissions data and pinpointing sources.

Although the role of banks is unclear, the rise in emissions from eastern China and the timely coincidence of this increase with the rapid decline in CFC-11 emissions raise questions about the potential replacement of illegal CFC-11 with unreported illegal production and use of HCFC-141b.

#### Previously Unidentified Emissions of CFC-11, CFC-12 and CFC-113

A 2021 study in Nature Communications estimated new, unexpected emissions of CFC-11, CFC-12 and CFC-13 during 2014-2016 of 23,200, 18,300 and 7,800 tonnes/yr, based on revised estimates of banks and lifetimes of the chemicals. The inferred unexpected emissions of CFC-11 exceed previous estimates.<sup>20</sup> Estimated direct emissions of CFC-113 (i.e. excluding bank emissions) have increased from 3,300 tonnes/yr in 2002-12 to 7,800 tonnes/yr in 2014-16, and are considerably larger than anticipated based on expected sources. CFC-113 is an important feedstock chemical. Based on a technically feasible 0.5% emissions rate and global reported feedstock use of 131,000 tonnes in 2014, expected emissions would be less than 700 tonnes/yr, more than ten times lower than estimated through atmospheric observations.

Scientists have also drawn attention to atmospheric concentrations of CFC-113a, which have increased by 40% between 2017-21. Updated global emissions of 1,700 tonnes/yr on average between 2012-16 are estimated.<sup>21</sup> The authors identify multiple possible sources of CFC-113a: its use as feedstock in the

production of HFC-134a or HFC-125; its formation as a by-product in the manufacture of HFC-125; exempted use in agrochemical production; and its use as an intermediate feedstock in the production of TFA and pesticides. Emissions could also result from CFC-113 banks where CFC-113a is present as an impurity.

#### New HCFC and CFC emissions potentially related to fluorocarbon production

A 2021 study reporting on unexpected emissions of three HCFCs, including newly discovered HCFC-132b in the atmosphere, further demonstrates the need to detect and monitor substances in the atmosphere and to identify their sources.<sup>22</sup> There are no known end uses for HCFC-132b, HCFC-133a or HCFC-31, yet global emissions for all three compounds show a generally increasing trend over the past two decades, with mean values for 2016-19 of 970 tonnes/yr for HCFC-132b, 2,300 tonnes/yr for HCFC-133a and 710 tonnes/yr for HCFC-31.

The three HCFCs are most likely emitted as intermediate by-products in the production of HFCs, namely HFC-134a, HFC-143a and HFC-32. The study notes that the dominant source is eastern China (Shandong/Southern Hebei for HCFC-132b and Shanghai for HCFC-133a) and, based on the temporal and geographical variability, suggests that emissions are highly sensitive to industrial practices at individual facilities.<sup>23</sup>

Unexpectedly high CFC emissions potentially linked to HFC production have also been reported in a 2018 study based on observations of CFC-114 (GWP 9,430), CFC-115 (GWP 9,600) and CFC-13 (GWP 16,200).<sup>24</sup> Growth rates of CFC-13 and CFC-114 have not declined as expected, while average annual emissions of CFC-115 in 2015-16 have doubled from their 2007-10 minimum levels, suggestive of additional recent production, mostly likely as a by-product in the manufacture of HFC-125. The authors also suggest that the source of CFC-114 could be fugitive emissions during synthesis of HFC-134a, where it is an intermediate compound.

#### Methyl bromide

A recent study estimated anthropogenic methyl bromide (MeBr) emissions from eastern China from 2008-19 to average 4,100 ± 1,300 tonnes/yr, about 2,900 ± 1,300 tonnes/yr higher than would be predicted based on consumption data reported to the Montreal Protocol.<sup>25</sup> Taking into account non-fumigation MeBr sources from rapeseed production and biomass burning, the scientists suggest the remaining 3,500 /yr discrepancy is likely attributed to unreported or incorrectly reported Quarantine and Pre-Shipment (QPS) and non-QPS fumigation uses or emissions from unknown sources, such as industrial waste.

**Below:** Atmospheric monitoring has revealed unexplained and unexpected emissions of various gases of concern to the Montreal Protocol.





# Gaps in the Montreal Protocol

In 2020, global production of ODS that have been 'phased out' amounted to more than half a million tonnes (see Fig 2).<sup>26</sup>

The Montreal Protocol has various exemption mechanisms which allow the continued production and use of phased-out substances where deemed appropriate. General exemptions include chemical feedstock, laboratory and analytical uses and QPS uses of MeBr.

In addition, there are various exemptions authorised for specific named Parties for essential and critical uses, process agents, as well as the high ambient temperature exemption under the Kigali Amendment.

While Parties are required to report on exempted uses, they are excluded from the calculation of ODS or HFC production and consumption. The growing prevalence of scientific studies linking unexpected emissions of potent ODS and HFC greenhouse gases to feedstocks and industrial processes warrants a re-examination of exempt uses.

## Feedstocks

In 2020, 1,457,007 tonnes of controlled ODS were used as feedstock, chemical building blocks for the commercial synthesis of other chemicals, primarily HCFCs, HFCs and other fluoropolymers, as well as agricultural chemicals.

Feedstock production and use of controlled substances has grown consistently and accounts for most of the reported production of phased-out substances.<sup>28</sup> According to the Montreal Protocol's Technology & Economic Assessment Panel (TEAP), HCFC-22 accounts for 48 per cent of feedstock uses, with CTC accounting for a further 20 per cent.<sup>29</sup>

The definition of production under the Montreal Protocol has excluded feedstocks due to the assumption that, as raw materials, feedstocks are converted to other products, except for *de minimis*

Figure 3: Feedstock uses of controlled substances

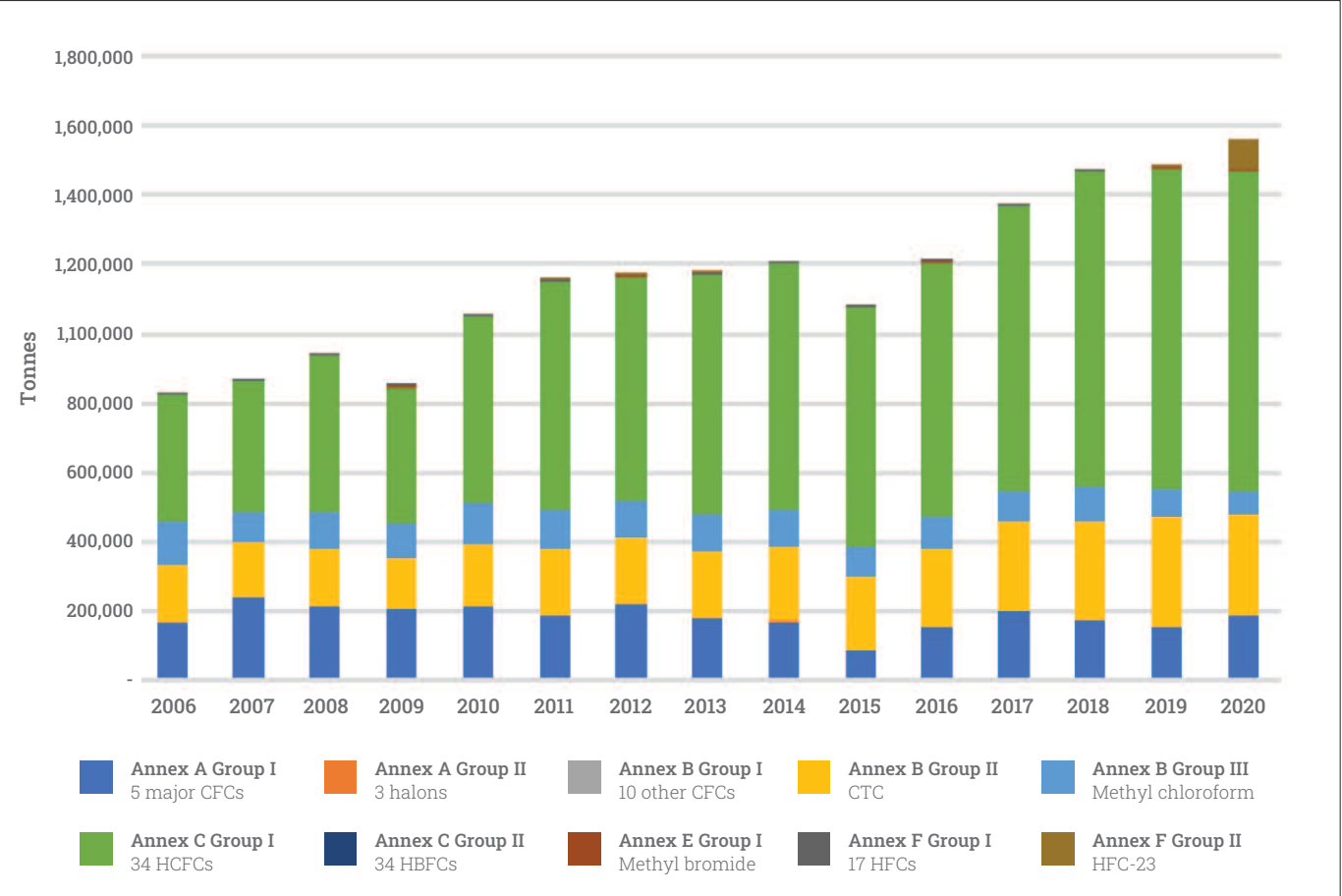


Figure 2: Reported production of phased-out substances (tonnes)<sup>27</sup>

Year	Substances	Annex group	Number of parties reporting	Total production for all uses and for exports (tonnes)	Production for own feedstock uses (tonnes)	Production for own essential or critical uses (tonnes)	Exported for feedstock uses (tonnes)	Exported for essential or critical uses of other parties (tonnes)	Amounts destroyed by the producers (tonnes)	Production for QPS uses (tonnes)
2020	Chlorofluorocarbons (CFCs)	A/I	4	188,008	186,349	-	1,515	-	230	
	Halons	A/II	3	1,486	1,266	-	220	-	2	
	Carbon Tetrachloride	B/II	12	299,179	273,346	124	16,553	-	9,320	
	Methyl Chloroform	B/III	3	69,558	69,199	-			682	
	Hydrobromofluorocarbons	C/II	3	3	2	-	2	-		
	Bromochloromethane	C/III	3	4,472	3,657	-	801	-	2	
	Methyl Bromide	E/I	5	13,396	3,061	0	236	26	19	10,143
	Totals			576,102	536,880	124	19,327	26	10,254	10,143
2019	CFCs	A/I	3	154,216	152,423		1,780		121	
	Halons	A/II	3	1,306	1,126	-	180		9	
	Carbon Tetrachloride	B/II	12	330,460	305,803	157	12,883		12,867	
	Methyl Chloroform	B/III	3	84,033	83,817				592	
	Hydrobromofluorocarbons	C/II	3	3	2		1			
	Bromochloromethane	C/III	3	1,729	1,001		912		1	
	Methyl Bromide	E/I	5	12,219	3,338	-	130	91	31	8,724
	Totals			583,966	547,510	157	15,886	91	13,621	8,724





residues and emissions of unconverted raw material.<sup>30</sup> Decision IV/12 exempted only “insignificant quantities” from its definition of controlled substances and urged Parties to “take steps to minimise emissions of such substances, including such steps as avoidance of the creation of such emissions, reduction of emissions using practicable control technologies or process changes, containment or destruction.”

Despite this, scientists are increasingly raising concerns that reported emissions from feedstock processes are underestimated and may account for significant elevated global atmospheric levels of a number of greenhouse gases, including CTC, CFC-113, HFC-23 and PFC-318.

Parties are required to report the production of controlled substances for feedstock uses annually; however, there are considerable problems with reporting. The 2022 TEAP Progress Report lists common feedstock applications of controlled substances, but TEAP acknowledges that it does not have an exhaustive list as Parties do not report how controlled substances are used, processes are proprietary and there is no official source to define

**Above:** HCFC-22 is used as a feedstock for the production of PTFE (often used to make Teflon), resulting in by-product emissions of GHGs including HFC-23 and PFC-318.

the manufacturing routes followed and their efficacy.<sup>31</sup> Moreover, some products are not reported because they are intermediates and not isolated in a chemical manufacturing process. These intermediates are, however, being emitted and detected by atmospheric monitoring. The 2022 TEAP Progress Report lists a large number of high-volume chemical products that may be produced by non-isolated controlled substance intermediates and are not reported, including CFC-11, CFC-112, CFC-114 and multiple HCFC and HFC species.<sup>32</sup>

Finally, there are clear concerns with by-production of ODS and other greenhouse gases, such as emissions of perfluorocyclobutane (PFC-318), which have risen sharply since the 2000s, correlating strongly with the use of HCFC-22 as a feedstock in the production of polytetrafluoroethylene (PTFE).<sup>33</sup>

Under Article 9 of the Montreal Protocol, Parties are required to “promote research, development and exchange of information on possible alternatives to controlled substances, to products containing such substances and to products manufactured with them; and costs and benefit of relevant control strategies.”

Parties are required to submit a summary of the activities it has conducted in this regard every two years, which could provide valuable information on strategies to reduce reliance on ODS as feedstocks.

However, over the past 10 years it would appear that the only reports received were from Sweden (in 2012), Norway (2015), Australia (2019) and Lithuania (2020).<sup>34</sup>

### Laboratory and analytical uses

A global exemption mechanism permits the production and consumption of ODS (mainly CTC and CFCs) to satisfy essential laboratory and analytical uses, as a type of general or blanket essential use exemption.<sup>35</sup> The conditions applied are set out in decision VI/9. In 2020, Parties reported consumption of 124.8 tonnes of controlled substances for laboratory uses, almost all of which was CTC (99.5 per cent).<sup>36</sup>

TEAP annually reviews the development and availability of alternatives and reports to the Parties, which have periodically removed specific uses from the global exemption if suitable alternatives are available. Decision XXXI/5 extended the global laboratory and analytical-use exemption indefinitely beyond 2021, without prejudice to the parties deciding to review the exemption at a future meeting.<sup>37</sup>

### Quarantine and Pre-Shipment (QPS)

MeBr used for official quarantine or pre-shipment treatments is exempt from the MeBr phase-out schedule (under Articles 2 and 5). Quarantine is

defined according to decision VI/11 as applications to prevent the introduction, establishment and/or spread of quarantine pests (including diseases) or to ensure their official control. Pre-shipment is defined as non-quarantine applications applied within 21 days prior to export to meet phytosanitary or sanitary requirements of the importing or exporting country, according to decision XI/12. MeBr imported, exported or produced for QPS is reported in annual Article 7 data reports and Parties are urged to minimise emissions and refrain from using MeBr wherever possible.<sup>38</sup>

In 2020, 44 Parties reported about 9,500 tonnes of MeBr being used for QPS.<sup>39</sup>

### Process agents

Process agents are certain ODS used in chemical processes which are exempt from Montreal Protocol controls. Most recently, process agent uses and maximum emission limits were established for the EU, Israel, US and China in 2019, allowing a total consumption of 4,328 tonnes and maximum emissions of 50 tonnes of CFCs, CTC and bromochloromethane (BCM).<sup>40</sup>

### Essential and critical use exemptions

Essential use exemptions apply to controlled substances used for a specific period of time after they have been phased out where their use is considered necessary for health and safety or critical for the functioning of society or where there are no available technically and economically feasible alternatives or substitutes. Criteria and conditions for authorising essential use are set out in decision IV/25, supplemented by several decisions on procedures and requirements.<sup>41</sup>

In recent years, essential use exemptions have been authorised only for CFCs for medical aerosols (metered-dose inhalers) and CFCs for aerospace applications. Such exemptions have been granted for a specified amount of substance for a specific use in the relevant Party, typically for one year at a time.

Critical use exemptions may be authorised for non-QPS uses of MeBr, based on conditions set out in Decision IX/6 and related Decisions. Requests are assessed by TEAP and its Methyl Bromide Technical Options Committee (MBTOC), and the MOP decides on authorisations and conditions.

Critical-use and emergency use exemptions granted to Parties for non-QPS uses of MeBr in 2021 amounted to almost 70 tonnes.<sup>42</sup>



# Emerging and enduring concerns

## PFC-318: Another potent by-product of HCFC-22 feedstock production

Perfluorocyclobutane or c-C4F8 (PFC-318) is a long-lived greenhouse gas with a potent GWP of 10,200.

According to a scientific study published in 2022, emissions of PFC-318 are rising sharply, having more than doubled since the early 2000s, reaching 2,200 tonnes in 2017 and 2,300 tonnes in 2020.<sup>43</sup>

The emissions are highly correlated with the production of HCFC-22 for feedstock uses. Almost all feedstock HCFC-22 is used to produce tetrafluoroethylene (TFE) and hexafluoropropylene (HFP), a process with PFC-318 as a known by-product, to in turn make PTFE and related fluoropolymers and fluorochemicals, including HFC-125, HCFC-225 and HFO-1234yf.<sup>44</sup>

## Nitrous oxide: Avoidable emissions of the most widespread ozone-depleting greenhouse gas

Nitrous oxide (N<sub>2</sub>O) is an ozone-depleting substance and the third most significant greenhouse gas; however, it is not controlled by the Montreal Protocol.

Anthropogenic emissions of N<sub>2</sub>O have grown by 20 per cent since the pre-industrial era and emissions could double by 2050 if left unchecked.<sup>45</sup> While the majority (two-thirds) of anthropogenic N<sub>2</sub>O emissions come from the agricultural sector, driven by overuse of nitrogen-based fertilisers, industrial sources are of note.

N<sub>2</sub>O is generated as a by-product of chemical manufacture including nitric acid for fertiliser and adipic acid for nylon and other synthetic products.<sup>46</sup> Technology to reduce N<sub>2</sub>O emissions by up to 98 per cent from industrial sources is market-ready and cost-effective. For example, industrial emissions of N<sub>2</sub>O mainly due to nitric and adipic acid production have decreased in North America and Europe since the widespread installation of abatement technologies in the 1990s.<sup>47</sup>

Despite this, significant quantities of N<sub>2</sub>O are still generated from industrial sources and may be growing rapidly in regions with expanding chemical production sectors. Some recent estimates of global N<sub>2</sub>O emissions assume these sources are largely abated, which recent investigations suggest may not be the case.<sup>48</sup> A 2021 study found that the rapid growth in China's industrial chemicals sector contributed N<sub>2</sub>O emissions that almost quadrupled between 2008-18, from 176,000 tonnes to 719,000 tonnes, expanding from 17 per cent

to 44 per cent of the country's overall anthropogenic N<sub>2</sub>O emissions.<sup>49</sup>

According to the Nitric Acid Climate Action Group (NACAG), the global nitric acid sector has an annual emission reduction potential of above 150 MtCO<sub>2</sub>e until 2030.<sup>50</sup>

## Unsustainable alternatives to controlled substances

### Sulfuryl fluoride (SO<sub>2</sub>F<sub>2</sub>)

Since its inclusion under the Montreal Protocol in 1992, global production and consumption of MeBr has decreased by more than 85 per cent.<sup>51</sup> However, in many applications, especially as a structural and post-harvest fumigant of dried fruits, tree nuts, grains, flours and timbers, MeBr has been replaced by sulfuryl fluoride (SO<sub>2</sub>F<sub>2</sub>). SO<sub>2</sub>F<sub>2</sub> has a 100-year GWP of 4,630 and a 20 year GWP of 7,510.<sup>52</sup> Since 1970, the global tropospheric background concentration of SO<sub>2</sub>F<sub>2</sub> has increased from ~0.1 ppt (parts per trillion, dry air mol fraction) to ~2.41ppt in 2018, mainly due to use in the post-harvest treatment sector.<sup>53</sup> Despite its high GWP and increasing use, sulfuryl fluoride is not regulated or monitored and is not covered by any reporting requirements under the UNFCCC.

The emissive use of SO<sub>2</sub>F<sub>2</sub> as a fumigation agent could be avoided by alternative methods and/or containment measures. There are sufficient, cost-effective alternatives to wood treatment against pest infestation. These treatment methods include irradiation, temperature treatments, debarking, drying with vacuum dryers, hot water steam vacuum process and hydrogen phosphide. The alternative treatments can be used in combination and can readily be scaled up.<sup>54</sup>

### High-GWP HFC alternatives to HCFC-22

High-GWP HFC alternatives to HCFC-22 continue to be adopted globally, such as HFC-404A (GWP 4,728) and HFC-507A (GWP 5,775) in commercial refrigeration applications and HFC-410A (GWP 2,256) in air-conditioning and heat pumps, despite the availability of low-GWP natural refrigerant alternatives.

Replacing HCFCs with high-GWP HFCs greatly reduces the environmental benefit of the ODS phase-out and will create significant challenges under the Kigali Amendment through a larger-than-necessary stock of equipment which will need servicing throughout its lifetime. Leapfrogging to low-GWP refrigerants and 'best-available technology' by 2050 could avoid 373 GtCO<sub>2</sub>e in-room air-conditioning and large commercial refrigeration alone.<sup>55</sup>

## HFOs

Since the phase-out of ODS began more than 30 years ago, the key sectors relying on ODS have undergone several transitions – from CFCs to HCFCs to HFCs. The Kigali Amendment is now spurring the uptake of fourth generation fluorinated refrigerants, HFOs.

While HFOs have been designed to have low direct GWPs, HFOs and HFO-HFC blends are linked to serious environmental concerns including trifluoroacetic acid (TFA), per- and polyfluorinated alkyl substances (PFAS) and high greenhouse gas emissions.<sup>56</sup> Concern over the environmental impact of HFOs has led Scandinavian countries recently to prioritise natural refrigerants over HFOs in green public procurement criteria.<sup>57</sup>

Several HCFCs, HFCs and HFOs degrade in the atmosphere to produce TFA as a final breakdown product, including HCFC 123, HCFC-124, HFC-134a, HFC-143a, HFO-1234yf and HFO-1234ze.<sup>58</sup> HFO-1234yf, the most commonly produced HFO,<sup>59</sup> which is used alone as a refrigerant and in many HFO blends, releases 100 per cent molar yield of TFA when it breaks down in the atmosphere. According to one study, the complete replacement of HFC-134a by HFO-1234yf leads to 33 times as much TFA worldwide in the lower approx. 8km of the atmosphere. Due to the short lifetime of HFO-1234yf in the atmosphere, the increase in TFA varies regionally. It would be significantly higher, for example, in areas with a high density of mobile air-conditioning systems, up to 250 times higher in Central Europe, for example.<sup>60</sup>

The Refrigeration, Air-Conditioning and Heat Pumps Technical Options Committee (RTOC) of the Montreal Protocol has stated that the high rate of TFA "may be of considerable environmental relevance in view of the expected future HFO production expansion".<sup>61</sup> Given the longevity of TFA in the environment, a precautionary approach is clearly needed.

HFOs are complex chemical compounds requiring significant amounts of energy to manufacture. Depending upon the production route, HFO-1234yf produces at least 13.5 kg CO<sub>2</sub>e emissions per single kilo of refrigerant produced.<sup>62</sup> In contrast, ammonia produces 1kg CO<sub>2</sub>e of emissions for every 1kg manufactured<sup>63</sup> and refrigerant grade CO<sub>2</sub> produces 0.5 kg CO<sub>2</sub>e for each kilo manufactured.<sup>64</sup>

**Top:** Sulfuryl fluoride used as a fumigant.

**Centre:** High-GWP HFC alternatives to HCFCs continue to be adopted globally despite lower-GWP alternatives being available.

**Bottom:** Significant quantities of N<sub>2</sub>O are still generated from industrial sources and may be growing rapidly.







Parties must now decide a structured way forward to strengthen the Montreal Protocol.

## Institutional processes for effective implementation and enforcement

After the illegal production and use of CFC-11 were identified in 2018, Parties to the Montreal Protocol were quick to respond, initiating a variety of studies to examine the Protocol's institutions and mechanisms to better understand how to avoid similar situations in the future.

This has highlighted a broad set of shortcomings which must be addressed and new challenges that will arise as the Protocol takes on additional HFC controls.<sup>65</sup>

These have been considered for several years now at meetings of the Parties to the Montreal Protocol including the Executive Committee to the Multilateral Fund and the Implementation Committee.

At OEWG44 in July 2022, the Parties met again to informally discuss areas for improvement to

strengthen the effective implementation and enforcement of the Montreal Protocol, producing a list for further discussion at MoP34 of topical "issues of interest", each with specific subitems.<sup>66</sup> These issues of interest include illegal trade and production, licensing systems, interpretation issues, products, capacity-building, trade through free trade zones and the Implementation Committee.

Each issue of interest is populated with specific subitems that require their own separate discussion. For example, under illegal trade and production,

specific sub-items include definitions, feedstock uses, stockpiling, HS codes, mislabelling and quota systems, each of which entails multiple considerations.

The Parties must now decide on a structured time-bound way forward.

EIA recommends that the Parties form a contact group at MoP34 to organise and refine the list of issues of interest into key elements to be addressed under a comprehensive review of the institutions and processes of the Montreal Protocol. These elements should include:

- atmospheric monitoring
- reporting and monitoring (including licensing systems)
- compliance mechanism (including the non-compliance procedure and implementation committee)
- capacity building and finance

- exempt uses and emerging issues (including feedstocks and by-product emissions)
- illegal trade and enforcement.

A decision at MoP34 setting a roadmap for consideration of each element and the related subitems over the coming years would allow the Parties to consult internally and externally in advance and to come prepared to exchange views and proposals on needed improvements. In support, the Secretariat could be charged with compiling the available background information to inform the discussion, including on horizontal issues, such as proportionality to expected benefits as well as the costs and burdens of any new recommended measures.

The overarching goal should be to strengthen the effectiveness of the Protocol's monitoring, reporting, verification and enforcement mechanisms to sustain the achievements of the Montreal Protocol and meet the new challenges of the HFC phase-down, securing its standing as the most successful multilateral environmental agreement.





# Conclusions and recommendations

Communities worldwide are faced with the devastating impacts of a rapidly warming planet and bracing for future threats, the extent of which will be determined by our collective success to curb the greenhouse gases accelerating global temperature rise.

The climate crisis dictates an urgent need to tackle unexpected and new emissions from the fluorochemical industry and advance the conversation on strengthening institutional processes to ensure the sustainability of the Montreal Protocol's achievements to date and to rise to new challenges.

The SAP estimates that the current combined GWP-weighted emissions of CFCs plus HCFCs are comparable to those of HFCs. Direct industrial emissions of greenhouse gases and ODS related to fluorochemical production amount to hundreds of millions of CO<sub>2</sub>-eq tonnes each year. The Montreal Protocol is clearly the most relevant institution to address this chemical climate bomb.

Parties are considering a number of steps towards this goal, with draft decisions on identifying sources of emissions originating from industrial processes,<sup>67</sup> ongoing emissions of CTC<sup>68</sup> and stocks and QPS uses of methyl bromide<sup>69</sup> on the agenda for MOP34. The Parties will also consider the periodic review of alternatives to hydrofluorocarbons.<sup>70</sup>

Meanwhile, a draft decision recognising the achievements of Crutzen, Molina and Rowland, whose pioneering scientific work paved the way for global action to protect the ozone layer, commits the Parties to the Montreal Protocol to “strive to continue to strengthen the institutions that their achievements helped to establish in order to achieve the aims of those institutions and protect the atmosphere for the benefit of all.”<sup>71</sup>

## EIA recommends Parties to the Montreal Protocol to:

- Adopt a decision on institutional processes that sets a roadmap for a comprehensive evaluation of the Montreal Protocol's institutions and processes
- Support draft decisions on sources of industrial emissions, ongoing emissions of CTC and stocks and QPS uses of methyl bromide
- Initiate discussions on fluorochemical feedstock and by-product emissions, in particular how to identify and address significant sources
- Commit to, wherever possible, avoiding the uptake of high-GWP alternatives to controlled ODS and HFCs
- Submit all relevant data under Article 9 before the 1 January 2023 deadline
- Support draft decision “Recognition of the achievements of Paul Jozef Crutzen, Mario José Molina and Frank Sherwood Rowland, winners of the Nobel Prize in Chemistry in 1995”.

**Above:** The climate crisis requires urgent action in all market sectors, including the fluorochemical sector.

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