Progress Report Pursuant to Decision 83/41 of the 83rd Meeting of the Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol

I. Background

According to Decision 83/41 of the 83rd Meeting of the Executive Committee (ExCom) of the Multilateral Fund, the Government of China will report to the ExCom, at the 86th meeting, on its latest progress in implementing the activities related to China's ODS monitoring and law enforcement.

II. Progress of monitoring and law enforcement activities

The Government of China attaches great importance to the unexpected emission increase of trichlorofluoromethane (CFC-11) in the atmosphere. On the one hand, control of CTC supply is strengthened to prevent diversion of CTC to illegal ODS production. On the other hand, China is constantly strengthening monitoring and law enforcement of ODS to prevent illegal sales and use of ODS. Since the beginning of 2020, although the COVID-19 pandemic has posed adverse impacts on monitoring and law enforcement in implementing the Montreal Protocol, the Government of China is still striving to overcome difficulties and take active actions to improve law and regulation system, conduct law enforcement actions, intensify CTC supervision and management, build capacity for implementing the Montreal Protocol, strengthen cooperation with the industry, and establish monitoring network, etc. The progress of relevant work from October 2019 to July 2020 is as follows (see Annex 1):

(I) Improve law and regulation system

In August 2019, the Ministry of Ecology and Environment (MEE) launched the revision of *the Regulation on the Administration of Ozone Depleting Substances* (hereinafter referred to as the Regulation), conducted an assessment of the implementation of the Regulation, and formulated *the Regulation on the Administration of Ozone Depleting Substances and Hydrofluorocarbons (Draft for Soliciting Opinions*) based on the assessment and new requirements for implementing the Montreal Protocol. The revision mainly includes: 1) Considering the future compliance requirements of the Kigali Amendment, hydrofluorocarbons (HFCs) are incorporated into the scope of control; 2) To further clarify definition and classification of uses, it is stipulated that co-production and by-production are classified as production activities, pre-blended polyols are included in the monitoring scope as mixtures, and pre-blended polyols manufacturing enterprises are strictly supervised as consumption enterprises with controlled use. At the same time, targeted monitoring measures are formulated for supervising controlled use and feedstock use; 3) Work related to monitoring and evaluation is included, a national monitoring network of controlled substances under the Montreal Protocol will be established, and the monitoring and evaluation work will be organized accordingly; 4) The legal responsibilities of both market entities

and supervisors are further elaborated, and the punishment measures on various violations are further reinforced, 5) Supporting policy measures will be improved and the R&D and application of testing and monitoring methods of controlled substances will be encouraged and supported.

As of the end of June 2020, public opinion solicitation has been completed. At present, it is being revised based on opinions and feedback. The Regulation (Revised Draft for Approval) will be submitted to the State Council for review within 2020, and will be issued upon the approval by the State Council in accordance with relevant procedures.

(II) Carry out law enforcement actions

1. Cracking down on illegal use of CFC-11

From June to August 2019, MEE dispatched law enforcement officers to form joint enforcement groups with local law enforcement personnel to 11 key provinces/municipalities including Shandong, Hebei, Henan, Jiangsu, Zhejiang, and Guangdong to conduct special inspections. In this action, 656 system houses and polyurethane foam enterprises were inspected. Testing through portable instant detectors found that samples from 37 enterprises, including 6 system houses and 31 foam manufacturers, contained CFC-11. After the laboratory retesting, it's confirmed that 16 enterprises have been engaged in illegal use of CFC-11. None of these 16 enterprises received funds from the Multilateral Fund or was registered with the China Plastic Processing Industry Association (CPPIA). The local ecology and environment bureaus (EEBs) have handled these cases in accordance with the law. Through laboratory testing, samples from the 21 enterprises were found to contain no or only trace of CFC-11. Hence, these 21 enterprises could not be confirmed using CFC-11.

Among these cases, one enterprise's legal representative was sentenced to 10 months of imprisonment for the crime of environmental pollution by the local court. The specific circumstance is: Through the sudden unannounced inspection in Huzhou Deqing Minghe Insulation Materials Co., Ltd. (hereinafter referred to as Minghe Company), Zhejiang working group found clues of the company's illegal practice which pointed out the criminal facts of Minghe Company's three-year illegal purchase and use of 849.5 tons of CFC-11 in the production of pre-blended polyols. The sentence of the case was pronounced by the People's Court in Deqing County in March 2020: Minghe Company was fined 700,000 RMB yuan for environmental pollution caused by its illegal production of pre-blended polyols using CFC-11, and illegal gains of more than 1.4 million RMB yuan was recovered; its legal representative Qi was sentenced to 10 months of imprisonment for the crime of environmental pollution and was fined 50,000 RMB yuan. Among the 4 suppliers (all dealers) of CFC-11 raw materials in this case, 2 were held criminally responsible for the crime of environmental pollution (one was sentenced to 8 months of imprisonment, the other was sentenced to 9 months of imprisonment), and the other 2 people are still under investigation. It is the first case that was sentenced to substantial punishment for the illegal use of ODS in the domestic polyurethane foam sector to date, which fully reflects China's

firm zero-tolerance attitude towards illegal activities related to ODS. MEE issued a public report with the theme of *China's First Case of Illegal Use of ODS Sentenced to Criminal Punishment*.

Among the other 15 enterprises which involved violations, including 4 system houses and 11 polyurethane foam enterprises, about 9.4 tons of CFC-11 raw materials, 4.35 tons of pre-blended polyols and 2.2 tons of polyurethane foam products were seized and soundly disposed of, a fine of 2,816,900 RMB yuan was imposed (including the confiscation of illegal gains). Facilities and equipment of one enterprise were dismantled, violation of one enterprise has been transferred to the public security bureau (the case is still under investigation), and another enterprise was shut down.

2. Additional law enforcement equipment for local EEBs

As of the end of December 2019, a total of 50 portable ODS instant detectors have been distributed to EEBs of 30 provinces (autonomous regions and municipalities) and law enforcement officers from some key cities and counties, so as to help them conduct on-site inspection.

3. Strengthen supervision and law enforcement

In December 2019, MEE formulated *the Guideline on Supervision of Ozone Depleting Substances (Trial)*, including specific requirements for methods and contents of law enforcement inspection and handling of illegal behaviors. The Guideline has been issued and distributed to local EEBs.

MEE has formulated and issued *the 2020 Work Plan for Law Enforcement Inspection on Ozone Depleting Substances* in July 2020 and launched a new round of special ODS law enforcement inspection nationwide at the end of July 2020 mainly targeting at HCFC-141b and HCFC-22 production enterprises and illegal production and use of CFC-11. Outcome of this special law enforcement inspection will be reported to MEE from local EEBs by the end of this year.

In 2021, through the national CTC online monitoring platform and industrial rewards for reporting platform, MEE will further intensify source control, crack down on illegal ODS production, and improve the identifying mechanism, investigation mechanism and disclosure mechanism of illegal ODS production cases in steps.

(III) Intensify source control

1. Establishment of CTC monitoring platform

MEE has imposed stricter control measures on the chloromethane producers generating CTC as by-product since 2019, requiring every enterprise to install a verifiable and quantitative CTC online production monitoring system. At present, all chloromethane producers have completed the installation

of the online monitoring systems. Meanwhile, MEE is working on establishing a national CTC monitoring platform, which is currently in the stage of system design and development. The online trial operation is expected to be completed by the end of 2020 to realize online monitoring of CTC by-production in all chloromethane enterprises.

With regard to perchloroethylene (PCE) production enterprises, according to the current available information, there is only one enterprise that uses the alkane chlorination process during the PCE production in China. On September 5th 2019, MEE conducted an on-site survey on this enterprise with local EEBs. In light of the survey, during the PCE production process of this enterprise, CTC is only generated as an intermediate conversion product and reactor diluent, which is not separated or purified as by-products in the system. Since CTC does not flow out of the system and the production facility has no outlet pipes for CTC, there is no need to take daily supervision measures targeting at CTC on this enterprise as applied to chloromethane enterprises.

2. On-site supervision

From June 2019 to January 2020, MEE dispatched supervisory working groups to 16 chloromethane enterprises with CTC by-production to carry out the on-site inspection on CTC crude output, purification, residue, storage, conversion and sales, and other key processes to ensure legal production and use. By January 2020, 14 rounds of on-site supervision with attendance reaching 577 had been conducted. Each round lasted for two weeks (including holidays), achieving continuous daily on-site supervision. Since February 2020, the on-site inspection of CTC by-production enterprises has been suspended due to the COVID-19 pandemic, however, MEE still requires chloromethane production enterprises to report CTC related data weekly, and local EEBs have taken measures to conduct on-site inspections as needed.

(IV) Building Capacity for implementing the Montreal Protocol

1. Construction of testing laboratories and development of testing standards

For construction of testing laboratories, by the end of 2019, MEE had completed the construction of 8 ODS testing laboratories for industrial products, and all of them have obtained the expansion of CMA (China Inspection Body and Laboratory Mandatory Approval) certificate to ensure testing reports with legal effect could be provided.

For the formulation of laboratory testing method standards for ODS in industrial products, in October 2019, MEE approved and issued two national environmental protection standards, *Determination of ozone-depleting substances including HCFC-22, CFC-11, and HCFC-141b in pre-blended polyols — Headspace/gas chromatography-mass spectrometry (HJ 1057-2019*) and *Determination of ozone-depleting substances including CFC-12, HCFC-22, CFC-11 and HCFC-141b in rigid polyurethane foam and pre-blended polyols—Portable headspace/gas chromatography-mass*

spectrometry (HJ 1058-2019), to standardize testing of controlled substances under the Montreal Protocol. At present, testing standards for ODS in liquid refrigerants and solvents are being developed and is progressing on schedule, and it is expected to be officially released by the end of 2020.

2. Hold Supervision and law enforcement training

In December 2019, MEE held a training workshop on ODS phase-out management, which trained about 120 officers and technical support personnel from the atmospheric environmental management division of local EEBs. In December 2019 and July 2020, MEE held two training workshops for law enforcement personnel, training a total of 400 environmental law enforcement officers at the provincial, city and county levels.

In order to further enhance the capacity of grassroots environmental protection personnel below the provincial level, some provinces and municipalities have also held ODS phase-out management training workshops within their provinces or municipalities. In October and November 2019, Henan, Jiangxi and Shanxi carried out training workshops respectively, a total of 1,130 personnel of atmospheric environmental management departments from provincial, city and county levels received training.

MEE and the General Administration of Customs will continue to jointly organize the training workshop on ODS import and export management for a total of 70 customs officers in this October.

3. Optimize ODS information management system

Since October 2019, MEE has launched the construction of the ODS data information management system, which will be comprehensively updated based on the existing HCFCs online information system to realize the online data reporting of enterprises. The online test of the system modules will be completed before the end of 2020.

(V) Enhance cooperation with industries

1. Enhance communication with industries

Industrial associations have been providing technical support for supervision and management, policy formulation, and law enforcement of the government over the long term. Some technical experts recommended by industrial associations directly participate in special law enforcement operation and on-site inspection, providing technical support for supervision and law enforcement from a professional perspective. During the revision of the Regulation, communications have been conducted actively with industrial associations, experts, scientific research institutions and others, and their suggestions have been fully incorporated during the revision process.

2. Market analysis of the PU foam sector

China Plastic Processing Industry Association (CPPIA) cooperated with industry experts to analyze the situation of the polyurethane foam market in 2018 and consumption of various blowing agents by using mass balance analysis. See Annex 2 for details.

3. Market analysis of refrigeration and air-conditioning sector

MEE has communicated with industrial associations and experts to discuss the feasibility and methodology of mass balance analysis in the refrigeration and air-conditioning market. The feasibility research on the mass balance analysis of the industrial and commercial refrigeration and air-conditioning (ICR) sector and room air-conditioning (RAC) sector has been completed.

Studies have shown that for the RAC sector, the use of HCFC-22 in the RAC manufacturing sector could be analyzed and calculated by collecting data on the annual output of various product types, charging quantity of various product types, and the proportion of using HCFC-22 as the refrigerant (See Annex 3 for details). However, scattered maintenance of room air-conditioners brings great difficulties on data collection, therefore it is impossible to conduct a mass balance analysis on the HCFC-22 consumption in the servicing sector.

The ICR sector has a wide range of equipment products and applications. The size of various products varies greatly and there are numerous models, which makes it difficult to obtain statistics on product data. A number of equipment in the ICR sector are non-standard or customized products. Considering factors include application occasions, customer needs, technologies and energy efficiency levels, even for similar products with the same cooling capacity, the refrigerant charge amount would vary greatly when different refrigerants are applied. In addition, various products' sales are affected by the domestic and international economic situation, policy changes, and weather, making it difficult to collect data on refrigerant consumption. Therefore, it is impossible to carry out mass balance analysis on refrigerant consumption in the ICR sector.

(VI) Establishment of monitoring and alerting capacity

In 2019, the Government of China officially launched the planning of the ODS atmospheric monitoring network to strengthen compliance monitoring and early warning capability and performance evaluation capability. According to the regional characteristics of the distribution of ODS production and consumption in China, through the scientific assessment of the existing atmospheric pollutant monitoring background stations, 6 stations which are suitable for monitoring ODS have been selected preliminarily. The monitoring capability will be progressively improved. National atmospheric ODS

monitoring network will be established in phases and steps, and a unified technical system of monitoring technology and comprehensive evaluation method, quality management, data sharing and information release will be built. At present, the National ODS Monitoring Expert Committee has been established and a joint expert team has been formed. At the same time, MEE is organizing relevant domestic research institutions to develop high-sensitivity ODS atmospheric monitoring equipment. MEE will start construction of ODS monitoring stations in 2021 and conduct ODS monitoring in 2022.

(VII) Non-governmental study

In accordance with the decision of the 83rd Meeting of the ExCom, MEE selected an independent non-governmental consulting agency (ESD China Limited) through public bidding to conduct a study to evaluate the ODS phase-out regulations, policies, law enforcement and market circumstances and risks in China. At present, the study report has been completed and will be submitted to the ExCom.

In general, since the unexpected increase in global emissions of CFC-11, the Government of China has promptly taken a series of actions to comprehensively strengthen the capacity of compliance management and supervision and law enforcement, to further provide guarantees to ensure sustainable compliance.

In terms of improving the laws and regulations, the Government of China has organized the revision of the Regulation to further clarify management measures and law enforcement basis for all aspects of ODS. For management scope, the life-cycle supervision of production, sales, use, import and export, recycle, reuse and destruction of ODS are to be achieved. For management system, the full process supervision on ODS monitoring and evaluation, directory management, technology research and development, quota approval, supervision and inspection, and violation punishment are to be realized. At the same time, the legal force and deterrence have been further enhanced by reinforcing the intensity of penalties for various cases of violations.

In terms of source control, all chloromethane production enterprises have installed a verifiable and quantitative CTC online production monitoring system, realizing real-time monitoring of the entire process of CTC from production to disposal. For the management of the production and consumption of ODS raw materials, through measures including the revision of the Regulation and establishment of the ODS data information management system, targeted supervision and reporting measures have been formulated for implementation. By adopting these measures, the Government of China has carried out more systematic and strict control over ODS from the source of supply to prevent the illegal outflow of ODS.

In terms of supervision and law enforcement, through a combination of national special law enforcement and daily supervision and inspection in all provinces and cities, the Chinese government has been severely cracking down on illegal ODS behavior and holding the offenders accountable,

continuously imposing high pressure and deterrence against illegal ODS behavior, which has fully demonstrated China's firm attitude of "zero tolerance" towards illegal ODS behavior. In response to the issue such as inadequate inspection capabilities of ODS law enforcement and testing methods, MEE has established 8 laboratories for testing ODS in industrial products and issued relevant testing standards, so as to provide timely and effective technical support for law enforcement inspections. By issuing *the Guideline on the Supervision of Ozone Depleting Substances (Trial)* and providing law enforcement detectors for local EEBs and organizing training for law enforcement officers from provincial, municipal and county levels, China has been continuously strengthening ODS supervision and law enforcement capabilities of local law enforcement officers, resulting in systematic and regular ODS supervision and law enforcement.

In terms of ODS atmospheric monitoring and evaluation, in response to the lack of scientific monitoring capabilities and the lack of effective compliance evaluation mechanisms, the Chinese government has initiated the planning and construction of an ODS atmospheric monitoring network. Through establishment of a unified technical system of monitoring technology and comprehensive evaluation methods, quality management, data sharing and information release, monitoring and evaluation work will be organized to timely collect, analyze and evaluate the background and trend of ODS in the atmosphere, strengthen compliance monitoring and early warning capabilities and performance evaluation capabilities, so as to provide technical support for compliance management.

On the basis of summarizing previous experience in compliance practice, the Chinese government has made further improvement in compliance supervision and management by adopting the above measures in terms of scientific monitoring, law and regulation system, supervision and law enforcement, capacity building etc., so as to comprehensively enhance the implementation of the Montreal Protocol. At the same time, public participation and industry collaboration have been further consolidated to form a sound system of ODS supervision and management. The system will continue to operate effectively in the future to provide a strong guarantee for ensuring effectiveness of compliance.

Appendix I: Progress of Decision 83/41 and all relevant work

No.	Activities	Decision 83/41	Progress
1	Improve Law and Regulation System	a)i) Increase and extension of penalties for enterprises' non-compliance with the controlled substance regulations C)d) Extension of penalties and prohibitions to consumers of controlled substances or products containing controlled substances, where appropriate;	● The implementation of the Regulation has been assessed and *the Regulation on the Administration of Ozone Depleting Substances and Hydrofluorocarbons (Draft for Soliciting Opinions*) has been formulated based on the assessment opinions and new requirements for implementing the Protocol. The revision reinforces the punishment measures on various cases of violations, and incorporate HFCs into scope of control; • As of the end of June 2020, MEE has completed the public opinion solicitation. At present, it is being revised based on the opinions and feedback; • The Regulation (Revised Draft for Approval) will be submitted to the State Council for review in 2020.
2	Carry out law enforcement actions	a)ii) Intensification of inspections of enterprises currently or formerly using controlled substances a)iii) Implementation of controlled-substance inspection plans for ecology and environment bureaus (EEBs); a)iv) Increased provision of support and enforcement tools to EEBs; c)ii) Increased direction on enforcement at the provincial	• During the 2019 special ODS law enforcement inspection organized by MEE, it is confirmed that 16 enterprises have been engaged in illegal use of CFC-11, the local EEBs have handled these cases in accordance with the law. In one case, the enterprise's legal representative was sentenced to 10 months of imprisonment for the crime of environmental pollution by

		level from the national government; c)vi) Random testing of products that might contain controlled substances; c)viii) Reporting on the details of enforcement activities, including the capacity of the reactor, amount of controlled substance on site, relevant records on feedstock purchases and sales, any penalties resulting from the enforcement action	the local court.; • As of December 2019, 50 portable ODS instant detectors have been distributed to local EEBs; • MEE launched a new round of special ODS law enforcement inspection nationwide at the end of July 2020. The inspection is mainly targeted at HCFC-141b and HCFC-22 production enterprises and illegal production and use of CFC-11; • *The Guideline on the Supervision of Ozone Depleting Substances (Trial)* was issued and distributed to local EEBs in December 2019; • In 2020, another joint special law enforcement action will be organized with participation by both central and local law enforcement officers. • In 2021, through the national CTC online monitoring platform and industrial rewards for reporting platform, MEE will further intensify source control, crack down on illegal ODS production, and improve the identifying mechanism, investigation mechanism and disclosure mechanism of illegal ODS production cases in steps .
3	Intensify Source Control	b)iii) Real-time flow monitoring of CTC at chloromethane production enterprises	• All 16 chloromethane enterprises with CTC by-production have completed the installation of the CTC online production monitoring systems. MEE compiled

			the CTC Monitoring Platform Construction Plan; the platform is currently in the stage of system design and development; • From June 2019 to January 2020, MEE has dispatched supervisory working groups to 16 CTC by-production enterprises to carry out the on-site inspection which achieved continuous daily on-site supervision. A total of 14 rounds of on-site supervision with attendance reaching 577 had been conducted.. During the COVID-19 outbreak, the enterprises were required to report CTC related data weekly, and local EEBs have taken measures to conduct on-site inspections as needed. • The online trial operation of the national CTC monitoring platform is expected to be completed by the end of 2020 to realize the online monitoring of CTC as by-product in all chloromethane enterprises.
4	Build capacity for implementing the Protocol	a)v) Development of an online registration and tracking system for controlled-substance users; a)vi) Increased training for customs officers; b)ii) Establishment of an additional six testing laboratories for controlled substances in products; c)iii) Development of performance indicators for enforcement activities, such as the number of customs	• MEE had completed the construction of 8 ODS testing laboratories for industrial products, and all of them have obtained the expansion of CMA certificate for these laboratories to ensure testing results with legal effect could be provided; • In October 2019, MEE has approved and issued two national environmental protection standards for the

		officers trained or inspections undertaken	determination of ODS in polyurethane foam and pre-blended polyols. • In December 2019, MEE held a training workshop on ODS phase-out management, which trained about 120 officers and technical support personnel from the atmospheric environmental division of local EEBs. In December 2019 and July 2020, MEE held two training workshops for law enforcement personnel, the two workshops trained a total of 400 environmental law enforcement officers at the provincial, city and county level; • Trainings have been conducted by key local EEBs: In October and November 2019, Henan, Jiangxi and Shanxi carried out training workshops respectively, a total of 1,130 personnel from provincial, city and county level atmospheric environmental management departments received training; • MEE and the General Administration of Customs will continue to jointly organize the training workshops on ODS import and export management for a total of 70 customs officers in this October. • Since October 2019, MEE has launched the construction of the ODS data information management system, which will be comprehensively updated based on

			the existing HCFCs online information system to realize the online data reporting of enterprises. The online test of the system module will be completed before the end of 2020.
5	Enhance Cooperation with Industries	a)vii) Conduct an annual mass balance analysis of foam blowing components to determine the market size of the foam sector; a)viii) Publicizing the outcome of investigations and increased communication with industry; c)v) Regular and frequent consultations with industry and enterprises to ascertain market conditions; c)vii) Conduct annual mass balance analysis of refrigeration and air-conditioning market to determine market size and verify reported HCFC consumption;	• Industrial associations have been providing technical support for supervision and management, policy formulation and law enforcement, and some technical experts directly participate in special law enforcement operation and on-site inspection supervision etc. During the revision of the Regulation, communications are conducted actively with industrial associations, experts, scientific research institutions and others, and their suggestions are fully incorporated during the revision process; • China Plastic Processing Industry Association (CPPIA) cooperated with industry experts to analyze the situation of the polyurethane foam market in 2018 and consumption of various blowing agents by using mass balance analysis; • MEE has communicated with industrial associations and experts to discuss the feasibility and methodology of mass balance analysis in the refrigeration and air-conditioning market. The feasibility research on the mass balance analysis of the ICR sector and RAC sector

			has been completed. The analysis found that mass balance analysis was applicable to the use of HCFC-22 in the room air-conditioning manufacturing sector, but not to the industrial and commercial refrigeration sector.
6	Establishment of measuring and alerting capability	b)i) Establishment of a national controlled atmospheric monitoring network for controlled substances; c)i) Fast-track atmospheric monitoring through movement or modification of existing equipment and/or flask sampling	• The National ODS Monitoring Expert Committee has been established and a joint expert team has been formed. • MEE is organizing relevant domestic research institutions to develop high-sensitivity ODS atmospheric monitoring equipment. • MEE will start the construction of ODS monitoring stations in 2021 and conduct ODS monitoring in 2022 as planned.
7	Non-governmental study	d) To note that the Government of China will consider engaging a non-governmental consultant to undertake a study (including quantitative data, where available, and qualitative market information) to determine the regulatory, enforcement, policy or market circumstances that might have led to the illegal production and use of CFC-11 and CFC-12	• Through public bidding, MEE selected an independent non-governmental consulting agency (ESD China Limited) to conduct a study to evaluate the ODS phase-out regulations, policies, law enforcement and market circumstances and risks in China. At present, the study report has been completed and will be submitted to the 86th meeting of the ExCom.

Appendix 2: Mass balance analysis of the PU foam sector in 2018

1. Background

Polyurethane (PU) foam can be divided into flexible foam (sponge), rigid foam and integral skin foam. Flexible PU foam is highly resilient and is widely used in sectors such as furniture manufacturing. The integral skin PU foam has high-resilience inner core and good strength skin, and is mainly used in sectors including automobiles and furniture in the manufacturing of auto seat, steering wheels, armrests, etc. Rigid PU foam mainly serves as thermal insulation materials, and as the material with the best thermal insulation performance known so far, it has been widely used in various sectors of the national economy. The main subsectors using PU rigid foam currently include household appliances (insulation), solar water heaters (water tanks), building materials (insulation materials), cold storage, refrigerated transportation (reefer containers, refrigerated vehicles, and square cabin, etc.), petrochemicals (pipelines), automobiles (integral skin foam for steering wheels, seat, ceilings, etc.), aerospace, furniture manufacturing, etc., and a small amount is used for non-insulation purposes such as shoemaking, floating body, etc.

The blowing agents of PU foam products are grouped into two categories, namely chemical blowing agents and physical blowing agents. Up to now, the main chemical blowing agent is water. PU physical blowing agents include the phased-out CFC-11, HCFC-141b in the phase-out process, as well as cyclopentane, hydrofluorocarbons (HFCs), hydrofluoroolefins (HFO) and methyl formate etc.. Due to the differences in molecular weights, different physical blowing agents require different amount of blowing agents to achieve the same foaming effect. Ratio of various blowing agents in PU foam pre-blended polyols is shown in Table 1.

Table 1 Ratio of various blowing agents in pre-blended polyols

Blowing agent	Ratio in pre-blended polyols	HCFC-141b equivalent coefficient
CFC-11	24-28%，maximum distribution 25%	0.80
HCFC-141b	18-25%, maximum distribution 20%	1
Water	2.5-5%, maximum distribution 2.5%	8
Hydrocarbon (cyclopentane etc.)	10-12.5%, maximum distribution 12%	1.67
HFC-245fa/365mfc	10-12.5% (compared with CFC/HCFC system, more water is needed), maximum distribution 12%	1.67

HFO	Around 20% (more water is needed)	1

Note: HCFC-141b equivalent coefficient is the ratio of the blowing effect by an amount of other blowing agents to that of HCFC-141b of the same amount with HCFC-141b as the baseline blowing agent. For example, the equivalent coefficient HCFC-141b of the hydrocarbon blowing agent is 20%/12%=1.67, indicating that, for the same amount of hydrocarbon and HCFC-141b blowing agent, hydrocarbon can produce 167% foam produced by HCFC-141b. The coefficient is used to simplify the calculation of the amount of various raw materials when a foam product uses multiple blowing agents. The HCFC-141b equivalent coefficient is not completely related to the molecular weight of the blowing agent because considering different costs of different blowing agents, water is usually added to the higher-cost blowing agents when needed.

2. Calculation and data sources of blowing agent consumption in the PU foam sector

There are two main raw materials for PU foam: isocyanates (polymeric MDIs) and pre-blended polyols, into which the blowing agents are usually pre-blended. For foam products mainly using physical blowing agents (blowing agents other than water), the ratio of MDI to pre-blended polyols ranges from 1.05 to 1.1. When water is added to replace part or all of the physical blowing agents, MDI consumption will increase gradually and could bring the ratio up to 2. In addition, for foam products with high flame-retardant requirements or heat-resistant requirements (such as polyisocyanurate panels and pipes), the ratio can also reach 2.

In Chinese PU foam sector, the number of MDI suppliers is extremely limited, and they are all super large enterprises. Many organizations in the polyurethane sector have conducted continuous statistical analysis on the consumption data of the entire sector and its sub-sectors, and the data is highly credible. In contrast, pre-blended polyol suppliers are numerous and vary considerably. Statistics of the sector, especially its sub-sectors, is inaccurate. Therefore, MDI is used as the base data for analyzing blowing agent consumption in the PU foam sector: the amount of pre-blended polyols in different sub-sectors can be achieved by calculating the ratio of MDI to pre-blended polyols in various sub-sectors through the proportion of HCFC-141b conversion in each sub-sector and the distribution of the various blowing agent consumption in each sub-sector; consumption of various blowing agents can be calculated in different sub-sectors by using the estimated ratio of various blowing agents in each sub-sector, and the ratio of blowing agent in pre-blended polyols. In this way, the consumption of various blowing agents in each sub-sector could be reached, and the total amount of various blowing agents can be compared with the annual amount of various blowing agents obtained by our investigation.

2.1 MDI consumption

MDI consumption in the PU foam sector and its sub-sectors is provided by the consulting firm in collaboration with the China Plastics Processing Industry Association (CPPIA). During estimation of blowing agents consumption in the sub-sectors, MDI consumption in polyurethane products (such as adhesives, sealants, elastomers, etc.) that use no or few blowing agents is excluded.

Table 2 MDI consumption in the PU foam sector and its sub-sectors in 2018

Consumption sub-sectors	Consumption of isocyanates (polymeric MDIs), 10,000T
Refrigerators and freezers	48.67
Small household appliances such as electric water heaters	4.33
Solar water heaters	1.08
reefer container	3.47
Automotive foam	15.20
Pipeline	8.62
Spraying foam	5.20
Panels	6.24
Filling (security doors)	2.00
Total	94.81

2.2 Investigation of various blowing agents consumption in the PU foam sector

1. HCFC-141b consumption in the PU foam sector comes from annual data reporting by the government. In 2018, HCFC-141b consumption in the PU foam sector was 34,176.74 metric tons.

2. Consumption of HFCs/HFOs blowing agents and hydrocarbon blowing agents were obtained through investigation of suppliers by CPPIA. The categories of HFCs blowing agents used in Chinese PU foam sector include HFC-245fa/365mfc (HFC-365mfc may also be mixed with HFC-227ea), with a total consumption of about 8,300 metric tons in 2018. HFO-1233zd(E) is mainly used in refrigerator foam, with a consumption of about 1,800 metric tons in 2018. The main hydrocarbon blowing agents is cyclopentane, and two other categories, namely n-pentanes and isopentanes are also used. The total consumption in 2018 was about 43,000 metric tons.

3. No objective data source was found for consumption of water foaming agents, but we know water foaming applications in the Chinese PU foam market well. Water foaming is mainly used in automotive foam (seat, car parts of integral skin foam and ceilings, etc.), pipe insulation and filling foam sectors with low thermal insulation requirements.

4. In China, the PU foam sector also consumes other blowing agents such as methyl formate and liquid carbon dioxide, and their consumption in 2018 did not exceed 3,000 metric tons.

3. Calculation of various blowing agents consumption in the PU foam sector

3.1 Analysis of rationality of blowing agent consumption in terms of foaming efficiency of various blowing agent and the total sector scale

Table 3 Proportion of blowing agents in foam products in the PU foam sector

Blowing agent	Amount, MT	HCFC-141b equivalent coefficient	Equivalent amount of HCFC-141b, MT
HCFC-141b	34,177	1	34,177
hydrocarbon	43,000	1.67	71,810
HFCs	8,300	1.67	13,861
HFOs	1,800	1	1,800
Water	5,600	8	44,800
Total	92,877		166,448

PU foam production, 10,000 MT	174.58
The proportion of blowing agent in foam products based on HCFC-141b blowing agent	9.5%

According to the above calculations, the total consumption of blowing agents based on HCFC-141b accounts for about 9.5% of the total foam production. This is generally consistent with the practice of the PU foam raw materials, including HCFC-141b accounting for about 20% of pre-blended polyols and the ratio of MDI to pre-blended polyols being around 1.1. The above calculations are rational analysis, but it should be pointed out that there are other blowing agents such as methyl formate and liquid carbon dioxide in the Chinese PU foam market, and the total consumption should not exceed 3,000 tons.

3.2 Calculation of various blowing agents consumption in the PU foam sub-sectors (see

Table 4)

3.3 Analysis of differences

According to Table 3 and Table 4, the consumption of HCFC-141b and water is relatively consistent, but the total consumption of hydrocarbons and HFC/HFO calculated in Table 4 is about 4,700 metric tons more than that in Table 3. In our analysis, the main reason for the difference lies in our investigation focus on the cyclopentanes because there are a limited number of cyclopentane suppliers with whom we have established long-term information cooperation. However, n-pentane and isopentane, the two blowing agents with increased consumption in recent years and with broad applications, have received relatively little attention because we are not familiar with suppliers of n-pentane and isopentane. Another reason for the difference in blowing agent consumption is the fact that there are about 3,000 tons of other blowing agents in the PU foam sector, such as methyl formate, and liquid carbon dioxide.

4. Conclusion

The above analysis demonstrates that the consumption of MDI and various blowing agents obtained through various information channels is relatively consistent and reasonable.

The uncertainty of the analysis is mainly derived from the judgment on the ratio of water foaming. Due to lack of objective sources, making professional judgments based on our understanding of the sector is the only way. We believe that the sub-sectors of Chinese PU foam sector that use water foaming can support our judgment on water consumption in the PU foam sector.

Table 4 Proportion of blowing agents and consumption calculation in the PU foam sub-sectors in 2018 (Unit: 10,000 MT)

Consumption sectors	MDI	ratio of MDI to pre-blended polyols	pre-blended polyols	Foam production	Hydrocarbon+ HFC+HFO	Hydrocarbon+ HFC+HFO	Water foaming	Water consumption	The amount of HCFC-141b in pre-blended polyols	HCFC-141b consumption
Refrigerators and freezers	48.67	1.15	42.32	90.99	97%	4.93	0%	-	20%	0.25
Small household appliances such as electric water heaters	4.33	1.15	3.77	8.10	92%	0.42	0%	-	20%	0.06
Solar water heaters	1.08	1.08	1.00	2.08	10%	0.01	15%	0.006	20%	0.15
Reefer container	3.47	1.15	3.02	6.49	100%	0.36	0%	-	20%	-
Automotive foam	15.20	1.50	10.13	25.33	0%	-	95%	0.385	12%	0.06
Pipeline	8.62	1.25	6.90	15.52	3%	0.02	60%	0.166	20%	0.51
Spraying foam	5.20	1.05	4.95	10.15	0%	-	5%	0.010	25%	1.18
Panels	6.24	1.08	5.78	12.02	5%	0.03	0%	-	21%	1.15
Filling (security door)	2.00	1.05	1.90	3.90	0%	-	85%	0.065	20%	0.06
Total	94.81		79.77	174.58		5.78		0.641	1.78	3.42

Note: In China's PU foam industry, hydrocarbon blowing agents and HFC blowing agents are mainly used in refrigerators, freezers and reefer containers. They are usually mixed, and they have the same HCFC-141b equivalent coefficients, so they are calculated together. HFO's HCFC-141b equivalent coefficient is different from that of hydrocarbons, but it is also mainly used in refrigerators, freezers and reefer containers. Considering small amount of HFO, it is also calculated in

combination with hydrocarbons and HFC.

Appendix 3: Mass balance analysis in room air-conditioning sector

1. Background

Based on the overall manufacturing and sales scale of the room air-conditioning (RAC) sector and the sales of room air-conditioners using HCFC-22 as refrigerant, China Household Electrical Appliance Association (CHEAA) conducted a mass balance analysis of HCFC-22 consumption in the RAC manufacturing sector for 2017 and 2018 to assess HCFC-22 consumption in the RAC sector and analyze HCFC-22 phase-out status in the sector in China.

2. Data sources

1) The total production of the RAC sector comes from statistical data of CHEAA;

2) Product mix and scale data of room air-conditioners for domestic sales are from Beijing All View Cloud Data Technology Co., Ltd.

3) Product mix and scale data of room air-conditioners for export come from the General Administration of Customs;

4) Sales of room air-conditioners using different refrigerants are from statistical and calculated data of CHEAA;

5) The HCFC-22 consumption per unit of room air-conditioners for various product types comes from investigation of refrigerant consumption in the RAC sector organized by CHEAA in 2011.

3. Calculation methodology

（1）At present, room air-conditioners using HCFC-22 refrigerant are mainly fixed-frequency products, which can be further subdivided into five categories: window air-conditioner, split air-conditioner with cooling and heating, stationary air-conditioner with cooling and heating, cooling only split air-conditioner and cooling only stationary air-conditioner.

（2）Since import of HCFC-22 air-conditioner products in non-A5 countries has been gradually banned around 2010, air-conditioners using HCFC-22 refrigerant for export are only sold to A5 countries.

（3）According to the calculation by CHEAA, the proportion of HCFC-22 refrigerant used in fixed-frequency room air-conditioners for domestic sale and export to A5 countries is about 70% at present;

（4）According to linear regression calculation results, marked HCFC-22 refrigerant charging quantity of a typical window air-conditioner (cooling capacity: 3 kW), split air-conditioner with cooling and heating (cooling capacity: 3 kW), a stationary air-conditioner with cooling and heating (cooling capacity: 5.5 kW), cooling only split air-conditioner (cooling capacity 3 kW), and cooling only stationary air-conditioner (cooling capacity: 5.5 kW) are respectively 0.89 kg, 0.89 kg, 1.66 kg, 0.84 kg, and 1.40 kg;

（5）According to sale scale of various product types, proportion of air-conditioners using

HCFC-22 refrigerant and charging quantity per unit, HCFC-22 consumption of various product types can be calculated separately, and the total HCFC-22 consumption of the RAC sector could be reached.

（6）Considering refrigerant leakage in the process of storage, transportation, charging, and repair, actual refrigerant charging quantity in the manufacturing process is often slightly larger than the quantity marked on the nameplate due to the manufacturer's consideration of product quality. Therefore, actual HCFC-22 consumption should be 10%~15% higher than the above calculation results.

4. Calculation results

According to the above methodology, HCFC-22 consumption in the RAC sector from 2017 to 2018 is estimated in the following table. HCFC-22 consumption in the RAC sector is about 53,600 metric tons in 2017, and about 51,500 metric tons in 2018, which are generally consistent with the annual sector consumption data reported to the Multilateral Fund Secretariat in 2017 and 2018.

Year	2017	2018
Sales of fixed frequency stationary air-conditioner with cooling and heating / 10,000	1161	1082
Sales of fixed frequency split air-conditioner with cooling and heating / 10,000	3800	3667
Sales of cooling only stationary air-conditioner / 10,0000	26	23
Sales of cooling only split air-conditioner / 10,000	254	306
Sales of window air-conditioner/ 10,000	1356	1445
Consumption of fixed frequency stationary air-conditioner with cooling and heating/ T	15273	13962
Consumption of fixed frequency split air-conditioner with cooling and heating consumption/ T	26743	25335
Consumption of cooling only stationary air-conditioner/ T	284	249
Consumption of cooling only split air-conditioner T	1691	1994
Consumption of Window air-conditioner consumption/ T	9568	10007

HCFC-22 consumption/ T	53559	51547