

EIA Briefing to the 30th Meeting of the
Parties to the Montreal Protocol

TIP OF THE ICEBERG:

Implications of Illegal
CFC Production and Use

November 2018





Dacheng Wan Fu Chemical Co. Ltd spraying foam in a cold storage warehouse in Hebei Province, China.

CONTENTS

Introduction	1
Immediate Response to the CFC-11 Scandal	2
CFC-11 found in Tested PU Foams	2
Understanding the Unexpected CFC-11 Emissions	3
Potential CFC-11 Emissions From Illegal Use in the PU Foam Sector	4
Potential Bank Created by Illegal Use	4
Areas of Uncertainty and Unanswered Questions	5
Illegal Trade in CFCs and other ODS	7
The CFC-12 Mystery	8
The CTC Mystery	8
Monitoring, Enforcement and Compliance	9
Trade in Polyols	10
Disposable cylinders	11
Conclusions and Recommendations	12

ABOUT EIA

We investigate and campaign against environmental crime and abuse. Our undercover investigations expose transnational wildlife crime, with a focus on elephants and tigers, and forest crimes such as illegal logging and deforestation for cash crops like 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.

EIA US

PO Box 53343
Washington DC 20009 USA
T: +1 202 483-6621
E: info@eia-global.org
eia-global.org

EIA UK

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

DESIGN:
www.designsolutions.me.uk

INTRODUCTION

In May 2018 scientists revealed that atmospheric levels of CFC-11, a potent ozone depleting substance banned globally since 2010, were significantly higher than expected, indicating new illegal production and use of CFC-11 occurring in East Asia.¹

EIA investigations quickly pinpointed that illegal use of CFC-11 in China's polyurethane (PU) foam insulation sector was likely a major source of the new emissions. Eighteen out of 22 companies interviewed from ten provinces confirmed using CFC-11 as the main blowing agent in the production of foam panels and spray foams. Traders and buyers of CFC-11 in China repeatedly stated that it was used in the majority of China's rigid PU foam sector. The core EIA findings were backed up by an independent investigation by the New York Times as well as official Chinese government documents. A 2016 report from environmental officials in Shandong, a key area for foam production, had already warned that there was "still a large volume of illegally produced CFC-11 being used in the foam industry".²

A report summarizing the investigations and analyzing the potential drivers for the illegal trade – *Blowing It: Illegal Production and Use of Banned CFC-11 in China's Foam Blowing Industry* – was published in July 2018 and distributed to the Parties to the Montreal Protocol at its 40th Open-Ended Working Group (OEWG) meeting in Vienna.³

Parties to the Montreal Protocol, including China, responded swiftly. China launched a nationwide inspection and has undertaken several enforcement actions including shutting down one illegal CFC-11 production site.⁴ At OEWG-40, the Parties unanimously agreed a draft Conference Room Paper expressing "serious concern" about the substantial CFC emissions, and requesting a number of actions to allow clear identification of the source of emissions, including analysis and further information from the Technical and Economic Assessment Panel (TEAP) and Scientific Assessment Panel (SAP).

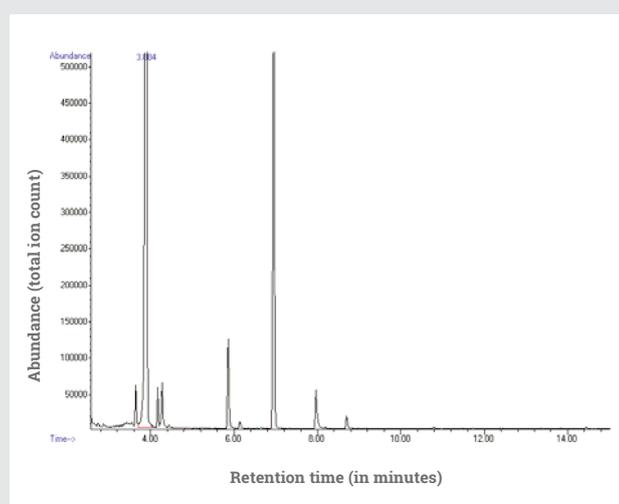
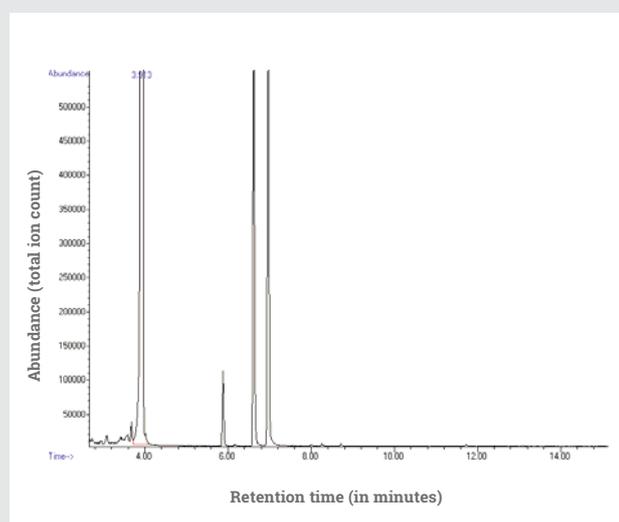
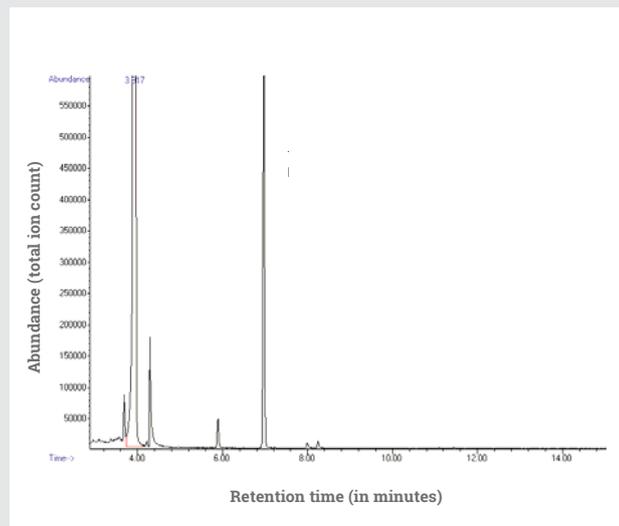
As Parties continue their deliberations at the 30th Meeting of the Parties in Ecuador, this report offers additional information and analysis regarding the illegal use and trade in CFC-11 and looks at the broader implications for compliance and enforcement of Montreal Protocol obligations. It highlights a number of remaining gaps in the understanding of the current status of CFC-11 use, estimates the size of the new bank of CFC-11 being created and offers recommendations to the Montreal Protocol and its Parties for next steps. This report also releases new independent laboratory test results that clearly confirm the use of CFC-11 in three enterprises previously identified by EIA, reinforcing the credibility of their statements that CFC-11 was the predominant blowing agent used at these facilities.

EIA cautions Parties not to treat the issue of illegal trade in CFC-11 as an isolated enforcement issue limited to one country. A new study that provides compelling evidence potentially linking elevated levels of another ODS, carbon tetrachloride, to the illegal production of CFC-11, suggests that this is just the tip of the iceberg. The scale and impact of the illegal trade demonstrates that the Montreal Protocol's current compliance and enforcement regime is not fit-for-purpose and requires modernization. This is particularly urgent considering the entry into force of the Kigali Amendment in 2019, which will present new challenges to all Parties. Lessons must be learned and swiftly applied to ensure that all Parties are able to comply with the critical obligations under the Protocol and maximize global efforts to combat global warming and ensure the recovery of the ozone layer.



EIA map illustrating enterprises that confirmed CFC-11 use in foam production in July 2018.

Total Ion Chromatogram (time range 3-15 minutes)
Foam Sample Number 1, 2 and 3



Intertek Allentown Lab report showing an overlay of total ion chromatograms of the three foam samples. CFC-11 blowing agent is detected in all three samples at a retention time (RT) 3.9 minutes. Identification of the blowing agent is based on the compound's EI mass spectrum and matches to a Wiley/NIST library reference spectra.

IMMEDIATE RESPONSE TO THE CFC-11 SCANDAL

In response to EIA's report, China announced a nationwide inspection on ODS compliance in July 2018, including a joint inspection with local authorities on 19 PU foam producers and a business cluster identified by EIA. In 12 of the enterprises under investigation no sales or use of CFC 11 were found but CFC-11 was found in one enterprise in polyether polyol. According to a report in August 2018, local authorities took enforcement measures and were continuing to investigate six remaining enterprises identified by EIA. However no further information has been released since this time.⁵

According to a report from China's Ministry of Ecology and Environment (MEE), authorities also uncovered an illegal CFC-11 production facility in Mengzhou City, Henan Province, in August 2018. The CFC production was hidden in a mechanical processing enterprise; 29.9 tonnes of illegally produced CFC-11 and about 30 tonnes of carbon tetrachloride were seized. According to the report, three suspects were arrested and two others were on the run.⁶ It had been previously reported by a spokesperson from the Chinese embassy in the UK that local authorities uncovered two enterprises in Liaoning and Henan province that had been producing CFC-11 and CFC-12 respectively. The seized CFCs and raw materials were confiscated and local police filed charges against the enterprises and were hunting down suspects.⁷ It is unclear if the Henan seizure is a separate enforcement action to the one reported by China's MEE.

Meanwhile, the China Plastics Processing Industry Association (CPPIA) launched an initiative to stop illegal CFC-11 use, stating it is the obligation of every company industry-wide to protect the environment, operate in accordance with the law, and to voluntarily boycott illegal blowing agents. Additionally, the CPPIA initiative included clearly labelling the blowing agent in raw material trading contracts and established a hotline to report illegality.⁸

CFC-11 FOUND IN TESTED PU FOAMS

EIA was provided with PU foam samples from three companies exposed in EIA's "Blowing It" report, namely:

Dacheng Aoyang Chemical Co. Ltd.

Dacheng Shengshi Tianchuang Chemical Co., Ltd.

Dacheng Desheng Chemical Co., Ltd.

Independent laboratory testing using mass spectrometry analysis has confirmed the presence of CFC-11 blowing agent in all three samples. HCFC-141b and HFC-245fa were not detected in the samples. These results corroborate the veracity of the statements made by these companies. It is notable that the first two companies listed specifically mentioned the export of CFC-11 containing polyols and ways to avoid customs controls, including by labelling as HCFC-141b. The third company, Desheng, claimed to be the biggest supplier of pre-blended polyol in the region and to use CFC-11 in 90-95% of their production.⁹

UNDERSTANDING THE UNEXPECTED CFC-11 EMISSIONS

The Nature study by Montzka *et al.* demonstrated that since 2013, the annual decline in CFC-11 concentration has been only half as fast as it was over the previous decade (2002-2012). By deriving emissions from the atmospheric data the scientists concluded that emissions of CFC-11 increased significantly (by around 25%) after 2012 and have remained elevated in all years since, including 2017.¹⁰ The study also demonstrated that the increased emissions after 2012 originate from East Asia.¹¹

Measured global atmospheric changes show a steady decrease in emissions in the 15 years before 2002 from a late 1980s peak of about 350 Gg/yr. From 2002 to 2012 emissions were relatively constant at 54 ± 3 Gg/yr. Then emissions sharply increased, with an average emission rate during 2014-2016 of 67 ± 3 Gg/yr, which is 13 ± 5 Gg/yr above the 2002-2012 average.

The significant post-2012 increase in CFC-11 emissions has dominated discussions, however there are also important questions to resolve regarding earlier CFC-11 emissions. From 2002 to 2012, the rate of decline of CFC-11 would be expected to accelerate, since production for uses gradually decreased to zero and the CFC-11 foam bank was being depleted. In fact, this decline was not

observed, which the authors of the study state "suggests a gap in our understanding of CFC-11 sources and sinks since the early 2000s."

Assuming the 25% increase in emissions post-2012 is attributed to new illegal production of CFC-11, these are in addition to higher than expected emissions since 2002. From 2014-16 CFC-11 emissions were 13 ± 5 Gg/yr above the 2002-2012 average, however the emissions during that period are in total 25-30 Gg/yr above expected emissions, based on an estimated constant release fraction from banks of CFC-11 in foam and equipment (see Figure 1). The absence of comprehensive data regarding the size of banks of foam (and chillers) containing CFC-11 and the rate of emissions from these banks is a key issue that needs to be swiftly resolved.

The significant post-2012 increase in CFC-11 emissions has dominated discussions, however there are also important questions to resolve regarding earlier CFC-11 emissions. The absence of comprehensive data regarding the size of banks of CFC-11 foam and their emissions is a key issue that needs to be resolved.

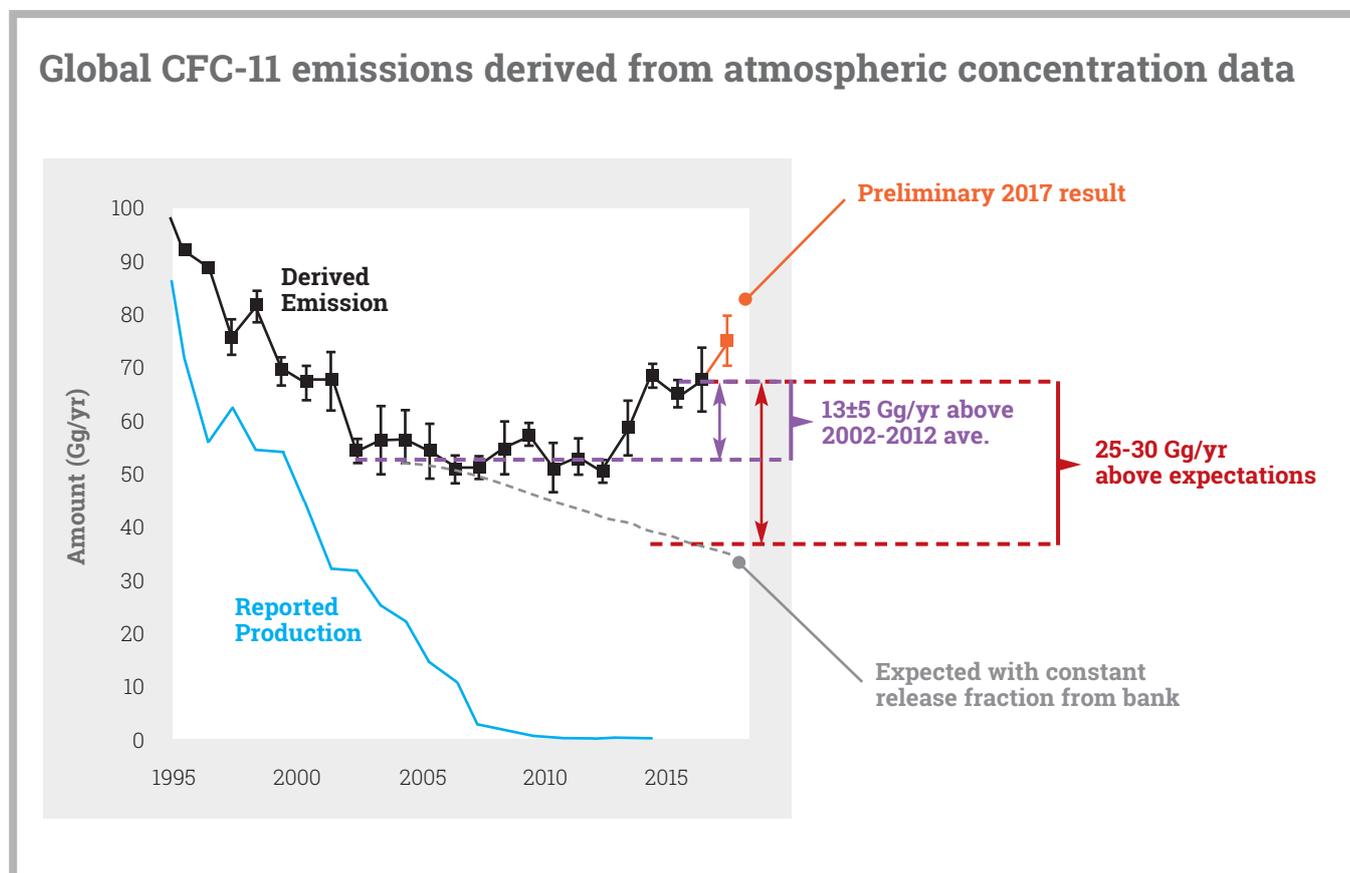


Figure 1: Global CFC-11 emissions presented by the Scientific Assessment Panel to OEWG-40.

POTENTIAL CFC-11 EMISSIONS FROM ILLEGAL USE IN THE PU FOAM SECTOR

EIA's previous report calculated potential emissions from the illegal use of CFC-11 in China's PU foam blowing industry using assumptions based on investigation findings, market data, research and consultations with industry experts. Over the 2014-16 period, based on the same assumptions, EIA calculates average emissions of 12,972 tonnes of CFC-11. This figure is within the range estimated by the Nature study, which estimated average emissions of 13±5 Gg/yr (8,000-18,000 tonnes) over the same period.

The assumptions are listed below. It is important to note that even with more conservative assumptions, the emissions calculations remain high.

- The size of China's rigid PU foam production from 2012-2015 was based on market data.¹² An 8.2% CAGR was assumed for 2016 based on market research reports.¹³
- CFC-11 is assumed to be the main blowing agent used in 70% of China's rigid foam production, according to the lower end estimate of foam companies and polyol producers interviewed by EIA. The use of CFC-11 in flexible foams is not considered.
- CFC-11 comprises 10% of the finished foam by weight, based on discussion with industry foams expert.¹⁴
- The calculation assumes an initial emission factor of 25% for PU spray foam and 5% for other rigid PU foams (5%), based on the EPA Vintaging Model, 2001 (Chapter 9) and advice from industry experts.¹⁵
- The calculation assumes 11% of rigid PU foam produced in China is spray foam, based on a 2016 market report on emerging market demand in foams by Technavio.¹⁶



Scraps of insulation and building materials from a demolished home.

POTENTIAL BANK CREATED BY ILLEGAL USE

Based on the same assumptions, EIA conducted a best-estimate of the size of the new CFC-11 foam bank created from the illegal use and production of CFC-11 in China's PU rigid foam sector after 2012.

Under this scenario, an additional bank of approximately 166,000 tonnes of CFC-11 was added annually between 2013-2017. The estimated size of the total bank of CFC-11 in foams created between 2013-2017 would be approximately 830,000 tonnes, equivalent to 3.94 billion tonnes of carbon dioxide equivalent (GtCO₂e) of CFC-11. Left unchecked this new CFC bank would grow to 7.38 GtCO₂e in 2020.

Given uncertainties in some assumptions and unanswered questions, the actual size of the foam bank could vary considerably. Additional scientific research and on the ground sampling in order to confirm the scale of CFC-11 banks in PU foam is required.

Based on EIA calculations, a bank of CFC-11 in foams of nearly 4 GtCO₂e could have been created between 2013-17 from the illegal CFC use.

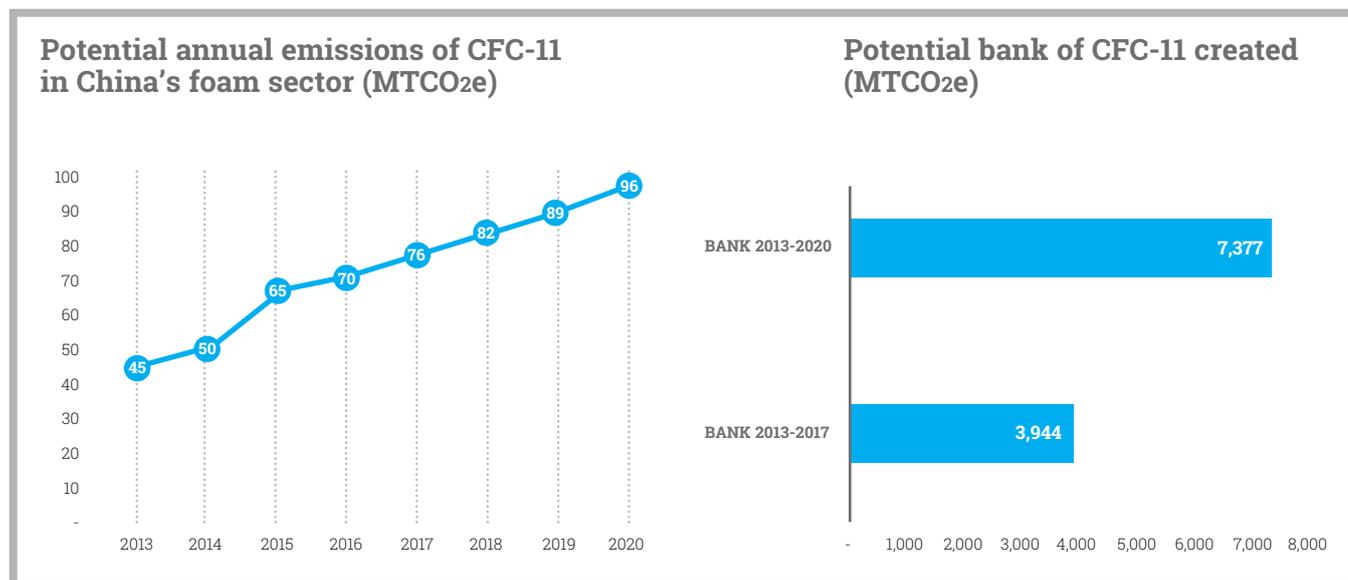


Figure 2: EIA calculations of the potential emissions and bank of CFC-11 created from the illegal use of CFC-11 in China, based on the assumptions described above.

AREAS OF UNCERTAINTY AND UNANSWERED QUESTIONS

The following areas require further research, data collection and validation in order to arrive at a more precise estimate of CFC-11 foam emissions and banks.

Uncertainty around the size of the PU foam sector

Available data on the total size of the foam sector in China has a large range across sources. There appear to be gaps or inconsistencies in various industry estimates for PU rigid foam production in China, as well as use and consumption estimated for blowing agent materials. Market reports on total PU rigid foam production in China vary widely. For example, one report from a Chinese industry group cites 2015 production of 2.7 million tonnes growing at a rate of 9.7% annually between 2012-2015,¹⁷ while another leading industry report from IAL consultants cites 2.3 million tonnes of rigid PU foam production in all of East Asia in 2016, citing a "collapse in the spray foam market" in China.¹⁸ This would make China's 75% portion of the East Asian market just 1.79 million tonnes. This significant difference in estimates regarding the overall size of China's rigid PU foam production suggests that a portion of production may not be accounted for in some estimates. Another key source of uncertainty concerning production is the proportion of spray foam in China's total rigid PU foam production.

Accurate and most recent data on the total size of the foam sector, and particularly the size of the spray foam industry versus other applications will be important for a better estimate of the size of the banks.

The proportion of China's rigid PU foam sector that is using CFC-11

EIA's information suggests that the use of CFC-11 in China's domestic foam sector has been widespread, particularly in the building and construction sector. Companies interviewed by EIA repeatedly stated that HCFC-141b only formed a small (10-30%) proportion of the domestic blowing agent market and that the majority of the blowing agent used in China is CFC-11. EIA used the lower-end estimate (70%) for the calculation, however the extent to which the companies interviewed represent the entire domestic sector is unknown.

It should be noted that EIA's findings are corroborated by official Chinese government statements. A press release of the Shandong Municipal Environmental Protection Bureau in 2015 stated that "CFCs producers came back to sight in 2013. Shandong had shut 15 CFC-11/CFC-12 producers since then and will perform spot check quarterly starting 2015."¹⁹

Moreover, a 2017 publication on the PU industry by the International Environmental Convention Implementation Office of Shandong Municipal Environmental Protection Bureau states: "There's still many CFC-11 used in foam industry. Shandong Municipal Environmental Protection Bureau is enforcing strict supervision over foam manufacturers that still use ozone-damaging blowing agent."²⁰ An independent expert from the Shandong

Institute of Commerce and Technology stated in 2017: "Currently the most frequent usage of ODS in cold chain industry is CFC-11 as PU foam blowing agent for cold storage and pipe insulation. Although there are alternatives (of CFC-11), its blowing efficiency, supporting facilities and blowing techniques are still to be improved."²¹ Added to this is the result of independent laboratory testing of foam samples from three of the companies interviewed by EIA sources which demonstrated CFC-11 in all the samples.

Proportion of CFC-11 blowing agent used in foam

Estimates of the amount of blowing agent used in the production of PU foam generally range between 5.5% and 10% of the foam product by weight.²² According to industry experts, 5.5% is an average of all blowing agents, which is dominated globally by pentane and water. If only considering fluorocarbons, the number is closer to 12-13% due to their higher molecular weight.²³ However it is possible, even likely, that unregulated foam manufacturers use higher proportions of CFC-11 with excess CFC-11 vented, in order to make the process as cost effective as possible, given that the CFC-11 is significantly cheaper by weight than the polyol or isocyanate. Excess CFC-11 is vented when the right density is achieved. EIA's calculation assumes that the proportion of CFC-11 in the production of the foam is 10%, but it could be as high as 20% or more when driven by costs rather than quality.

Timeline of illegal CFC-11 production and use

The size of the CFC-11 bank depends on when the illegal use of CFC-11 began, which remains unclear. EIA's estimate is derived based on a conservative assumption that production and use began in 2013 in line with the period of observed emissions increase, however it is clear that some illegal production and use occurred before this time, which could increase the size of the bank.

Other uses of CFC-11

According to TEAP, CFC-11 has also been used as a blowing agent for flexible foam, especially slabstock, with very high emission rates (up to 100%).²⁴ Since dichloromethane (and other alternatives) replaced CFC-11 in flexible foams and is readily available at low cost, it seems unlikely that producers would revert to CFC-11. Initial outreach by EIA to flexible foam companies did not



It is important to understand the proportion of spray foam production in China's PU foam market given the high emissions.

uncover any evidence of illegal CFC-11 use, however the possibility that CFC-11 is still being used for flexible foams remains.

According to TEAP, CFC-11 is also produced as a by-product in other chemical manufacturing pathways, including in the production of HCFC-22. Levels of production would be expected to be negligible, however (up to 0.1%).

A search on Google patents reveals multiple relatively new patents that feature CFC-11, however the extent to which these are commercialized is unknown. Although there is no concrete information about other new uses of CFC-11, it must be looked into as a possibility and further investigated.

The initial emissions from the foam blowing process

According to TEAP, the foaming process results in 3-5% emissions of the foam blowing agent when rigid polyurethane foam is produced in an enclosed space (as in appliances or molds), or 15% emissions from the use of spray foam.²⁵ Industry experts consulted by EIA have suggested spray foam emissions can be as high as 25%. If CFC-11 use has been concentrated in the spray foam sub-sector this would elevate emissions.

Additional emissions due to unregulated and inefficient processes

The assumptions made for these calculations are generally based on rather tight production and usage patterns from industry where, because of production and consumption controls, CFC-11 was efficiently used and accounted for. In a system where the refrigerant is not

controlled or reported in the same manner and is cheaply available, there may be significantly more leakage and emissions during production, transport and application.

A 2017 presentation on the official government website of the Shandong International Convention Implementation concerning illegal ODS operations noted that "These enterprises generally lack well-performing facilities and thorough management."²⁶

The size of the current CFC-11 bank in equipment and foams and their emission rates

The size of the current (pre-illegal use) CFC-11 bank in equipment and foams and the emissions from the bank is a critical data gap. There are significant challenges for the cost-effective separation and treatment of blowing agent refrigerants from PU foam and abatement is generally lacking in most parts of the world.

According to the 2014 FTOC Assessment report, global banks of blowing agents in foams are estimated to have grown from 3 million tonnes in 2002 to an estimated 4.45 million in 2015 and predicted to grow to well in excess of 5 million tonnes by 2020.²⁷

According to TEAP, at the end of life, foams are sent to landfill sites generally where CFC-11 would slowly emit over time (0.5% per year) excluding any amount that might be bioremediated (chemical breakdown of CFC-11 by bacteria) in the landfill. There is the potential for bioremediation of up to 94% of the blowing agent that reaches a landfill. Foam bank emissions after destruction of buildings or appliances are likely to occur over time from landfill.²⁸



There are significant challenges in the treatment of ODS banks in foams and abatement is generally lacking in most parts of the world.

ILLEGAL TRADE IN CFCs AND OTHER ODS

Under Paragraph 7 of Decision XIV/7 information on illegal trade should be reported to the Ozone Secretariat. Unfortunately, very few Parties to the Montreal Protocol share data on their enforcement efforts. Four countries submitted data in 2018 and just one in 2017.²⁹ Since 2010 there have been a number of cases of illegal trade in CFC-12 cylinders and one case of CFC-11 illegal trade reported.³⁰

In August 2014, customs officials in Turkmenistan detected four cylinders of CFC-11 weighing 50kg in total, along with five cylinders of HCFC-22 that had been exported from Iran.³¹

Although not reported under Decision XIV/7, in January 2014 Russia's Ministry of the Interior detained and arrested criminals engaged in smuggling ODS including 18.8 tonnes of CFC-11 from China into the Russian Federation. The operation resulted in the seizure of more than 1,500 cylinders of various size with CFC-11, CFC-12, HCFC-22 and HCFC141b, along with homemade reclamation and filling equipment, documents, seals and labelling devices such as templates and stencils.³² The seized refrigerants were of Chinese origin and were transferred from original cylinders into ones labelled as containing ozone-safe refrigerants. The CFC-11 was imported under the guise of ethylene-glycol and contained in a 250kg drum typically used for blowing agents.

Multiple cases of CFC-12 illegal trade occurring in 2015 have been reported by Uzbekistan.³³ In total almost 695kg

of CFC-12 were seized in four separate enforcement actions between February and August 2015. Three of the four seizures were imported from Kyrgyzstan.

Micronesia also reported a 2015 seizure of CFC-12, falsely labelled as HFC-134a. Six cases of canisters, each containing 30 canisters of 250g of CFC-12 labelled as Arkane R-134a were seized.³⁴

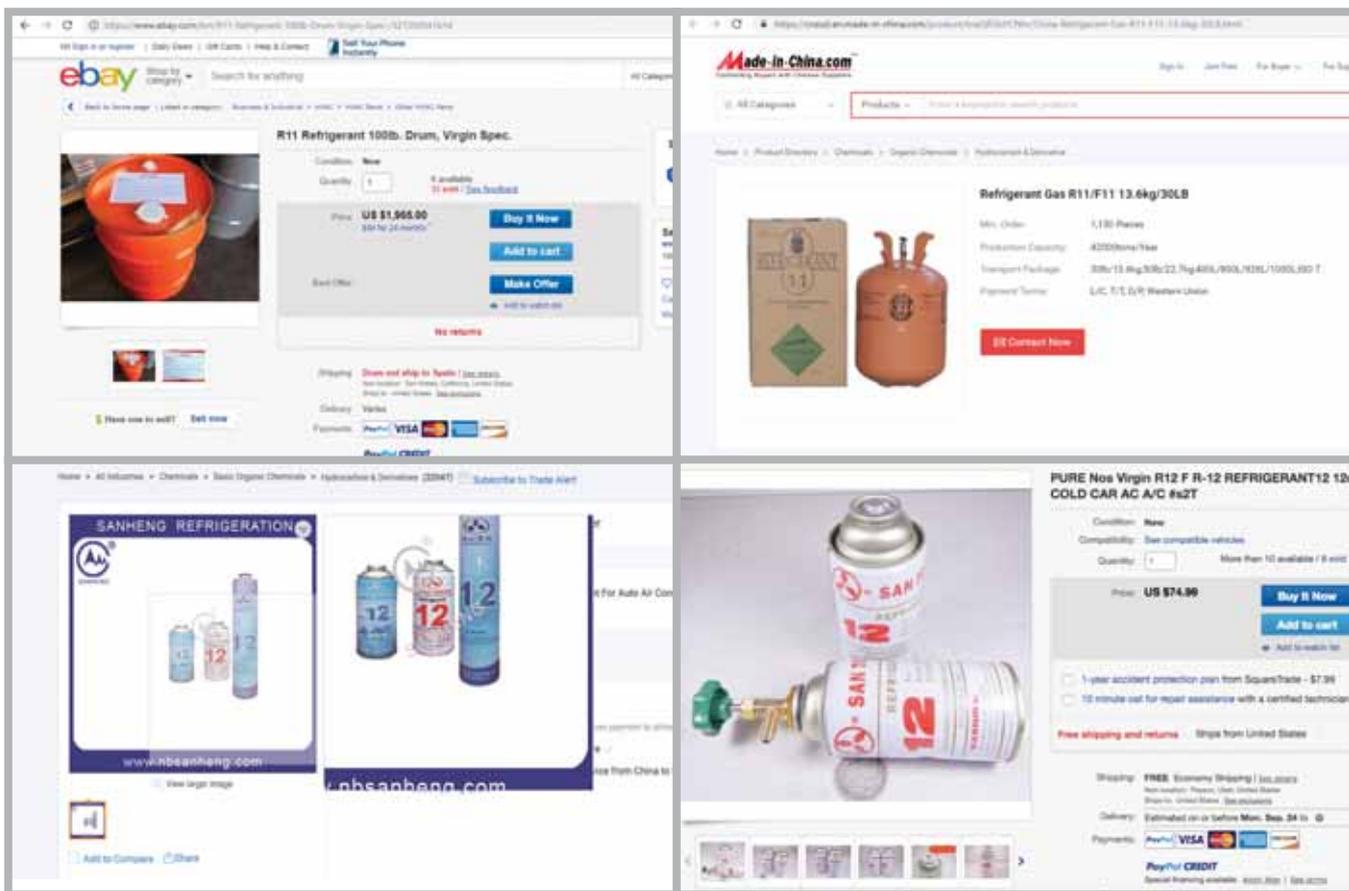
Also in 2015, the Dutch Environmental Inspectorate blocked two containers in the Port of Rotterdam with gas bottles containing HCFC-22 and CFC-12, labelled as HFCs (HFC-134a and HFC-407c). The containers originated in China and were headed for Russia via the Netherlands.³⁵

EIA is also aware of a number of large CFC-12 seizures in 2018 that have not yet been officially reported to the Ozone Secretariat. For example in Southern Africa a shipment of two tonnes of cylinders was seized, labelled and packaged as HFC-134a. Analysis indicated that the actual content of the cylinders was 98% CFC. In Central Asia 900 new cylinders of CFC-12 were seized; the cylinders did not appear to be from old stocks. Also in South-East Asia in 2018, 400 disposable cylinders of CFC-12 mis-declared as other goods were confiscated by Customs. The cylinders and boxes appeared to be in good condition and had the branding of a well-known manufacturer.³⁶

CFCs continue to be openly advertised on ebay and other internet sale sites. While it cannot be confirmed that these sales are genuine, they represent a failure to adequately inform and raise awareness of the illegality of CFCs.



Illegal CFC-11 seized in Russia in 2014, imported from China under the guise of ethylene-glycol.



Screenshots of products claiming to be CFC-11 and CFC-12 available for purchase online.

THE CFC-12 MYSTERY

CFC-12 is co-produced with CFC-11 with the proportion of each controlled by varying the operating conditions. While 100% of either chemical can be achieved, 100% CFC-11 is difficult therefore one would expect significant amounts of CFC-12 production alongside illegal CFC-11 production.³⁷ If all the CFC-12 was emitted elevated atmospheric levels would be expected, which so far have not been observed. It is clear from recent enforcement efforts including the discovery of production in China, that CFC-12 is available in the market, however the volumes are not known due to poor reporting by the Parties to the Montreal Protocol on illegal trade enforcement. There is a possibility that CFC-12 is also being produced for a target market and this should form a part of ongoing analysis and investigation.

Given existing knowledge about the likelihood of co-production and indications that CFC-12 is available on the market from potentially illegal sources, including through online retailers, Parties should not wait for increased emissions to be observed before pursuing investigations and proactive enforcement measures.

THE CTC MYSTERY

CFC-11 is produced from carbon tetrachloride (CTC or CCl₄) and hydrogen fluoride.³⁸ CTC is also an ozone-depleting substance whose emissive use and production were globally banned under the Montreal Protocol with a

2010 phase-out although production and consumption for non-dispersive use as a chemical feedstock and as a process agent are still allowed. Like CFC-11, global emissions of CTC in the atmosphere from observation-based methods are much higher (~ 35 Gg/yr) than emission estimates from reported numbers to UNEP under the Montreal Protocol (3 Gg/yr).³⁹

Sherry *et al.* (2018) provided revised estimates of global bottom-up CTC emissions, totaling 15-25 Gg/yr based on: 13 Gg/yr of global emissions from unreported non-feedstock emissions from chloromethane and perchloroethylene plants; 2 Gg/yr fugitive emission from use of CTC as feedstock; and up to 10 Gg/yr from legacy emissions and chlor-alkali plants.⁴⁰ This still leaves some 10-20 Gg/yr CTC emissions unaccounted for which requires further research and improvement in bottom-up estimates.

A recent study estimated top-down emissions from China of 23.6 ±71 Gg/yr from 2011-2015, compared to most recently reported bottom up estimates of 4.3-5.2 Gg/yr, noting that the missing emissions of 19 Gg/yr are equivalent to around 54% of global CTC emissions.⁴¹ A new study published in October 2018 provided further information, pinpointing a new source of emissions from the region of Shandong after 2012. The study published in Geophysical Research Letters estimated eastern Asian emissions of CTC to be 16 (9–24) Gg/yr on average between 2009 and 2016, with the primary source regions being in eastern China. The spatial distribution of derived emissions suggests that over the 8 year period, the source distribution of CTC in China changed, with a new

source or sources of emissions from China's Shandong province after 2012. The study states:

"The discovery of a new source of emissions in Shandong province may potentially have wider implications linked to the recent discovery of a new source of CFC-11 into the atmosphere (Montzka *et al.*, 2018), given that CCl₄ is used in the production of CFC-11, and the timing of the change in source distribution after 2012 is consistent with an increased CFC-11 source around this time found by Montzka *et al.* More detailed work is required to confirm whether the findings of these two studies are linked."⁴²

Shandong is a region that has been identified as a hotspot for the illegal production and use of CFC-11 by EIA and through Chinese enforcement efforts. Although there would be economic incentives to minimize emissions of CTC in the production process of CFC-11, this study along with the continued demand for CFC-11 as well as the recent seizure of newly produced CFC-11 and CTC reported by the Chinese government provides compelling data to support the likelihood that at least a proportion of elevated CTC levels are linked to the illegal production of CFC-11.

MONITORING, ENFORCEMENT AND COMPLIANCE

Parties to the Montreal Protocol have invested heavily in creating the legislation and institutional structures necessary to implement their global commitments under the Protocol over the last 30 years. However, the CFC-11 scandal demonstrates that simply putting laws in place does not ensure compliance. Robust enforcement is essential and must comprehensively cover the life-cycle of the chemical, product or equipment in question – from production to storage, transport, use, trade, emissions, recycling and destruction.

The immediate goal should be to crackdown on illegal producers and their networks through a thorough investigation and coordination of enforcement officials from environment, police and prosecutorial agencies as well as experienced stakeholders in this space such as customs, implementing agencies and NGOs. It is important that the Montreal Protocol is able to provide assistance to enhance national capacity, as enforcement officers may have little to no previous experience in the complexities of the issue, which is required to lead

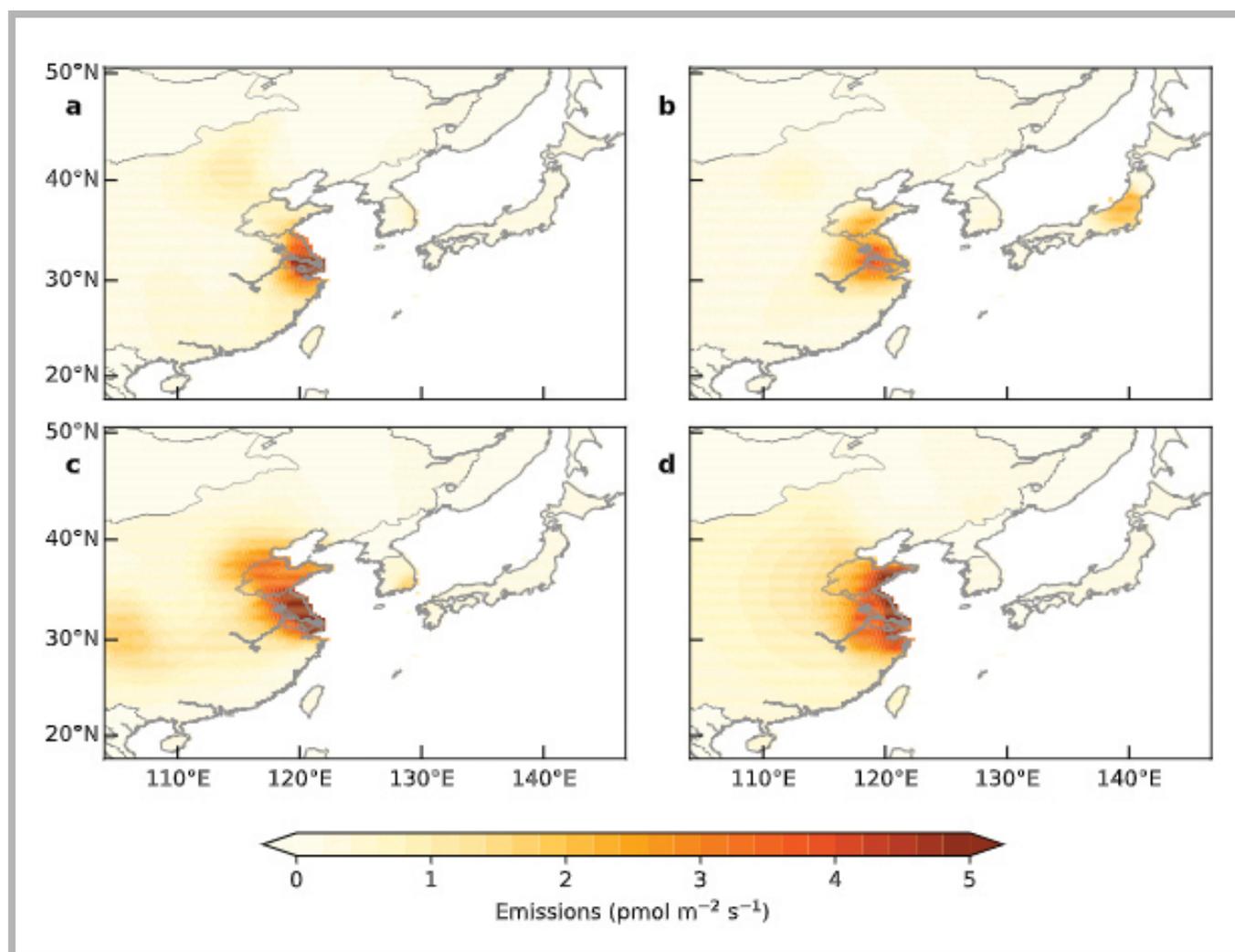


Figure 3: Mean spatial distribution of posterior CTC emissions during (a) 2009–2010, (b) 2011–2012, (c) 2013–2014, and (d) 2015–2016. Darker colors represent regions of highest emissions, which are concentrated in eastern China. The borders of Jiangsu and Shandong provinces in China are outlined in gray. Source: Lunt *et al.* (2018), Figure 3, referenced from <https://doi.org/10.1029/2018GL079500>



A government official in the Philippines tests counterfeit cylinders labelled as HFC-134a but containing CFC-12.

investigations and bring criminal cases against the illicit producers and their networks. Lessons from these exercises can inform implementation of the HCFC phase-out as well as the soon to be implemented global phase-down of HFCs.

Beyond the immediate goal of shutting down the illegal production and use, it is critical to ensure a sustainable fit-for-purpose enforcement regime that can prevent against future compliance failures. While much of the institutions and capacity were put in place in previous decades, there is an opportunity for designing modern national traceability systems that could provide end-to-end visibility of production, transport and use of controlled substances by securely and seamlessly exchanging information in real time. For example, blockchain technology can help ensure provenance, providing traceability across the supply chain without giving away proprietary information, thwarting counterfeiters and allowing traceability for monitoring and enforcement. There are examples of environmental governance systems and industry already using/designing mechanisms such as electronic permitting and GPS-enabled devices in real time to track transport of chemicals.⁴³

TRADE IN POLYOLS

Although large foam manufacturing enterprises tend to blend all chemical ingredients by themselves in-house, purchasing blowing agent separately as a stand-alone chemical, smaller foam producers normally purchase pre-formulated polyols from systems houses or chemical suppliers. In many countries, these are imported. The scale of international trade in pre-blended polyols is difficult to assess accurately. The agents can be imported under two HS codes, HS3907.20 (other polyethers) or HS3909.50 (polyurethanes) however both codes cover all kinds of polyols.⁴⁴

According to UN comtrade, between 2012-2016, 413,000 tonnes of 'other polyethers' and 128,000 tonnes of 'polyurethanes' were exported from China, primarily to countries in Asia and the Middle East but also to the US and Turkey.⁴⁵

Given the volume of export in polyols from China, together with EIA's information from Chinese producers, it is clear that there is a possibility that CFC-containing pre-blended polyols have been imported by other

Montreal Protocol Parties, with or without the knowledge of the importer.

The international trade in polyols creates a potentially massive loophole in the implementation, compliance and enforcement regime of the Montreal Protocol. Pre-blended polyols are not considered controlled substances however Parties take an inconsistent approach to them in reporting import and export of ODS, with some Parties reporting imported ODS-containing polyols as consumption and others not. According to the MLF, countries exporting formulated polyol systems count the ODS blowing agent as consumption and do not report it as export, thereby resulting in some double counting.⁴⁶

The system is wide open to abuse and allows countries to continue producing foams with controlled substances even after they have committed to phase-out the use of that substance in the foam sector.

Given the difficulties in tracking the trade in polyols via international HS codes, it is clear that Parties need to include pre-blended polyols in licensing systems and transparently report on import and export of controlled substances in pre-blended formulations.

DISPOSABLE CYLINDERS

Recent examples of illegal trade in HFCs in Europe as well as continued ODS illegal trade worldwide strengthens the call for a global ban on the use of disposable cylinders. The vast majority of known ODS smuggling cases are facilitated by the use of disposable cylinders (sometimes referred to a “non-refillable containers”), as their disposable nature means they can be freely traded.⁴⁷

Disposable cylinders are specifically-manufactured ‘one-way’ containers charged with refrigerant, sold, used for servicing or commissioning equipment and then discarded. Aside from the additional waste management issues this brings, the cylinders result in a residual quantity of refrigerant, or ‘heel’, being emitted to the atmosphere as

they must be cut or punctured before entering the waste stream. If the cylinders do not enter the formal waste stream the heel remains until the container degrades and is ultimately released. According to the 2010 RTOC assessment the vapor heel represents about 3% of refrigerant charge, and the liquid heel represents between 5 and 8%.⁴⁸

EIA is not aware of any global estimates of disposable refrigerant cylinders in use. The EU banned disposable refrigerant cylinders in the EU and on EU flagged vessels in 2007. Similar bans are also in place in Canada, India and Australia. However, disposable refrigerant cylinders are still in wide use elsewhere in the world and the European market has recently been flooded with illegal HFCs in disposable cylinders.⁴⁹

A report by a major refrigerant distributor, A-Gas, estimated that 225,000 disposable cylinders are sold in South Africa every year, of which 70% are thought to be filled with R22. Assuming a residue of 400g (2.94%) per cylinder, this equates to an estimated 63 tonnes of emissions into the environment each year (114,000 tCO₂e/yr). In some instances, the heel could be as high as 5% of the contents, which is 680g per cylinder, which equates to 107mt of ODS emitted into the atmosphere each year.⁵⁰

Moreover, it has been reported that despite clear guidelines on packaging and disposable cylinders, end users are circumventing the one-way valve and refilling them, which is not only illegal, but extremely dangerous. In many instances, this involves bypassing an integral safety device built into the disposable cylinder itself to prevent overpressure. This can result in explosions if the safe operating conditions are exceeded.⁵¹

The vast majority of known ODS smuggling cases are facilitated by the use of disposable cylinders.



Disposable cylinders containing CFC-12, seized in India in 2004.

CONCLUSIONS AND RECOMMENDATIONS

Just six months after scientists revealed unexpected and high emissions of CFC-11, much has been done to address this enormous environmental crime. China has responded with an unprecedented nationwide enforcement action and has shut down at least one illegal CFC-11 production factory. The Parties to the Montreal Protocol unanimously responded at OEWG-40 to the crisis and will agree vital next steps at the 30th Meeting of the Parties in Quito, Ecuador.

This is an opportunity for the Montreal Protocol to take action not just to solve the CFC-11 problem, but to ensure a compliance and enforcement regime robust enough to effectively implement all its decisions. This is a critical time: the Kigali Amendment comes into force in 2019, and major cuts in HCFCs are now occurring in developing countries, setting the scene for increased illegal trade as prices rise and supply runs out.

At the same time there has never been a greater need to make all possible reductions to greenhouse gas emissions. The recent International Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5C was unequivocally a "final call" on global warming, urging 'rapid, far-reaching and unprecedented changes in all aspects of society' in order to stay below 1.5°C.⁵² The illegal trade in ODS threatens to exacerbate the already dire situation we are in, threatening recovery of the ozone layer and tipping the planet closer to catastrophic global warming.

Information obtained by EIA earlier in 2018 demonstrated the widespread use of CFC-11 in China's rigid polyurethane (PU) foam insulation sector. The independent lab test results demonstrate the veracity of company officials stating they predominantly used CFC-11 in their foam production. China is to be commended for taking immediate action to investigate and enforce its laws, however it is clear that more follow through is required.

In particular, China should: ensure that penalties and enforcement efforts are widely publicized in order to signal the market and increase understanding of ODS regulations; carry out targeted testing of foam products and pre-blended polyols, including at foam production facilities and construction sites; and investigate through regular customs checks and testing procedures the export of CFC-containing foam agents.

It is also important to examine and further understand the drivers of the illegal CFC-11 trade; if they are not addressed the enforcement challenge will be insurmountable. In EIA's view, the explosive growth in demand for PU insulation foams, combined with the low cost and high effectiveness of CFC-11 as a blowing agent and the absence (at least until recently) of effective enforcement are the key drivers. This should be a lesson to all Parties to the Montreal Protocol, and taken into

consideration within the context of future projects implemented under the Multilateral Fund.

The creation of a new CFC-11 bank and the uncertainties over emissions from the historical CFC bank underline the need to better understand and deal with ODS and HFC banks. This issue has not received attention from the Montreal Protocol for almost a decade; a new analysis of ODS and HFC banks is well overdue.

There is also a need for better monitoring of feedstock production and uses. Close to 500,000 tonnes were reported as production in 2016, with CFCs, CTC and methyl chloroform accounting for 97% of that production. This includes over 156,000 tonnes of CFCs for feedstock uses.⁵³ The continued production of feedstocks of otherwise banned substances helps perpetuate risks of byproduct emissions and diversions to illegal emissive markets.

Finally, EIA's report highlights a number of critical data and understanding gaps that must be addressed in order to comprehensively tackle CFC-11 emissions.



Lab testing of a foam sample from Dacheng Desheng Chemical Co. Ltd tested positive for CFC-11.



© ISD/Mike Muzurakis (enb.isd.org/ozone/oeiw40/19jul.html)

The CFC-11 contact group in session at the Vienna meeting of the Montreal Protocol in July 2018.

EIA recommends the Montreal Protocol to:

- Ensure that all data gaps to be addressed are included in the Terms of Reference for the TEAP and SAP as they further investigate unexpected emissions of CFC-11;
- Conduct a comprehensive review of the monitoring and enforcement regime of the Montreal Protocol (including all past decisions on illegal trade in ODS), in order to ensure compliance with ODS controls and prepare for new controls on HFCs.
- Support customs to address the logistical and bureaucratic challenges faced in testing large containers (e.g. iso tanks) of ODS and HFCs;
- Require monitoring and reporting of pre-blended polyols containing controlled substances;
- Ensure that the current global system of atmospheric monitoring stations and satellites is maintained and enhanced to ensure it can continue to act as an early warning system for supporting compliance with Montreal Protocol controls;
- Initiate a task force to examine current and future ODS and HFC banks, and mitigation scenarios;
- Initiate a task force to examine current and future feedstock uses and alternatives to the use of controlled substances as feedstocks;
- Review all past Montreal Protocol decisions on illegal trade in ODS

EIA recommends that the Parties to the Montreal Protocol:

- Undertake national measures to ensure that CFC-containing polyols are not being imported, including legislative measures, customs inspections and testing of polyols and foams and testing of large tanks such as ISO tanks;
- Implement a fit for purpose licensing system which includes ODS- and HFC-containing polyols, as well as HFOs and other ODS/HFC substitutes that may be used to disguise illegal trade;
- Implement a ban on disposable cylinders, as recommended in Decision XIX/12: Preventing Illegal Trade in ozone depleting substances;⁵⁴
- Implement new HFC World Customs Organization (WCO) customs codes as described in UNEP/OzL.Pro.30/INF/7;⁵⁵
- Explore new technologies and methods available for undertaking design and implementation of modern national traceability systems that could provide end-to-end visibility of production, transport and use of controlled substances;
- Report on cases of illegal ODS trade and include information on export destinations and source countries of imports in reporting as per Decision XIV/7 and Decision XXIV/12.⁵⁶

REFERENCES

1. Montzka, S.A., Dutton, G.S., Yu, P., Ray, E., Portmann, R.W., Daniel, J.S., Kuijpers, L., Hall, B.D., Mondeel, D., Siso, C., Nance, J.D., Rigby, M., Manning, A.J., Hu, L., Moor, F., Miller, B.R., Elkins, J.W. (2018). An unexpected and persistent increase in global emissions of ozone-depleting CFC-11. *Nature* Vol 557 (413-417)
2. See Shao Changying (2017). Status of HCFC-141b phase-out policy and supervision and management in Shandong Province. *Polyurethane Industry*, Issue B05. Available at: <http://www.cqvip.com/qk/92231x/2017b05/673076995.html>
3. EIA (2018). Blowing it: Illegal Production and Use of Banned CFC-11 in China's Foam Blowing Industry. Available at <https://eia-international.org/report/blowing-it/>
4. Hou Liqiang (August 2018), 'Crackdown launched on ODS', *China Daily*. Available at: <http://www.chinadaily.com.cn/a/201808/04/W55b64f144a3100d951b8c8930.html>
5. See Letter from Zeng Rong, (August 5 2018), 'China's efforts to protect the ozone layer', *The Guardian*. Available at: <https://www.theguardian.com/environment/2018/aug/05/chinas-efforts-to-protect-the-ozone-layer>
6. See He Yingchun (2018). 生态环境部查获一起非法生产消耗臭氧层物质案件 (Ministry of Ecology and Environment seized a case of illegal production of ODS). *People's Network*. Available at: <http://env.people.com.cn/n1/2018/10/15/c1010-30342683.html>
7. Ibid, ref 5, Zeng Rong.
8. See China Plastics Processing Industry Association (2018). Initiative to consciously resist illegal blowing agents. CPPIA. Available at: <http://www.cppi.com.cn/cppi/20187591208.htm>
9. Ibid, ref 3, EIA.
10. Ibid, Ref 1, Montzka et al.
11. Ibid, Ref 1, Montzka et al.
12. Press Release (2017). Rigid Foams Market Worth 99.78 billion USD by 2022. *Markets and Markets*. Available at: <https://www.marketsandmarkets.com/PressReleases/rigid-foam.asp>
13. See China Polyurethane Enterprise Alliance (2015). 2017 China's polyurethane industry market demand forecast and competition analysis. Available at: <http://www.flexane.com/index.php?s=/Home/Article/detail/id/539.html>
14. Pers. Comm. Industry experts, also see Krieger, Terrinoni et al (June 2015) Low GWP Spray Foam Expansion Agents: Why Performance also Matters. Dupont. Available at: https://www.chemours.com/Formacel/en_US/assets/downloads/20120924_CPI_paper.pdf
15. Pers. Comm. Industry experts. Also see U.S. Environmental Protection Agency (June 2001). *Vintage Model, Chapter 9, Cost and emission reduction analysis of HFC emissions from foams in the United States*. Available at: <http://citeseerx.ist.psu.edu/viewdoc/download?sessionid=91EB7624BE46A56FCE803F7966A867AF?doi=10.1.1.224.135&rep=rep1&type=pdf>
16. Technavio (December 14, 2016). High Demand from Emerging Markets to Boost Polyurethane Foam Market through 2020. *Business Wire*. Available at: <https://www.businesswire.com/news/home/20161214005038/en/High-Demand-Emerging-Economies-Boost-Global-Polyurethane>
17. Ibid, ref 13.
18. IAL Consultants (September 2017). *Polyurethane Chemicals and Products in Asia Pacific (APAC) 2017*. Available at: http://www.ialconsultants.com/uploads/CUBE_press_release/2017-09-06/Polyurethane_APAC_Press_Release_2017.pdf
19. Buckley, C. & Fountain, H. (June 4, 2018). In a High-Stakes Environmental Whodunit, Many Clues Point to China. *New York Times*. Available at: <https://www.nytimes.com/2018/06/24/world/asia/china-ozone-cfc.html>
20. Ibid, Ref 2.
21. Ibid, Ref 19.
22. RTOC (February 2015). 2014 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee. 2014 Assessment Report. UNEP. Available at: <http://conf.montreal-protocol.org/meeting/mop/mop-27/presession/Background%20Documents%20are%20available%20in%20English%20only/ROTC-Assessment-Report-2014.pdf>
23. Pers. Comms. Industry experts with global fluorochemical company.
24. TEAP (July 13, 2018). Background document on CFC-11. Available at: http://conf.montreal-protocol.org/meeting/mop/mop30/presession/Backgroundcfc11/TEAP_CFC-11-background-information_revised.pdf
25. Ibid, Ref 24, TEAP.
26. Liu Le from Shandong Institute of Commerce and Technology, Presentation on "Status of ODS alternatives in cold chain industry". Available at: <http://www.sd-hjly.com/upload/201711/03/201711030932297031.pdf>
27. FTOC (March 2015). 2014. Report of the Rigid and Flexible Foams Technical Options Committee, 2014 Assessment Report. UNEP. Available at: <http://ozone.unep.org/sites/default/files/FTOC-2014-Assessment-Report.pdf>
28. Ibid, Ref 24, TEAP.
29. Information reported by the Parties on illegal trade in ODS (decision XIV/7 (7)). Available at: <http://ozone.unep.org/information-reported-parties-montreal-protocol-illegal-trade-ozone-depleting-substances-paragraph-7> Accessed 29 October 2018.
30. Ibid, Ref 29.
31. Information on illegal trade in ozone-depleting substances reported by Turkmenistan pursuant to paragraph 7 of decision XIV/7. Available at: <http://ozone.unep.org/sites/default/files/Turkmenistan-DecXIV-7.pdf>
32. Customs Block Trade in Illegal Refrigerant. (13 May 2014). *Cooling Post*. Available at: <https://www.coolingpost.com/world-news/customs-block-trade-in-illegal-refrigerant/>
33. Information on illegal trade in ozone-depleting substances reported by Uzbekistan pursuant to paragraph 7 of decision XIV/7. Available at: <http://ozone.unep.org/sites/default/files/Uzbekistan-DecXIV-7-2015.pdf>
34. Information on illegal trade in ozone-depleting substances reported by Kenya and Micronesia pursuant to paragraph 7 of decision XIV/7. Available at: <http://ozone.unep.org/sites/default/files/Kenya-and%20Micronesia-DecXIV-7.pdf>
35. Information on illegal trade in ozone-depleting substances reported by Netherlands pursuant to paragraph 7 of decision XIV/7. Available at: <http://ozone.unep.org/sites/default/files/Netherlands-DecXIV-7.pdf>
36. Confidential Pers. Comm.
37. Ibid, Ref 24, TEAP.
38. Ibid, Ref 24, TEAP.
39. Liang, Q, Newman, P, and Reimann, S. (2016). Report on the Mystery of Carbon Tetrachloride. SPARC Report No. 7, WCRP-13/2016. Available at: www.sparc-climate.org/publications/sparc-reports/sparc-report-no-7/
40. Sherry, David et al (2018). Current sources of carbon tetrachloride (CCL4) in our atmosphere. *Environmental Research Letters*, Vol 13. Available at: <https://doi.org/10.1088/1748-9326/aa9c87>
41. Park, Sunyoung et al (2018). Toward resolving the budget discrepancy of ozone-depleting carbon tetrachloride (CCL4): an analysis of top-down emissions from China. *Atmospheric Chemistry and Physics*, No.18. Available at: <https://doi.org/10.5194/acp-18-11729-2018>
42. Lunt, M.F., Park, S., Li, S., Henne, S., Manning, A.J., Ganesan, A.L. et al. (2018). Continued emissions of the ozone-depleting substance carbon tetrachloride from eastern Asia. *Geophysical Research Letters*, 45. <https://doi.org/10.1029/2018GL079500>
43. For example see Jenks, Tyler (February 2018). Top blockchain use cases for supply chain management. *Very Possible*. Available at: <https://www.verypossible.com/blog/top-blockchain-use-cases-for-supply-chain-management>, *Blockchain and the future of collecting*. (May 2018). *BLMP*. Available at: <https://hackernoon.com/blockchain-and-the-future-of-collecting-7de67053d4b9>
44. UNEP Fact Sheet No. 34. *Collecting Data on Pre-blended polyol*. Available at: <http://www.unep.fr/ozonaction/information/mmcfiles/4766-e-34PreBlendedPolyol.pdf>
45. See <http://comtrade.un.org>
46. UNEP (2010). UNEP/OzL.Pro/ExCom/61/53. Consumption Arising from HCFC-141b contained in pre-blended foam chemicals (polyols). 2010. Available at: <http://www.multilateralfund.org/sites/61/Document%20Library/21/6153.pdf>
47. EIA, UNEP (2011) Risk Assessment of Illegal Trade in HCFCs. Available at: http://www.unep.fr/ozonaction/information/mmcfiles/7507-e-risk_assessment.pdf
48. RTOC (February 2011). 2010 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee. 2010 Assessment Report. UNEP. Available at: <http://ozone.unep.org/sites/default/files/.../ROTC/ROTC-Assessment-report-2010.doc>
49. Disposables may contain dangerous mix. (25 August 2018). *Cooling Post*. Available at: <https://www.coolingpost.com/world-news/disposables-may-contain-dangerous-mix/>
50. A-Gas (22 May 2017). Renewed call to ban disposable refrigerant cylinders in SA. Available at: <https://www.agas.com/insights-news/news-renewed-call-to-ban-disposable-refrigerant-cylinders-in-sa/>
51. Ibid, Ref 50, A-Gas.
52. IPCC Press release (Oct 8, 2018). Summary for Policymakers of IPCC Special Report on Global Warming of 1.5°C approved by governments. Available at: https://www.ipcc.ch/news_and_events/pr_181008_P48_spm.shtml
53. UNEP/OzL.Pro/ImpCom/61/2. Information provided by parties in accordance with Articles 7 and 9 of the Montreal Protocol on Substances that Deplete the Ozone Layer. UNEP. Available at: http://conf.montreal-protocol.org/meeting/mop/mop30/presession/English/MOP-30-9_IMPCOM-61-2E.pdf
54. Montreal Protocol Decision XIX/12: Preventing illegal trade in ozone-depleting substances. (2007). Available at: <http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/285?language=es>
55. See UNEP/OzL.Pro.30/INF/7, Designated Harmonized System codes for the most commonly traded fluorinated substitutes for hydrochlorofluorocarbons and chlorofluorocarbons. UNEP. Available at: <http://conf.montreal-protocol.org/meeting/mop/mop30/presession/Information-Documents/MOP-30-INF7e.pdf>
56. Decision XIV/7: Monitoring of trade in ozone-depleting substances and preventing illegal trade in ozone-depleting substances and Decision XXIV/12: Differences between data reported on imports and data reported on exports. Available at: <http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/549>,



EIA US
PO Box 53343
Washington DC 20009 USA
T: +1 202 483-6621
E: info@eia-global.org
eia-global.org

EIA UK
62/63 Upper Street
London N1 0NY UK
T: +44 (0) 20 7354 7960
E: ukinfo@eia-international.org
eia-international.org