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STUDY ON THE STRATEGY FOR THE LONG TERM MANAGEMENT OF HCFCs IN CHINA (PRESENTED BY GERMANY)

EXECUTIVE SUMMARY

1. Based on the “Terms of Reference for Development of a Suitable Strategy for the Long Term Management of HCFCs, in Particular HCFC-22, in China”, the College of Environmental Sciences, Peking University has elaborated the following primary results:

(a) China may have reached the status of largest HCFC producer and consumer in the world by 2004. By the end of 2004, there were 18 HCFC-22 producers in China, with a total capacity of 368,000 MT/yr and actual output of 247,687 MT in 2004. Domestic consumption was 177,150 MT, of which about one third was used as raw material;

(b) Excluding this feedstock consumption, about 90,000 MT of HCFC-22 was used as refrigerant and about 10,000 MT were used as foaming agent and aerosol;

(c) Future demand of HCFCs is likely to continue to increase unabated for domestic consumption to about 300,000 MT during the next 10 years, unless constrained by policy and technology improvements;

(d) The largest share of HCFC-22 consumption is for room air-conditioners. Total production for domestic use and export reached a total of 67.6 mio units in 2005. The room air-conditioner sector is expected to grow at a rate of 7% annually. Expanded polystyrene (XPS) foam production is expected to increase by 9 % annually. These growth rates are the highest of all HCFC-22 uses, and therefore total consumption of HCFC-22 will continuously increase;

(e) A range of viable alternatives is available for HCFC-22 uses. Several of these already exist commercially, especially those using R-410a and R-407. Expanding the use of alternatives is hampered mainly by economic barriers;

(f) Three examples of possible alternative development routes (scenarios B, C and D) are analysed and compared to the forecast based on business as usual (BAU, scenario A), reflecting different levels of consumption management policy. These include demonstration projects, public information campaigns, training activities, consumption limitations, production quotas and standards on energy efficiency and leakage rates. Compared to BAU with 18,920 ODP tonnes in 2015, the scenarios lead to 15,730 (scenario B), 13,640 (scenario C) and 11,990 ODP tonnes in 2015 for scenario D. Basically, scenario B would require to convert a quarter of air-conditioner production to non HCFC-22, whereas scenario C necessitates one third and scenario D implies that one half of all air conditioner production is converted to alternatives by 2015;

(g) Cost estimates for production line conversions, new types of compressors, alternative refrigerants and gains from air-conditioner energy efficiency are provided. The estimates are based only on one example, namely the conversion from HCFC-22 to R-410a. Other possible conversions, i.e. using hydrocarbon technology, were omitted in the current study as cost and efficiency gains could not be estimated with sufficient accuracy at present;

(h) Consideration of Scenario B is recommended as the most feasible for implementation because its requirements for available capital, degree of executing laws and impact on chemical industries are lower than for scenarios C and D. Total costs for scenario B between 2007 and 2015 are estimated at 14.4 bn Yuan. Two thirds of the additional cost estimates reflect the conversion of the production of compressors to non-HCFC-22 refrigerants;

(i) Potential energy savings achievable from widely increasing non-HCFC-22 air-conditioner sales in the domestic market may increase the policy makers' attention for HCFC-22 replacement.

Study on the Strategy for the Long Term Management of HCFCs in China

College of Environmental Sciences, Peking University

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- Excluding this feedstock consumption, about 90,000 MT of HCFC-22 was used as refrigerant and about 10,000 MT were used as foaming agent and aerosol.

- Future demand of HCFCs is likely to continue to increase unabated for domestic consumption to about 300,000 MT during the next 10 years, unless constrained by policy and technology improvements.

- The largest share of HCFC-22 consumption is for room air-conditioners. Total production for domestic use and export reached a total of 67.6 mio units in 2005. The room air-conditioner sector is expected to grow at a rate of 7% annually. Expanded polystyrene (XPS) foam production is expected to increase by 9 % annually. These growth rates are the highest of all HCFC-22 uses, and therefore total consumption of HCFC-22 will continuously increase.

- A range of viable alternatives is available for HCFC-22 uses. Several of these already exist commercially, especially those using R-410a and R-407. Expanding the use of alternatives is hampered mainly by economic barriers.

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- Cost estimates for production line conversions, new types of compressors, alternative refrigerants and gains from air-conditioner energy efficiency are provided. The estimates are based only on one example, namely the conversion from HCFC-22 to R-410a. Other possible conversions, i.e. using hydrocarbon technology, were omitted in the current study as cost and efficiency gains could not be estimated with sufficient accuracy at present.

- Consideration of Scenario B is recommended as the most feasible for implementation because its requirements for available capital, degree of executing laws and impact on chemical industries are lower than for scenarios C and D. Total costs for scenario B between 2007 and 2015 are estimated at 14.4 bn Yuan. Two thirds of the additional cost estimates reflect the conversion of the production of compressors to non-HCFC-22 refrigerants.

- Potential energy savings achievable from widely increasing non-HCFC-22 air-conditioner sales in the domestic market may increase the policy makers' attention for HCFC-22 replacement.

Chapter 1 Introduction

1.1 Background for Implementation

Chinese Government signed Vienna Convention for the Protection of the Ozone Layer (hereinafter Vienna Convention) in June 1989, Montreal Protocol on Substances that Deplete the Ozone Layer (hereinafter Montreal Protocol) in May 1991 and ratified the London Amendment. Since then, China has been committed to phase out the Ozone Depleting Substances (ODS) in accordance with its designation as an Article 5 country. The standing committee of national people's congress authorized to ratify the Copenhagen Amendment in April 2003, and Copenhagen Amendment becomes effective in China.

In order to implement the phase out of ODS, Chinese government compiled “Country Program for Phase out of Ozone Depleting Substances” (hereinafter Country Program) in Jan. 1993 and established phase out strategy for major sectors of ODS production and consumption in 1995. In November 1999, the State Council approved and updated the Country Program.

According to the Country Program, the Chinese government established a group to lead Ozone Layer Protection and a working office to organize the phase out actions. The State Environmental Protection Administration (SEPA) is in charge of the leading group, and its members include: ministry of foreign affairs, national development and reform commission (NDRC, the former planning commission, the former the former state economic & trade commission), ministry of science and technology, ministry of public security, ministry of finance, ministry of information industry, ministry of agriculture, ministry of commerce and general administration of customs, etc. The leading group takes charge of deliberation on guidelines and policies for management and control of ODS, and harmonize important issues of ODS management and implementation. The Leading Group has established a project management office (PMO) with administrative responsibility of implementation. According to the convention and the protocols, SEPA is assigned to communicate with the secretariat and other members to the convention/protocol.

After the effort of more than ten years, Chinese government established and implement some policies for the country and sectors, several key policies include: Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution, Inform of Prohibiting New Equipment for ODS Producing or Consuming (to control the new/additional production capacity), Inform of carry out license of production quota for CFCs/Halon (to control the production), Management for ODS Imports and Exports (to control the import and export), etc. Through the implementation of these policies and laws, China has effectively controlled the increase of production and consumption for major ODS, and implemented the freezing and reducing target in Montreal Protocol for CFCs/Halon production and consumption in 1999 and 2005, which ensures the ODS phase out to schedule. The State Council published “Temporary Stipulates for The Promotion of Industry Structure Adjustment” in 2005, and the NDRC published Guidance Catalog of Industrial Structure Adjustment (2005), relevant contents in the “elimination category” include:

- **Production line of CFCs as tobacco expanding agent (to be banned according to the country general plan for implementation of the conventions)**
- **Production methods of CFCs as foaming agent for polyurethane foam, and extrusion PE/PS foam (to be banned according to the country general plan for implementation of the conventions)**
- **Production line of CFCs as foaming agent or refrigerant in refrigerators, automobile air conditioning, deepfreeze and refrigeration in industrial and commercial sectors (to be banned according to the country general plan for implementation of the conventions)**
- **Production methods of CTC as cleanout agent (to be banned according to the country general plan for implementation of the conventions)**
- **Production methods of CFC-113 as cleanout agent (to be banned according to the country general plan for implementation of the conventions)**
- **Production methods of TCA as cleanout agent (to be banned according to the country general plan for implementation of the conventions)**
- **Production equipment of CFCs (to be banned according to the country general plan for implementation of the conventions)**
- **Production methods that mainly for CTC (to be banned according to the country general plan for implementation of the conventions)**
- **Production methods of all chemicals with CTC as additive (to be banned according to the country general plan for implementation of the conventions)**
- **Production methods of fluorinated polymer with CFC-113 as additive (to be banned according to the country general plan for implementation of the conventions)**
- **Production equipment of TCA as cleanout agent (to be banned according to the country general plan for implementation of the conventions)**
- **Production equipment of CH_3Br (to be banned according to the country general plan for implementation of the conventions)**

Besides, production of medical aerosol with CFCs is listed to the “restrict category” in

Guidance Catalog of Industrial Structure Adjustment (2005).

At present, the government is compiling the regulation for Ozone Protection to roundly carry out the requirement of the convention and protocol and to meet the demand of environment protection and human health.

1.2 Requirement of Montreal Protocol and International Trend

Control requirement for ODS in Montreal Protocol is a dynamically changing process. Requirements and chemicals controlled in each amendment to Montreal Protocol are given in Table 1-1.

According to the requirement of Montreal Protocol Copenhagen Amendment, HCFCs, HBFCs and CH_3Br are added to the control list in China.

Table 1-1 **Change of Chemicals controlled in each amendment**

Chemicals controlled in London Amendment			Time limit for elimination
Annex A	Category I	CFCs	2010 (production and consumption)
	Category II	Halon	2010 (production and consumption)
Annex B	Category I	Other fully halogenated CFCs	2010 (production and consumption)
	Category II	CTC	2010 (production and consumption)
	Category III	TCA	2015 (production and consumption)
Chemicals controlled in Copenhagen Amendment			
Annex C	Category I	HCFCs	2040 (consumption)
	Category II	HBFCs	2016 (freeze the production)
Annex E		CH3Br	2015 (production and consumption)
Chemicals controlled in Beijing Amendment			
Annex C	Category III	CH2BrCl	2002 (production and consumption)

According to the requirement of Montreal Protocol Copenhagen Amendment, China should freeze HCFCs consumption and production at the 2015 level by 2016 and phase out HCFCs by 2040. (Seen in Fig. 1-1 and Fig. 1-2).

It is noticeable that step of HCFCs phase out is accelerating, especially for HCFC-22 and HCFC-141b. Some developed countries have already taken different measures to control HCFC-22 and HCFC-141b, and their total production and consumption of HCFCs has decreased far more quickly than required in the Protocol.

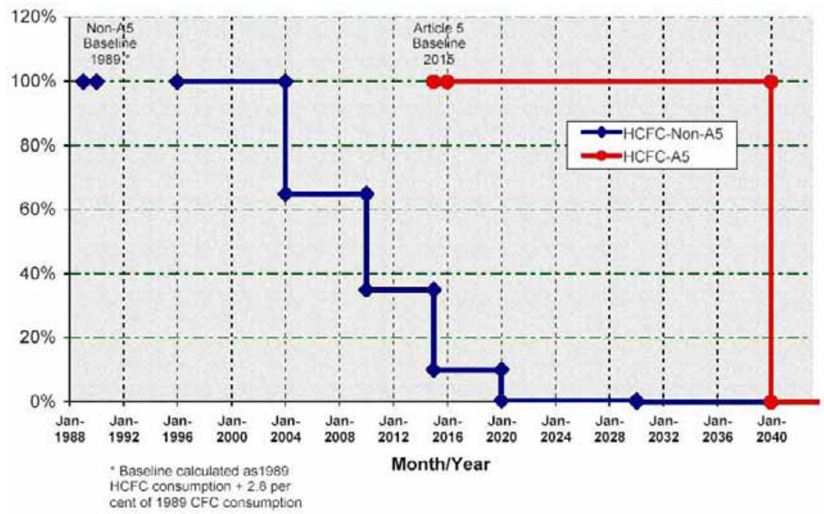

Fig. 1-1 HCFCs (Annex C/I) Consumption Reduction Schedule to Montreal Protocol

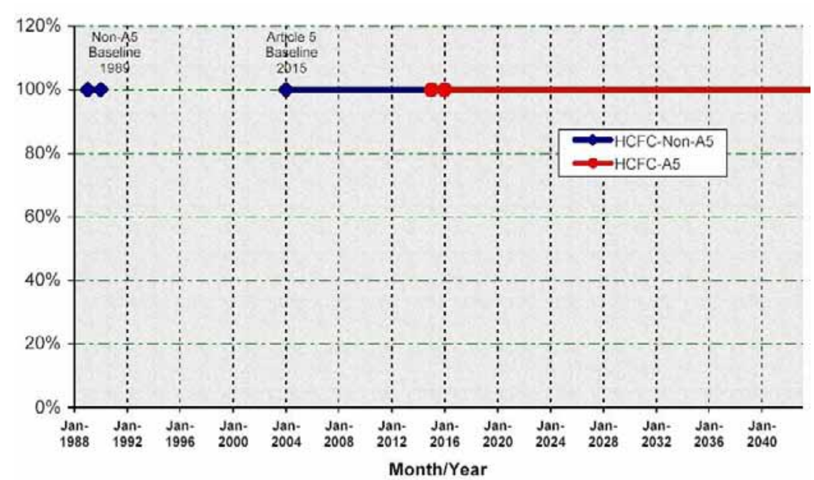

Fig. 1-2 HCFCs (Annex C/I) Production Reduction Schedule to Montreal Protocol

1.3 Basic Information of HCFCs

HCFCs mainly include HCFC-22, HCFC-123, HCFC-124, HCFC-141b, HCFC-142b and HCFC-225ca, etc. HCFCs in China are mainly used as refrigerant, foaming agent, solvent and feedstock for other chemical products; therein, HCFC-22 has been used for room air conditioning for a long time. During the CFC phase out process in China, HCFC-123 and HFC-134a as alternatives for CFC-11 and CFC-12 in central air condition;

HC600a, HFC-134a and a few HFC-152a/HCFC-22 as alternatives for CFC-12 as refrigerant in refrigerant in freezers; cyclopentane and HCFC-141b as alternatives for CFC-11 as foaming agent; HCFC-22 and HCFC-22/HFC-143a as alternatives for R502 in small size deep freezers; CO_2, hydrocarbon, HCFC-141b, HCFC-142b, and HCFC-142b/HCFC-22 as alternatives for CFC-11, CFC-12 and CFC-114 in foaming sector; HCFC-141b as alternative for CFC-113 and TCA in apparatus cleanout. Usages of HCFCs as transition alternatives at present play an important role in reducing the ozone depletion as soon as possible.

Table 1-2 HCFC consumption field in China

Name	HCFC-22	HCFC-123	HCFC-124	HCFC-141b	HCFC-142b
Consume field	Domestic air conditioning sector	Central air conditioningor lager size centrifuge chillers	Traffic refrigeration, domestic refrigeration and commercial refrigeration	Rigid polyurethane integral foam and self-skin foam	Refrigerant at high temperature
	Industrial and Commercial conditioning sector	Rigid polyurethane integral foam and self-skin foam	Fire-extinguishing agent	Cleanout agent	Material for PVDF and FKM
	Refrigerant in refrigerator and freezers	Fire-extinguishing agent			Foaming agent for extrusion PE/PS foam
	XPS plate	Cleanout agent for metallic and electronic component			
	Feedstock for PTFE				

In 2004, production of HCFCs in China is nearly to 300,000 MT, of which HCFC-22 covers more than 80%; HCFC-141b covers more than 10%; others cover about 10%. Therefore, key point of HCFCs control is about HCFC-22 control

HCFC-22 is added to the control list in the first category of Appendix C, with an ODP value of 0.055, and a relatively shorter tropospheric lifetime of 12 year; however HCFC-22 is also greenhouse gas with a GWP value of 1,780 (WMO 2002). However, at present, the total production of HCFCs has already been three times larger than the largest CFCs production, and also HCFC-22 producing closely correlates with carbon tetrachloride [CCl_4, hereinafter CTC (ODP＝1.1)] and trifluoromethane [CHF_3, hereinafter HFC-23 (GWP=11,700)]. Therefore management on HCFC-22 control becomes very important in China.

In order to reduce and prevent the ozone depletion by HCFCs effectively and control of GHG (Green House Gas) release during corresponding production and usage, and to reduce and avoid social and economic effect by HCFCs phase out in the future, Chinese government started the Study on the Strategy for the Long Term Management of HCFC-22 in China under the financial support by GTZ.

1.4 Specific Objective of the Study on Strategy for HCFCs Control

In accordance with requirement in the contract and by consultation and investigation, the objective of the study on strategy for HCFCs control is: to identify key issues that meet the requirement, control and substitution of HCFCs under Vienna Convention, other environmental convention and their protocols, and to develop a strategy frame to implement the Montreal Protocol.

The fundamental principles for study on the strategy for HCFCs control in China are as follows: the key objective is to promote sustainable development; the ultimate goal is to protect human health and the environment; the main route is to control HCFC production, consumption and emissions; one priority is focusing on reduction and prevention of leakage from production and consumption sectors with high ODP, short term release and mature substitutive technology; integrated with eleventh five-years plan and control of HFC emissions, to constitute the laws, regulations and policies that are needed for implementation of international environment conventions for strengthening supervising of execution, improving environmental management ability and establishing feasible financial mechanism; according to Chinese reality, establishing the mechanism, which the government is leading and where the enterprises are the main body and the sectors and public are involved; putting forward technically feasible and economically efficient strategies and action plans to ensure that the implementation of the Montreal Protocol does not damage the development of China.

The HCFC strategy follows and combine with principles and plans of “The national eleventh five-year plan outline of the People’s Republic of China”(the national eleventh five-year plan outline, hereafter), “the State Council’s decision on strengthening environmental protection” and “the National eleventh five-year plan for environmental protection of the People’s Republic of China”, such as some chapters, “promoting optimizing the industry structure”, “construction the resource saving and environmentally sound society” etc., as well as some articles, “establishing and perfecting the long-term mechanism of environmental protection”, etc.

1.5 Basic Content of the Strategy Study Report

The study on strategy for HCFCs control is composed of six chapters. Chapter 1 mainly introduces background of China signing the Montreal Protocol and main requirements of the Convention and Protocol, objectives and principles of the study, mechanism of the study on the strategy, and uncertainties and issues to explain in the study. Chapter 2 describes relevant fundamental information of HCFCs, including production and consumption of HCFCs in China. Chapter 3 describes relevant substitutes of HCFCs. Chapter 4 forecasts future production and consumption demand of HCFCs in China. Chapter 5 analyses different control scenarios. Chapter 6 specifies the strategy for implementation of the Montreal Protocol, including the whole objective, specified objectives and action plan.

1.6 Compiling Process

Preparation of the study on strategy for HCFCs control received strong support and active participation by relevant institution and organization at home and abroad. This study is financed and technically supported by GTZ (Germany). Under the leadership of compiling leading group of study on strategy on HCFCs control, SEPA organizes experts from College of Environmental Science, Peking University to combine with the compiling work. China association of organic fluorine and silicone material industry, China petroleum and chemical industry association, China household electrical appliances association, China refrigeration and air conditioning industry association and China plastic processing industry association assist in data investigation and strategy evaluation. During the compiling process of the study on strategy for HCFCs control, several workshops were held, and FECO/SEPA (Foreign Economic Cooperation Office of SEPA) organizes series of national and international workshops during June and October in 2005, May and December in 2006, involving officers of all levels, HCFCs production and consumption enterprises, relevant environmental NGOs, delegates and experts from international organizations and government. In the workshop, oral and written suggestions were given on the study (discussion draft) and discussed in detail. This study on strategy for HCFCs control is amended based on suggestions in the workshops.

1.7 Explanation of Relevant Issues

According to the basic law in Hong Kong and Macao special administrative region, Montreal Protocol Copenhagen Amendment becomes effective in the two regions. However ODS data in Hong Kong and Macao is not included in this report; therefore the study does not include study on strategy for implementation of Montreal Protocol in the two regions.

Chapter 2 Production and Consumption of HCFCs in China

HCFCs including HCFC-22, HCFC-141b, HCFC-142b, HCFC-123, HCFC-124 etc. are produced in China, which are mainly used as refrigerants, foaming agents, solvents and raw materials of other chemical products.

China is currently the top producer and consumer of HCFCs in the world. Until 2004, the HCFC-22 annual production capacity had reached to 373,500 MT/yr with the actual output 261,751 MT in 2004, in which 192,150 MT for domestic consumption, including 68,902 MT for Export, new production capacity increased 145,500 MT in 2004 compared with that in 2003. It could be expected that the production capacity of HCFC-22 will increase further aftertime. In addition, there were a total of six enterprises producing HCFC-141b, with the total annual production capacity of 58,000 MT/yr; actual production of 41,213 MT in 2004, in which 24,799 MT of domestic sales and 14,323 MT for exports; new production capacity increased 6,700 MT in 2004 compared with that in 2003. Three HCFC-142b production enterprises in China, with 2004 annual production capacity reached 11,000 MT, produced actually 4,750 MT, including 4,103 MT of domestic consumption, and 498 MT for exports.

The latest production data show that, there has been an increase of HCFCs output in 2005, in which HCFC-22 production exceeded 30 million MT in which domestic consumption as raw materials occupied approximately 1/3.

Table 2-1 HCFCs output and sale in China in 2004 (MT)

Category	HCFC-22	HCFC-141b	HCFC-142b	HCFC-123	HCFC-124	Total
capability	373,500	58,000	11,000	3,000	1,500	447,000
Output	261,751	41,213	4,750	2,040	418	310,172

2.1 HCFC-22 Production and Consumption

There are 21 enterprises that are producing or once produced HCFC-22 in China, and several of them have disposed of their equipments. By 2004, there were 12 producers running 23 production lines and a total capacity of 373,500 MT/yr; in which one with the highest capacity of 100,000 MT/yr, four with 30,000~40,000 MT/yr, six with 10,000~30,000 MT/yr, and one with 9,500 MT/yr. Besides the 12 producers that are running well, there are 9 that have stopped producing, whose capacity is not counted in. The new trend is that production capacity of HCFC-22 is increasing rapidly and centralizing to large corporations.

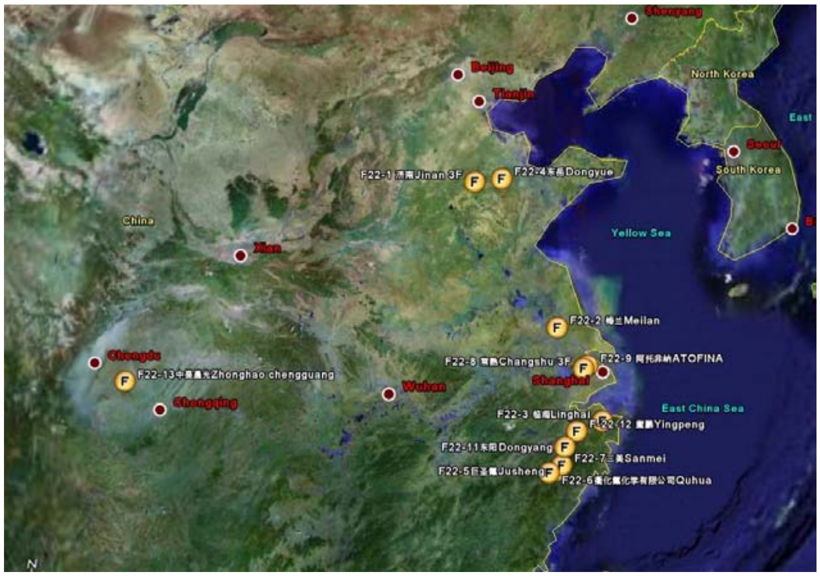

Fig. 2-1 Distribution of HCFC-22 producers in China

Chinese HCFC-22 producers are mainly centralized in Jiangsu, Zhejiang and Shandong, etc.

2.1.1 Production of HCFC-22

Table 2-2 HCFC-22 production and sale in China (MT/yr)

year	*capacity*	*output*	*consumption by self*	*Total Sales*	*export*	*Domestic sales*
2000	82,500	69,790	16,912	50,427	9,941	40,486
2001	163,500	95,444	25,905	68,843	16,727	52,115
2002	184,500	130,535	25,397	99,663	28,816	70,847
2003	213,000	185,670	32,818	153,085	50,520	102,565
2004	358,500	247,687	69,445	176,608	68,902	107,706

Raw materials for HCFC-22 include: AHF, $HCCl_3$, NaOH (l), Cl_2(l),and $StCl_5$ catalyst. The prices of the material are rising in recent years. From the information provided by enterprises, the price of chloroform, with product cost at 1.5 MT / MT, rose 1000~2000 Yuan per MT in 2004 as compared with that in 2002; the price of hydrofluoric acid, with product cost at 0.5 MT / MT, also rose 1000~2000 Yuan per MT in 2004 as compared with that in 2002. The raw material cost increased considerably in China.

Price of $HCCl_3$: Besides the increase of $HCCl_3$ domestic demand, anti-dumping which causes supply can not meet the demand also makes the rise of $HCCl_3$ price.

Price of HF: There are two reasons for rise in HF price：(1) the increase of HF domestic demand; (2) after restriction of fluorite export, HF export went up speedily, which made HF more expensive for its shortage. The export of fluorite and HF in recent years are shown as follows:

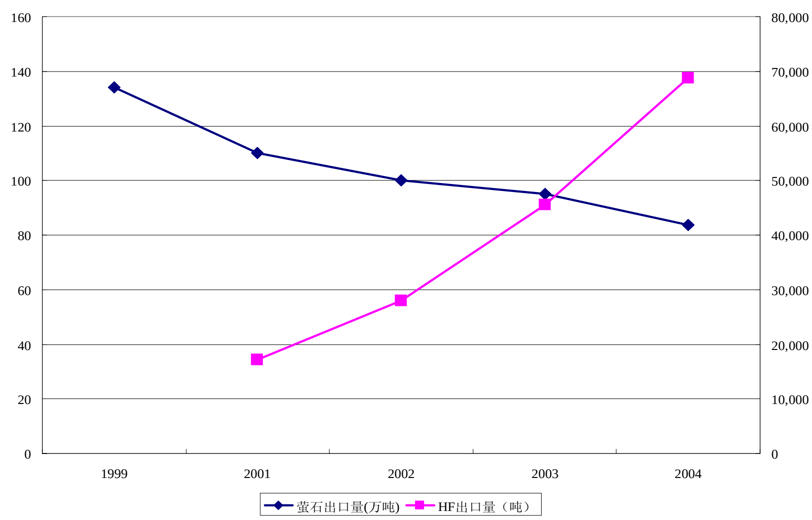

Fig. 2-2 Export production of fluorite in (10,000MT) and HF (MT) in China

Due to the rapid development of room air conditioners, industrial and commercial refrigeration etc. and the increasing demand and considerable benefit from PTFE market, the enterprises in China continually invest for expansion or new production line of HCFC-22. The average increasing rate of HCFC-22 production is up to 27% in the past five years, which makes the supply beyond the demand and the price goes down.

Quality of HCFC-22 made in China is excellent and different products were warranty on different quality standards for variable purposes. The main criteria used were national standards GB7373-87 and GB9016-88; but some enterprises met user's requirements by using of enterprise standard which was stricter than national standards.

2.1.2 HCFC-22 Consumption

For its fine characteristic, HCFC-22 is widely used as refrigerant, foaming agent, blends of refrigerant, and raw materials of PTFE. It can be applied in refrigerator compressors of piston, screw rod and centrifugal types, including air-conditioners and small refrigeration equipments etc. The demand of HCFC-22 increased rapidly along with the increased production of room air-conditioner using HCFC-22 as refrigerants from the initial production in China and its application was increasingly prevalent. Besides, the demand of HCFC-22 as the alternative for CFCs in the production field of small refrigeration equipments increased continuously. In recent years, consumption of HCFC-22 as raw material also enlarges with the development of organ-fluorine polymer material. What's more, for the rapid demand growth of polystyrene boards (XPS) in construction industry, the consumption of HCFC-22 as foaming agent also reached the level of 10,000 m^3 in 2005 in China.

Table 2-3 HCFC-22 consumption in China (MT/yr)

Domestic sales	2000	2001	2002	2003	2004
Raw materials	18,119	22,662	29,332	50,344	
Refrigerant in room air conditioners sector	9,826	13,126	15,882	16,788	
Refrigerant in the Industrial and Commercial refrigeration conditioning sector	50	11,135	12,839	18,099	
Foaming	-	-	814	1,569	
Dealer sales	28,084	32,610	43,814	51,747	
Other purpose	785	306	1,507	3,164	
Total	56,863	79,839	104,189	141,711	177,150

Among the HCFC-22 producers, eight of them using HCFC-22 as raw material for further processing, in which two enterprises consumed half the output for self-use, while another two consumed the whole . Nine of them exported some of the HCFC-22. The rest HCFC-22 was sold as refrigerant and foaming agent etc. at home.

2.1.2.1 Room Air-conditioner Industry

Room air-conditioner production develops rapidly from the 1990s, which is currently the biggest consumer of HCFC-22 in China. According to the survey data, the average annual growing rate of the output of room air-conditioner from 1991 to 1993 is up to 144%, during 1994 to 1998 and 1999 to 2004, the rates are 23% and 41%, respectively. The output of room air-conditioner reaches to 63,900,000 units in 2004 while 67,640,000 units in 2005, 5% growth compared with that in 2004 and enormously under previous rates. This industry consumes about 80,000 MT of HCFC-22 annually (containing new product fillings and services)

The export of room air-conditioner, starting in the mid-1990s, has maintained rapid growth trend. During 1995 to 2004, the export annual growth rate was 59%. Currently, room air-conditioner for export still mainly uses HCFC-22 as refrigerant, only a small amount uses refrigerant R-407c and R-410a to meet with the requirements of refrigerator, energy consuming and safety indexes set by EU, Japan and other countries and regions.

Currently, HFCs (R-410a) and hydrocarbon (HC, R-290) are most likely to substitute HCFC-22 for room air-conditioner, whose ODP can satisfy the demand of protecting ozone layer, and what's more, a good energy efficiency performs significantly. Although there is a difference between HCFC-22 and R-410a in performance and it's not a drop-in alternative. Some enterprises reconstructed the production lines to produce room air conditioner using different refrigerant, meeting export requirements. Although the reconstruction parts were not so much, while facing with the safety problems from production, installation and maintenance processing etc. and what's more, it's only a beginning of HC production in China and unknown factors are plenty.

One Ningbo air-conditioner Ltd., one Corporation in Shandong province and other room air-conditioner enterprises were interviewed. The targeted air-conditioner Ltd. in Ningbo had 7 production lines, with annual production capacity of 5 million room air-conditioners. The output was 2.5 million and 70% of them used about 2,400 MT HCFC-22 as refrigerant in 2004. Part of the company's production lines had been reconstructed and can be compatible to product R-407c or R-410a as regrigerant to meet the demand of exports. All domestic sales of products used HCFC-22; 50% of exports products used R-410a or R-407c as refrigerant. However, the scale and technical conditions of the above mentioned air-conditioner Ltd. and Corporation are ones of the most advanced in more than 50 enterprises that produce room air conditioner in China, therefore they are not representative of the integral technology level of China. Most enterprises particular for small-medium ones do not have the capacity to use alternatives. Table 2-5 shows the HCFC-22 air-conditioner production and consumption of HCFC-22 in one enterprise.

Table 2-4 HCFC-22 air-conditioner production and consumption of HCFC-22 in one enterprise

Year	2001	2002	2003	2004
Output (units)	487,500	780,000	1,520,000	1,880,000
HCFC-22 consumption (MT)	600	960	1920	2400
Average single cost (grout volume) (kg/machine)	1.23	1.23	1.26	1.28

Based on the analysis of survey data of the visited enterprises, the HCFC-22 consumption of room air conditioner industry was verified, which coincided with data from HCFC-22 production enterprises. For room air conditioner, refrigerant consumption was averagely 1.3~1.4kg/set.

Table 2-6 lists the Production standards and product situations in room air conditioner industry in China. Qualification and grades of energy efficiency for room air conditioners (GB12021.3-2004) was issued on Aug.23, 2004, and implemented from March 1, 2005, which should advance technique renovation and advancement and facilitate application of new refrigerant.

Table 2-5 Production standards and product situations in room air conditioner industry

Quality standards adopted by enterprises	***GB/T7725, GB 4706.32, GB4706.1***
HCFCs leak proof and detection measures	Helium and halogen leak detection measures, etc.
HCFCs reclaim measures for recycle	Enterprises commonly have recycling measures on production lines
Product life expectancy and influencing factors	Commonly the life expectancy is 8-10 years, and it can be restricted by user's environment
Compressor fault rate and maintenance rate of open refrigeration system	Compressor fault rate rate of open refrigeration maintenance system are both below 0.3%
Alternative or its technology	R-407c and R-410a can be used as refrigerants
Alternative technology sources and alteration charge	Self Developed alternative technology, with product line reconstruction cost of 3 million RMB/line
Cost increasing rate after using alternative and its market impact	Cost increases by 30% compared with that using HCFC-22, and the difficulty of after-sales service increases

2.1.2.2 Industrial and Commercial Refrigeration Sector

The refrigeration industry in China has attained an important advancement in enterprise reform, foreign funds utilization, technology imports, technology innovation, and product quality improvement and ODS consumption reduction etc. Base on the annual reports by the China Refrigeration Industry Associations from 1989 to 1999, there was only 217 enterprises producing kinds of refrigeration equipments and products in 1989 and the value of industry output was 6.5 billion RMB[1] by year. While in 1998, the number of refrigeration equipment production enterprises had reached to 1,000 and corresponding value was 40 billion RMB (residential air conditioner industry not included), among the ten years the increasing rate was 20%. And meanwhile the number of foreign investment enterprises including joint and independent capital ventures increase from 6 in 1990 to 110 in 1998. Nowadays, the refrigeration industry of China is an integrated industry system containing large, medium and small types of refrigeration equipment production, product quality, methods and technology standards continuously enhance and the technological gap with developed countries is getting shorter. China becomes the third largest refrigeration equipment production country after USA and Japan. The demand and production of compressors increase with the development of economy.

Industrial and commercial refrigeration equipments widely used in industry production and commercial fields can be divided into 5 parts according to their variable applications: commercial refrigeration, refrigeration and freezing machining, industrial refrigeration, transportation refrigeration and central air conditioner.

In this industry, variable kinds and sizes of refrigeration equipments were produced, which included refrigerators, unit refrigeration machines and centrifugal chiller, each of them had different sizes. Smaller ones need a few kilograms of refrigerant, and bigger ones need tons. And what's more, the refrigerant is generally charged in after the equipment has been installed, therefore it is difficult to manage and exactly register the use amount of refrigerant in this industry.

During the investigation of this industry, the China Refrigeration Industry Associations suggested strengthening equipment management and registration, which included setting up file for each set of refrigeration equipment, and establishing statistical system and regulation for monitoring refrigerant consumption, and meanwhile, strict product standard and technological modification to improve tightness and reduce leakage. Supervision and regulation on maintenance reclaim and abandoned reclaim should be reinforced. At present and the next 10 years, the main refrigerant for industrial and

[1] The output of commercial and industrial refrigeration is expressed by output value.

commercial refrigeration equipments will still be HCFC-22.

In view of the current problems, such as incomplete management regulations, refrigeration equipment without excellent hermetic quality resulting in large amount of refrigerant leaked, and unsuitable maintenance operations, the Industry Associations made the following recommendations. Firstly, strengthening the management of HCFCs, reducing emission of refrigerant in the process of manufacture, installation, operation, maintenance and disuse of refrigeration equipment; drawing up and promulgating relevant laws and policies, clearly defining any refrigeration air conditioner equipments and system should continuously improve hermetic quality, reduce refrigerant leakage, strengthen management of maintenance reclaim and disuse reclaim, ban random discharge; establishing management systems and institutions; implementing refrigerator recovery, recycle reuse and maintenance training and examination system on regeneration; drawing up relevant technical criterion; HCFC-123 refrigerant used in centrifugal chiller being suggested to be held for long period usage due to its five advantages on global environmental integrated impact.

Due to variable refrigeration equipment capacities, the alternatives of HCFC-22 are also different, in choosing alternatives in industrial and commercial refrigeration sector. HFC-134a becomes major alternative refrigerant for medium-size screw-type compressor chiller, while some using R-410a or other. HCFC-123 and HFC-134a were used for chiller of large-size centrifugal compressor and the use of HCHC-22 stopped by most manufactures. Comparatively speaking, HCFC-123 had a higher acceptable degree compared with HFC-134a.

Refrigeration enterprises in Zhejiang, Chongqing and Liaoning etc. were visited. One group in Zhejiang mainly manufactured cold storage house with capacity of 50~60 m^3, and each refrigerator needed refrigerant (HCFC-22) about 70~80 kg. Another company mainly produced 3.5~30kW refrigeration compressor and production capacity was 7,000 sets/yr, and the actual output was 3,000 sets in 2004, averagely charged 40 kg HCFC-22 for each set, R-407c and R-404a were both available as alternatives to meet with users requirement. One company in Chongqing produced equipments using HCFC-123 as refrigerant and the output was 17 sets in 2004, a total of 13.6 MT of HCFC-123 was charged in. One group in Liaoning produced 4,000 refrigeration compressors in 2004, 50% of which was charged with HCFC-22, and the residual half with liquid ammonia. The survey showed that alternatives of HCFC-22 had been applied in certain degree which mainly based on customer's requirements to choose refrigerators.

Table 2-7 listed the products situation of industrial and commercial refrigeration in China. Qualification and grades of energy efficiency for unit air conditioners (GB19576-2004) and Qualification and grade of energy efficiency for water chiller (GB19577-2004) were issued on Aug. 23, 2004, and implemented from Mar. 1, 2005, which would push technical renovation and advancement, facilitate application of new refrigerant.

Table 2-6 Product status in industrial and commercial refrigeration industry

Quality standards adopted by enterprises	***JB/T3355-1988, GB/T19001-2000, GB/T10079-2001***
HCFCs leak proof and detection measures	Yes
HCFCs reclaim measures for recycle	Yes
Product life expectancy and influencing factors	Commonly theLife expectancy was 8-15 years and it could be restricted by user's environment
Compressor fault rate and maintenance rate of open refrigeration system	Compressor fault rate was under 0.3%~2% and rate of open regrigeration maintenance system was 0.7%-5% and up to 20％ tiptop
Alternative or its technology	HFC-134a, R-404a, R-407c, R-410a could be used as refrigerators
Alternative technology sources and alteration charge	Compressor could be used with multi-media but needed to to change frozen oils and refrigerators
Cost increasing rate after using alternative and its market impact	The cost increased by 2,000 RMB/set or 10-15 % of cost and the difficulty of after-sales service increased

2.1.2.3 Foam Industry

In foam industry, HCFCs were use as foaming agents included HCFC-141b, HCFC-142b and HCFC-22. HCFC-22 and HCFC-142b were mainly used to produce XPS (Expanded Polystyrene) board as building thermal insulation materials. At present, there were not less than 150 XPS product lines and the produce capacity was 10 million m^3/yr in China. The output was 1-3 million m^3 in 2005 and the consumption of HCFC-22 as foaming agent was 5,000-10,000 MT. The annual increased rate of output was more than 20%. The increasing demand of this type of insulation material was due to new standard of energy efficiency of building had been implemented in China. Currently, HFC-152a, CO_2, alcohol and ether etc. could be used as XPS foaming agent to substitute HCFC-22 and HCFC-142b, whereas the application of HFC-134a was limited for itsr green house effect and using other foaming agents were immature.

2.1.2.4 Chemical Industry (Raw material consumption)

HCFC-22 could be used as raw material to produce kinds of fluorinated fine chemicals, including tetrafluoroethylene, hexafluoropropene, tetrafluoropropyl, octafluorocyclobutane, HFC-23 and HFC-227ea etc., among which the uppermost kind was PTFE. Due to its more excellent characteristic compared with general engineering plastics, PTFE was widely used in petrochemicals, electronic appliances, aerospace, machine, biological medicine, construction, national defense industry and advanced science etc. It turned into one of indispensable newly materials in modern industry. PTFE industry in China started in 1960s, developed among 1990s and grew rapidly in recent 10 years.

Many companies further processed HCFC-22 and supplied the raw material themselves. Especially in recent years, this trend was more obvious because the market price of HCFC-22 dropped by which companies wanted to gain more profit. Most companies producing HCFCs-22 used it as raw material to produce other products. Raw material consumption accounted for 40 % of domestic HCFC-22 consumption.

Currently, there were 5 companies in Shanghai, Zhejiang, Shandong and Sichuan that produced PTFE. Production status was shown as followings and the product standards all adopted Enterprise standards.

Table 2-7 Tetrafluoroethylene production status of China's enterprises

Product line	Production capability (MT/yr)	Output (MT)				Raw material consumption (MT/MT)
		2001	2002	2003	2004	
10	33,200	9,372	12,200	18,639	29,125	1.95-2.30

2.2 HCFC-141b/142b Production and Consumption

There were 6 HCFC-141b producers in China, 4 in Zhejiang Province and 2 in Jiangsu Province, 4 HCFC-142b producers, 2 in Zhejiang Province, 1 in Jiangsu Province and 1 in Sichuan Province.

Furthermore, in Zhejing Province there was a producer producing HCFC-123 and HCFC-124.

2.2.1 Production of HCFC-141b

Chemical enterprises started to produce HCFC-141b since the early 1990s. The total production capacity was 58,000 MT/yr in 2004 in China and the actual output was 39,907 MT, with 24,799 MT for domestic consumption and the rest for export in 2004. The production capacity increased 6,700 MT in 2004 compared with that in 2003.

Table 2-8 Production and sales of HCFC-141b in China (MT/yr)

Year	Capacity	Output	Interior consumption	Total sales	Export	Domestic sales
2000	12,500	7,682	0	8,059	3,120	4,939
2001	20,000	14,366	20	13,289	5,038	8,251
2002	30,000	23,353	68	23,761	10,475	13,286
2003	49,500	32,494	0	32,140	9,501	22,640
2004	58,000	39,907	179	38,943	14,323	24,620

The raw materials for HCFC-141b production could adopt vinylidene chloride, trichloroethane, vinyl chloride and hydrofluoric acid (AHF). The HCFC-141b producers adopted national standard GB/T18827-2002 or enterprise standard, mainly due to export the requirements were higher than national standard.

2.2.2 Production of HCFC-142b

Chemical enterprises in China started to produce HCFC-141b since the 1990s. As the alternative for CFCs, HCFC-142b could be used as expanded polystyrene foaming agent to produce construction material, refrigerant and other products such as the raw material of vinylidene fluoride. There were 4 HCFC-142b producers in China and total production capacity was 11,000 MT/yr in 2004. The actual output was 4,750 MT, with 4,103 MT for domestic consumption and 498 MT for export of in 2004. Since 2005, the companies using Hcfc-142b to product XPS board increased rapidly and the corresponding demand went up speedily.

Table 2-9 Production and sales of HCFC-142b in China (MT/yr)

Year	*Capacity*	*Output*	*Interior*	*Total sales*	*Export*	*Domestic*

			consumption			*sales*
2000	2,000	505	-	470	-	470
2001	4,500	750	-	1,166	-	1,166
2002	5,000	2,082	171	2,059	282	1,777
2003	9,000	3,948	603	3,445	266	3,221
2004	11,000	5,481	663	3,939	498	3,441

The raw materials of producing HCFC-142b could use vinylidene chloride and hydrofluoric acid (AHF) or HFC-152a and chlorine liquid. Based on the relevant information provide by the producers, the sale price of HCFC-142b was about 15,000 RMB/ton in recent years. The profit of different producers varied obviously for its applied technology, and management etc. All HCFCs -142b producers adopted enterprise standard.

2.2.3 Consumption of FCFC-141b/142b

HCFC-141b had a poor conduction of heat, so it was widely used in plastic foam area as the best alternative for polyurethane rigid foam (PU-R) foaming agent. Compared with CFC-11, ODP value of HCFC-141b was one tenth of CFC-11, therefore in the stage of phaseout CFCs, it was feasible to be taken as transition substance. HCFC-141b could also be the alternative of CFC-113 as solvent. It could be used as large scale air-conditioning refrigerant and foaming agent mainly in the XPS board industry.

Table 2-10 Sales distribution of HCFC-141b/142b (MT/yr)

Domestic demands	*2000*	*2001*	*2002*	*2003*	*2004*
HCFC-141b					
Dealer sales	91	140	1,699	3,743	
Foaming agent	4,638	7,748	10,669	18,271	
Others	210	363	918	626	
Producer self-use		20	68	0	
Total	4,939	8,271	13,354	22,640	
HCFC-142b					
Dealer sales	470	1,166	1,777	3,221	3,757
Others					
Producer self-use			171	603	303
Total	470	1,166	1,948	3,825	4,060

HCFC-141b was the main alternative of CFC-11, used in PU-R, some of fridge and refrigeration equipment. It was also applied as foaming agent in the production of insulation container. One Electric Appliances Co., Ltd. in Jiangsu produced 300,000 freezers in 2004, which totally consumed 57 MT of HCFC-141b; one company in Heilongjiang produced 136,255 freezers in 2004, which consumed 65 MT of HCFC-141b. There were some defects in the alternative technology of polyurethane spray painting foam and the product quality could not be guaranteed. The Industry Association was willing to directly develop the technology using HFC-245fa or HFC-365mfc, but patent and price were the biggest obstacles. The international organization was appealed to prompt the opening of patent, application of alternative technology and proper fund support.

Furthermore, some HCFC-141b was used as solvent. One company in Sichuan produced 1.8 million sets of compressors in 2004, which consumed HCFC-141b 190 MT as solvent. This enterprise didn't have recovery facilities of HCFCs; One compressor factory in Xi’an produced 2.11 million sets of compressors in 2004 and used 17.25 MT HCFC-141b as solvent. The cleaning equipment had recovery and distillation facilities for HCFCs in that company.

2.3 Other HCFCs

One company in Zhejiang developed producing HCFC-123 and used it as raw material for HCFC-124 production. HCFC-123 could be used as alternative for CFC-11 and CFC-113 as solvent, foaming agent, fire-extinguishing agent and refrigerant, whereas its toxicity attracted consistent concerns. Currently, its main application was refrigeration system of better-off sealed environment. HCFC-124 was mainly used as alternative for CFC refrigerant in special refrigeration system and fire-extinguishing agent. The production capacities were 3,000 MT/yr and 1,500 MT/yr, respectively. Production control was under enterprise standard put on record by provincial bureau; product quality reached international standard.

Table 2-11 Production and sales distributions of HCFC-123

Year	Capacity	Output	Interior consumption	Total sales	Export	Domestic sales
2000	1,000					
2001	1,500			374		
2002	2,000	1,011	555	350	214	112
2003	3,000	1,758	1,019	436	238	184
2004	3,000	2,040	1,502	780	605	231

Table 2-12 Production and sales distributions of HCFC-124

Year	Capacity	Output	Interior consumption	Total sale	Export	Domestic sale
2000	100					
2001	500			12		
2002	800	153	6	41	36	5
2003	800	208	13	160	147	13
2004	1,500	418	243	257	151	106

The raw materials of HCFC-123 were trichloroethylene and hydrofluoric acid, sale prices decreased in recent years.

The raw materials of HCFC-124 were HCFC-123 and hydrofluoric acid. It had good benefit as the cost of production decreased in recent years.

2.4 Understanding and Technological Preparation of Enterprise for the Convention

The survey result indicated that most of the enterprises had a deep understanding of the Convention. The main reasons were as followings:

- Due to the execution of "National Implementation Plan for Phase-out of ODS" and particularly of "Phaseout Plan of CFC Production in Chemical Industry", a series of propaganda were carried out in chemical industry which made producers know about Montreal Protocol, duties and phaseout target of China. Many of the HCFC producers joined in the phaseout of CFC/Halon production.
- In recent years, the government strengthened the propaganda about ozone layer protection, promulgated relevant policy and regulations and reinforced supervision. Early planning for long-term development, enterprises were forwardly willing to learn the relevant policy.
- Consciousnesses of setting up enterprise self-image and joining in environmental protection activities were constantly strengthened.
- Seizing the alternative market was also a motivation of enterprise's concern about implementing the Protocol. Enterprises forwardly understood the target and programming of the implementation and devoted to developing and producing alternative in order to occupy alternative market.

- The implementation might bring a certain effect on production benefit, whereas the survey showed that the anti-risk ability of enterprises had been strengthened and forwardly adapted to the requirement of implementation. Enterprises had been turned to produce varieties of products and develop new alternatives. The enterprise size had been enlarged as large enterprises played a dominate role in the production. The technical levels were improved constantly as the anti-risk ability became stronger..
- In view of benefit analysis of the enterprise, benefit of HCFCs was not so high that advanced process was an effective way to increase it.
- Capital support and technical assistance were needed during the process of HCFC phase out.
- Most of the HCFCs producers were concerned about relevant alternatives for HCFC and prepared or even had already produced them. Most of the alternatives were HFCs substances, such as HFC-32, HFC-134a, HFC-143a, HFC-125, HFC-152a and HFC-245, etc. Technology was mainly self-development by producers.

2.5 HCFC Production Management Regulations in China

The Chinese government had started to strengthen environmental legislation since the 1970s, besides articles of environment protection and natural resources were listed in the Constitution, a series of laws for environmental protection were promulgated in recent years, such as Environmental Protection Law of the People's Republic of China, Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution. Environmental protection statutes relevant to ODS production management were shown in Table 2-17. Environmental Protection Law and Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution provided legal basis of these regulations. It was prescribed in the 45th article of the Prevention and Control of Atmospheric Pollution: The national government encourages and supports the production and consumption of ODS alternative, reducing the production stage by stage and finally stopping it. The 59th article provided particularly prescript for sanctions against enterprises or individuals that disobeyed the rules of the 45th article.

The State Environmental Protection Administration (SEPA), former Foreign Trade and Economic Corporation Ministry and General Administration of Customs promulgated management regulation for ODS imports and exports in Dec. 1999, which became effective in Apr. 2004. It required to register all imports and exports of ODS. Management of imports and exports of ODS combined with production quota system, had been effectively controlled the supply and demand.

3 Table 2-13 Regulations and Policies relevant to management of HCFCs in China

Date	***Title***	***Institution***
Management policy of imports and exports		
1999.12.3	Appendix of Inform for printing and distributing Management for ODS Imports and Exports ()Management for ODS Imports and Exports	State Environmental Protection Administration, Foreign Trade and Economic Corporation Ministry, General Administration of Customs
2000.1.19	Inform of the publication of <Directory of Controlled ODS (the first group) in imports and exports> Appendix: <Directory of Controlled ODS (the first group) in imports and exports>	SEPA, FTECM, GAC
2000.4.13	Inform of the printing and distributing< Enforce the Management for ODS Imports and Exports> Appendix: < Enforce the Management for ODS Imports and Exports>	SEPA,, FTECM, GAC
2000.5.15	Inform of the Publication of "recovered ODS" Symbol	SEPA
2000.7.1	Reply to the constitution of the Management Office for ODS Imports and Exports	Office for Central Governmental Human Resource
2001.1.18	Inform of the publication of <Directory of Controlled ODS (the second group) in imports and exports>	SEPA, FTECM, GAC
2004.2.6.	Inform of the publication of <Directory of Controlled ODS (the third group) in imports and exports>	SEPA, FTECM, GAC
Management policy of supervising and management		
1995.1.12	Inform of the problem about environmental impact assessment on the project granted by Montreal Multilateral Fund	SEPA
1996.4.24	Inform of printing and trial implementation of <Guidebook of the implementation on the project granted by Montreal Multilateral Fund >	SEPA
1997.2.24	Inform of enforce the supervising and management function of local government on the job of protecting the ozone layer	SEPA
1997.1.13	Inform for Emission Declare register	SEPA

1997.7.22	Inform for Use of Database Management System for Declare register of ODS Consumption	SEPA

Chapter 3 HCFCs Alternatives Assessments

There are some principles for selecting alternative of HCFCs in China should be obeyed. First of all, alternatives should be non-ODS; secondly, non-GHG chemicals are preferable if the technology is feasible and the cost is acceptable; thirdly, China should select proper alternative according to its abilities and not compare unrealistically with the advanced alternative foreign countries applied and the way of phaseout in advance, since China is a developing country and its production method and technique are comparatively falling behind.

At present, China has the ability of developing and producing on ODS alternative and makes greater progress. The production of some alternatives has grown to considerable scale, and successfully developed some significant production technology and technics which were the main ODS alternatives identified internationally such as HFC-134a, HFC-152a, HFC-32, HC-600a (isobutane), cyclopentane and ABC dry powder etc. Due to the technical limits and limited demand for some alternatives, the available equipment capacity of some alternative present is on the small scale. Some high-tech alternatives are in the primary phase and not yet at large scale. Some products haven't got the domestic market for the sake of high price. In the future, along with the phase out action being carried out thoroughly, the demand of alternative will grow rapidly. Besides, the consumption of alternative must increase as the technology of ODS alternative develops more and more maturely, the application field expands, and what's more the rapidity and persistent increases of national economy and the technical advancement, the international competitive power of ODS alternative production and relative industries will enhance. More and more ODS alternative and machines containing ODS alternative will export which helps increase the alternative export swiftly.

On the consumption of alternatives, some main consumption industries have made a positive development on alternative technology, due to they positively seek after alternative technology and equipment reconstruction. It is worth noting that along with advancement of science and technology, human continually enhance the environmental and health requirement and the technology index were renewed. Some developed ODS alternative may cause other environmental problems such as high value of greenhouse effect facing with under control or phase out soon. Therefore higher requirements for selection and development of ODS alternative bring new opportunity of ODS alternative exploitation and relevant industries develop.

3.1 Probable Alternatives of HCFC-22

3.1.1 Man Made Products

At present, HFCs is the primary non-ODS alternative of HCFC-22. Since the GWP value of HFCs is relatively large and controlled by Kyoto Protocol. Although the contribution of HFCs to GHG is not significant (account for 0.5% in 1997, expecting for 2~4% in 2050). Whereas HFCs is in the list of the controlled substances in Kyoto Protocol, and many countries began to preserve its application. Some European countries have already put forward the suggestions about phase out HFCs. While in the practical application, on the condition that equipment possesses well sealing property, worker practice following technological standard and criterion, there is limit impact on using HFCs as refrigerants, particularly when considering about the variable coefficient of energy efficiency (COP), HFCs refrigerator can reduce energy consumption at equipment operation, furthermore indirectly reducing the discharge of carbon dioxide.

There 4 kinds of HFCs mixture refrigerants in common use: R-407c, R-410a, R-404a, and R-507a. Their detailed components and properties are showed in table 3-1.

Table 3-1 Components and properties of R-407c, R-410a, R-404a and R-507a mixture

refrigerator	component(mass percentage)	slippage temperature	producing manufacturer	trade name
R-407c	HFC-32=23%	non-azeotropic mixture, slippage temperature 6K	DuPont	SUVA AC 9000
	HFC-125=25%		ICI Americas	KLEA 407C(used name KLEA 66)
	HFC-134a=52%			
R-410a	HFC-32=50%	near-azeotropic mixture, slippage temperature 0 K	Allied signal	AZ-20
	HFC-125=50%		DuPont	SUVA

				AC9100
R-404a[1]	HFC-125＝44%	near-azeotropic mixture, slippage temperature 0 K	DuPont	R-404a
	HFC-143a＝52%		Honeywell	
	HFC-134a＝4%			
R-507a[2]	HFC-125＝50%	azeotropic mixture, slippage temperature 0 K	DuPont	AZ-50
	HFC-143a＝50%		Honeywell	

R-425a self-developed by Tsinghua University, has lower GWP value (about 960), is innocuous, non-combustible and the pressure, refrigeration capacity increase 8.7% and 4.1%, respectively, while refrigerant charge decreases 16.6% compared with HCFC-22. It can be directly used for compressor and heat exchanger and has already been used in batch production of room air conditioner by AUCMA Corporation. ZCI-7 and ZCI-8 developed by Zhejiang Blue-sky Environmental Protection Company with GWP value of 1220 and 1370, respectively have a good potential application.

Currently, it is generally considered that using HFC to substitute HCFC-22 is a feasible plan in refrigeration industries. In the middle of 1990s, R-407c was accepted in the use of domestic air-conditioning and heat pump in European market. Science R-407c has almost the exact operation pressure and temperature compared with HCFC-22, it needs little reconstruction to HCFC-22 system then R-407c can be used. Yet R-407c is non-azeotropic refrigerator and the temperature drift can reach to 4-6 , the R-407c system's operation efficiency is on the low side and its stability is not guaranteed. After using R-407c for several years in Europe, R-410a gradually replaced it. R-410a is used as HCFC-22's alternative refrigerator at the very beginning in Japan. While in the USA, R-407c can't be the favor of refrigeration air condition industry and the alternative refrigerator is R-410a. After several years' development, air-conditioning and components producers in China have already mastered relevant R-410a technology and have R-410a system producing ability, which products from some producers have export to EU and Japan etc.

Although the use of HFC is limited by Kyoto Protocol for its high GWP, the scientific research reported that the climate warming impact by CO_2 emission from power plant producing electricity to drive air condition surpasses refrigerant leakage impacted greatly

Promoting the power efficiency of refrigeration equipment is important for the reduction of greenhouse gases. Through features comparison between R-410 and HCFC-22 used in air-conditioner, such as refrigerating capacity and energy efficiency ratio efficiency, electricity consumption of whole year operation, environmental features and production cost etc. some researchers concluded that R-410a was propitious to reduce the size of air-condition heat exchanger, promote system operation efficiency, save electricity and operation cost. They also estimated that R-410 and HCFC-22 air-conditioners had close producing cost along with the rise of raw material price and enlarged producing capacity of R-410a compressor; and meanwhile, R-410a was in favor of reducing the effect of climate warming by reducing energy consumption, air-conditioner refrigerator charging amount and leakage.

3.1.2 Natural Refrigerant

Natural refrigerants have been paid more and more attention since they have no global environmental harm and can also complete industrial mission. Whereas natural refrigerants are not perfect alternatives, there is safety problem while using a substantial amount of them, such as the toxicity and combustibility of NH_3. Therefore the application of natural refrigerants is still limited in the near future. The primary advantages, disadvantages as well as their application sites of natural refrigerants are listed in following table.

Table 3-2 Main virtues, Problems, and Application Sites of Important Natural Refrigerants

Natural refrigerants	advantage	pboblem	application situation
HCs	their COP values almost the same as those of CFC-12 or HCFC-22	strongly combustible	refrigerator
			automat
NH_3	higher COP value than that of HCFC-22	toxic, combustible	business refrigeration
	high tasification latent heat	it can't be contacted with copper material	industry-used water chiller
	quick heat transfer	expensive safety precautions	
CO_2	avirulent, non-combustible	lower COP value	hot water heater
	low pressure loss	high pressure(10 MPa)	automobile air-conditioning

	proper for heating unit		secondary circuit refrigerator

HCs substances, such as propane, cyclopropane, butane (R-600), R600a etc. are good refrigerators, however their combustibleness limits widely application. The maximal permitting irrigating quantity is 150 g according to European safety standard and 50g to USA safety standard. Low permitting irrigating quantity makes this kind of refrigerant only fit for domestic refrigerator. At present, in the domestic refrigerator market of North Europe, China and Japan, HCs refrigerator has taken an important position (the production of HC-600 refrigerators exceeds 50 million sets). The advantage of propane is its good heat transfer, low irrigating quantity, mutually dissolved with mineral oil and high latent heat. The environmental harmful coefficient of propane is zero and its toxicity to human is close to zero, therefore propane has postulate of substituting HCFC-22 in domestic refrigerator. For Air-conditioners, maximum quantities for propane (R-290) proposed (IEC 60335-2-40-A2) vary between 180 and 650 g depending on the floor area, providing a suitable safety standard. This standard can be met for Window-type Air-conditioners using propane and will require special designs for Split unit Air-conditioners. HCs are more and more recognized in the use of improving equipment performance. Some studies have demonstrated that HCs are better than fluoride concerning about its thermodynamics transport performance. The components of each system using HCs have superior performance than those with CFCs, HCFCs and HFCs. HCs have higher steam pressure compared with HCFC-22 and show well performance of reducing temperature difference in boiler and condenser. It is in favor of lowering pressure loss and increasing coefficient of performance (COP).

CO_2 is incombustible, non-toxic, low compression ratio, large refrigerating capacity per unit volume, cheaply obtained, no causticity to common materials, with these properties, CO_2 probably becomes the only refrigerant can be used in different areas among natural refrigerants. Compared with traditional refrigerants, the most difference between them is the low critical temperature (31.1℃), which results in CO_2's particularity of its refrigeration system, i.e., in most cases, the system releases heat to outside under the condition of supercritical pressure. Since the high pressure of supercritical CO_2 system is determined by the charge amount of CO_2 and is related with the saturation temperature, therefore the device of high pressure and assembly's capability to endure high pressure must be considered in the process of system design. CO_2 can be used as the low temperature refrigerant for supermarket and large scale industrial cold storage house.

NH_3 has high refrigeration efficiency. It is an excellent refrigerant with good thermodynamic property. The history of using NH_3 as refrigerant is long with excellent experience about devising, application procedure and safety measurements of NH_3 refrigeration system. Its advantages are 0 ODP, close to 0 GWP, easy to obtain and low cost; high energy performance, good diathermancy, good thermo-dynamical and thermo-physical characters, proper internal pressure ratio at room and common low temperature; widely applied, high phase change latent heat and easy leak check. The shortcomings include its insolubility with lubricant oils, corrosiveness to copper and its alloys; high exhaust pressure; toxicity and combustibility as well as irritable smell. To sum up from the above analysis, the directions of technique development in NH_3 refrigeration system include:

(1) Reduce charge amount, such as reduce the diameter of loop, intensify heat transfer and use new secondary loop refrigeration etc.;

(2) Reduce leakage, such as develop semi-hermetic compressor without tank etc.;

(3) Increase COP value, such as use plate-heat exchanger;

(4) Widen its application range of temperature.

With recent years' development, its safety problem has been effectively solved in new types of NH_3 refrigeration system. NH_3 and CO_2 can also be used in overlapping type refrigeration systems in supermarkets. These have already been applied in European supermarkets. Compared with other refrigerants, NH_3 has obvious advantages in large refrigeration system.

3.2 Probable Alternatives of HCFC-141b

3.2.1 HFC-245fa

The physical characters of HFC-245fa are similar with those of HCFC-141b but matches better than HCFC-141b. The mixture of HFC-245 with some alcohols can increase cleanout capability in cleaning industry. At precise cleanout area, HFC-245fa can be used as solvents to clean printed circuit boards, magnetic head, relay, variable kinds of communicating and medical equipment, jewelry etc. The main advantages of HFC-245fa are zero ODP, lower GWP, less impact on the environment. Its main disadvantage is low boiling point. With it to substitute HCFC-141b, the equipment must be modified a lot.

In foam industry, HFC-245fa is always considered as the first choice of substituting HCFC-141b. The refrigerator made by foaming HFC-245fa has the same performance compared with that by HCFC-141b. HFC-245fa can alternative HCFC-141b at foam insulated materials of polyurethane and polyisocyanate PUR, including insulated foam for refrigerator and cold-storage closet, board foam for roof structure and shroud, and spray foam for building.

3.2.2 HFC-365mfc

The physical characters of HFC-365mfc are similar with those of HCFC-141b, but matches better than HCFC-141b. The mixture of HFC-365mfc and some alcohols can increase its cleanout capacity. In cleaning industry, HFC-365mfc substitutes HCFC-141b in most occasions.

HFC-365mfc can substitute HCFC-141b as foaming agent and solvent. Among all alternatives, the gas-phase heat conductivity of HFC-365mfc is the worst. It is only 1 mW/m.K higher than that of HCFC-141b. This character has been approved by contrastive measurement of heat conductivity on the condition of room or higher temperature.

3.3 The Selection and Use of Alternatives in Various Industries

Among room air-conditioners and heat pumps in which HCFC-22 is the largest amount of usage, R-410a is the primary alternative. Most of the facility manufacturers produced the production of R-410a with currency standard, although HCFC-22 and R-410a have different properties and can not be substituted directly. At present, about 10% of the room air-conditioners all over the world have used R-410a and the ratio is much higher in USA, in which the ratio will exceed 80% at the end of 2007 and completely being phased out at the end of 2009. Among the reconstructive room air conditioners, terrestrial heat/water source heat pumps and small scale water chillers, R-410a is also the primary alternatives of HCFC-22.

With the increasing of equipment refrigeration power, the selection of alternatives for HCFC-22 will also be changed. In the water chiller of middle scale screw compressor, HFC-134a becomes the primary alternative refrigerant, while of course, a small number of manufacturers use R-410a or other refrigerants. In the super-large water chiller of centrifugal compressor, most of the manufacturers have stopped using HCFC-22 and turn to use HCFC-123 and HFC-134a. Comparatively speaking, the acceptance level of HCFC-123 is much higher. As a kind of HCFCs, the production of HCFC-123 will be phased out, but phaseout time of HCFC-123 is later than that of HCFC-22 due to its lower ODP value.

The refrigeration equipment using HCFC-22 as the refrigerant in China can be divided into room air-conditioner, household air-conditioning and industrial and commercial refrigeration equipment. Industrial and commercial refrigeration equipment can be divided into 5 parts according to different uses: commercial refrigeration, refrigerating and freezing processing, industrial refrigeration, transport refrigeration and central air-conditioner.

According to the type of refrigeration equipment, the main alternatives of HCFC-22 are summarized and shown in Table 3-3. It can be drawn from the table that the primary alternatives of HCFC-22 are all HFCs substances except NH_3 and HCFC-123.

Table 3-3 Primary alternatives of HCFC-22 classified by the type of equipment

Classification	Typical Application	Primary Alternatives
Room air-conditioner	Household	R-410a
Unit air-conditioner, heat pump (air to air)	Household, Commerce	R-410a
Application system: terrestrial heat, water source heat pump	Commerce, Organ	R-410a
Application system: multi-units	Household, Commerce, Organ	R-401a, R-407c
Large scale air-conditioner	Commerce, Organ	HFC-134a, R-410a
Water chiller		
Wind cooling	Central system	HFC-134a, R-410a, HCFC-123
Water cooling	Central system	HCFC-123, HFC-134a
Commercial refrigeration	Commerce	HFC-134a, R-404a, R-410a, R-507a
Industrial refrigeration	Industry	HFC-134a, NH_3
Transport refrigeration	Transport	HFC-134a

3.3.1 Room Air-conditioner Industry

The refrigerant used in room air-conditioner which are produced in China is HCFC-22 as early as room air-conditioner came out. At present the products from domestic market still use HCFC-22, while some for export have used alternatives. In 2002, the number of air-conditioner using R-407c was approximately 100,000. In 2003, the number increased 9 times and the number of air-conditioner using R-410a was approximately 500,000. It was estimated that the alternatives production would be doubled in 2004 compared with that in 2003. (The data was from China Household Electrical Appliances Association) The aim of using new refrigeration by enterprises in producing air-conditioners is meeting the relevant demand of international market and keeps export proportion.

R-407c is ternary non-azeotropic mixed refrigerant, its primary advantages are that its energy efficiency and pressure ratios are close to those of HCFC-22 and it can be charged directly. The primary disadvantages are non-azeotropic. The components will be changed while the system leaks. Therefore, it can not be used in the flooded evaporator or low pressure receiver, whereas the heat transfer efficiency can be increased by using countercurrent heat exchanger. At present, R-407c has been used in a large amount in all kinds of air-conditioners in Europe assembled with compressors types of rotary, scroll and reciprocating. R-410a is duplicate near-azeotropic mixed refrigerant. The temperature slippage is small, while the discharge pressure and volume refrigeration capacity etc. are much larger than those of HCFC-22, its high pressure is 50% higher than that of HCFC-22, therefore, it can not be directly charged and needs to redesign the compressor and primary components. Generally speaking, R-410a is only suitable for newly designed system, and R-407c is usually applied in the reconstruction of existing system.

As the physical properties of R-407c and R-410a are different from HCFC-22, there are some considerations on compressors as followings:

(1) As the operating pressure of R-407c and R-410a is relatively high, the bearing load increases, there is a necessity to increase the intensity of whole system and devise and optimize the compressor with high speed. The method of reducing the height of air cylinder can be used to reduce the bearing load to guarantee the reliability.

(2) As there is no chlorine atom in R-407c and R-410a refrigerants, their lubricants can not use mineral oil, but ester oil. Selecting proper lubricant can reduce power

consumption of compressor and increase the reliability and life expectancy.

(3) For motor coil, since the breakdown voltage and dielectric constant of R-407c and R-410a are relatively low to pay attention to the material selections of insulation and enameled wirewound of motor when devising.

(4) Adjust processing manufacturing and installation intervals, devise the muffler device properly and reduce the noise. As to satisfy the increasing need of comfort, air-conditioner manufacture technology develops gradually. The development directions of future compressor in room air-conditioner are efficient, energy saving, environment protected, steeples speed variation, low noise and completely intellectualized control.

Due to the different physical characters of alternative like R-407c and R-410a with that of HCFC-22, reconstruction of production equipments and special requirements for compressor, lubricant, and pipeline material are needed, which results in the increase of production cost. At present, except that a few major enterprises have reconstructed product lines and used alternative for the satisfaction of European and Japanese markets. Most of the enterprises are lack of capital and technology. They can only use HCFC-22 as refrigerant for products.

3.3.2 Commercial Refrigeration

Commercial refrigeration refers to the cold-storage and exhibition cabinets for fresh food, drinking and etc.; it always has two refrigeration temperature, i.e. refrigeration temperature and freezing temperature. Different countries and areas use different alternatives due to different environmental standards and habits.

Since 2000, European regulation 2037/2000 have forbidden charging HCFCs into the new producing equipments. At present, in large capacity (such as cold water chiller or varieties of centralized refrigeration equipments) of low and middle temperature refrigeration equipments, Europe mainly uses R-404a or R-507a as refrigerant. While for small capacity single machines, HFC-134a is used in middle-temperature refrigeration; HFC-134a and R-404a can both be used for low temperature refrigeration. In the past 5 years, some European countries had ever used some natural refrigerants including HCs, NH_3, and CO_2.

Some new progress has been made on the refrigerant alternatives in single machine and condensing unit. Some drinking and ice-cream enterprises recently made an announcement that if the price of alternatives refrigerant/alternatives technique was acceptable, them would not use HFCs any more after 2004. Coca-Cola Company has come to investigate the refrigeration capability of HCs, CO_2 and stirling cooling technique. Cold storage selling machine and small scale commercial refrigeration device can use HC-600a, HC-290 or HCs mixtures refrigerant whose maximum safety charge amounts are 2.5kg, 1.5kg and 150g, respectively, according to related regulation. Whereas their small densities, the charge amount of HCs is 40% lower than HFCs and HCFCs, therefore, the limitation of refrigerant charge doesn't obstruct the usage of HCs refrigerant.

As for centralized refrigeration devices, 3 non-HFCs refrigeration techniques have been developed, which include CO_2 direct expansion refrigeration system, NH_3 and HCs indirect expansion refrigeration systems, CO_2 is used as heat-transfer fluid in indirect expansion refrigeration system.

3.3.3 Cold Storage, Freezing Processing

The alternatives of refrigerant in food storage, freezing and processing sub-industry include man-made HFCs refrigerants and natural refrigerants.

HFC-134a: HFC-134a is mainly used to substitute CFC-12, since the amount of which used in food storage and freezing processing sub-industry is very small, therefore, the consumption of HFC-134a is also small in those sub-industries.

R-404a and R-507a: These two mixture refrigerants have similar components and refrigeration properties. They are both widely used as refrigerants in food storage and freezing processing sub-factory. Their COP values are similar to R-502, but much lower than NH_3 and HCFC-22. The higher the condensing temperature is, the worse the effect is, therefore, they can't be used in air-cooling device.

R-410a: Compared with other refrigerants (except for CO_2), the compressor for R-410a needs pretty small volume, so it is widely used in food cold storage, freezing and processing industries. Owing to its high refrigeration capacity per unit volume (40% higher than that of HCFC-22), the efficiency of R-410a applied compressor is higher than that of HCFC-22. The COP value of R-410a is similar to NH_3 and HCFC-22, while a little higher than those of R-404a and R-507a, when the evaporation temperature is above -40℃.

Except for the man-made refrigerants mentioned above, the alternatives of refrigerant in food cold-storage, freezing and processing sub-industries also include natural refrigerants, such as NH_3, HCs and CO_2.

NH_3: NH_3 is the primary refrigerant in cold-storage, freezing and processing sub-industry. In many North European countries, NH_3 accounts for 80% in refrigerant supermarket of this sub-industry. In the USA, about 90% of the food processing devices whose refrigeration capacity is no less than 100kW using NH_3. Since low-temperature material and better welding process are used, there is new quality advancement in NH_3 device system. Unless there are human errors or direct physical damage, these devices will not be easily damaged or leak NH_3, and what's more the electricity consumption will obviously decrease by using plate heat exchanger or direct-expansion shell-and-tube heat exchanger.

HCs: Low charge of HCs is gradually used in refrigeration devices in some European countries, but the market share is relatively small due to its combustible property. The commercial HCs refrigerants used in food cold-storage, freezing and processing sub-industries include HC-290, HC-1270 and the mixture of HC-290 and HC-600. However, the combustible property is still the focus. Whether devising and maintenance, there must be relevant safety measures. There have been some HCs standards and relevant safety detailed rules in the European industry area.

CO_2: Since the thermo-physical property of CO_2 is pretty good, its refrigeration technique fits the low-temperature refrigeration device (such as food cold-storage and etc.) very well, especially the multi-stage refrigeration system, where CO_2 is used in the low-temperature stage and NH_3 in high. Another advantage of CO_2 refrigeration technique is that the refrigeration capacity per unit volume is 5 times higher than that of R-410a, and 8 times higher than those of NH_3 and other refrigerants. It is estimated that CO_2 refrigeration technique will be more widely used in food cold-storage and freezing-storage.

3.3.4 Industrial Refrigeration

Industrial refrigeration includes specialized refrigeration systems and large refrigeration systems. Due to their special purposes, these equipments are always user-defined and on-site constructed. The vapor temperature in industrial refrigeration ranges from 15 to -70℃ and corresponding cooling/heating capacity of these equipments ranges from 25kW to 30MW (shaft power). According to different cooling capacities and purposes, types of reciprocating, screw and centrifugal compressors can be selected in these refrigeration systems.

To acquire high efficiency of thermal energy, it tend to use flooding evaporator, therefore, single refrigerant is preferred. As industrial refrigeration system is generally located in industrial areas, where the public has little chance to contact with and workers clearly understand the toxicity and combustibility of NH_3 and dispose it very well, therefore, NH_3 can be broadly used. In some disposal processes of combustible liquid (such as the process of chemicals), hydrocarbon can be used as the alternatives of NH_3. The different regulations in different countries result in different refrigeration technique development. In Europe, HFCs is seldom used unless hydrocarbon and NH_3 can not satisfy the refrigeration need, and yet the producers are unwillingly to use HFCs as refrigerant, because HFCs is green house gas, which may be controlled by Kyoto Protocol.

3.3.5 Transport Refrigeration

Transport refrigeration system is primarily used to transport cold-storaged and frozen food. The heat entering the freezing chamber through insulation layer and produced by freezing food (such as the maturation process of fruit) will both cause the temperature in freezing chamber to increase. The role of transport refrigeration system is to maintain the temperature constant in freezing chamber. The technique requirement of transport refrigeration system is higher than other refrigeration processes.

Container Transport Refrigeration: No matter using which form of transportation, the temperature in the refrigerated container must be constant all the time. There are two kinds of reefer containers: vent container and integrate container. Vent container is an old style insulated container which has no refrigeration system inside, but 2 vent holes in the front. Its refrigeration is carried out by the central refrigeration system or a specified refrigeration system installed on the boat. The use amount of vent container is decreasing. It is estimated that, the transport refrigeration system will all come to use integrate container in 2006. Integrate container has its own refrigeration system and the refrigeration capacity is approximately 5kW. The increasing trend of using integrate container is obvious. These systems are mainly use HFC-134a, R-404a, and HCFC-22 as refrigerant, R-407c is only used in rare occasions.

Marine Transportation and Fisheries Vessels Refrigeration: For the sake of providing cold-storage food to sailors and passengers, about 35,000 merchantmen all over the world are equipped with vessel refrigeration system, and most of these refrigeration systems apply HCFC-22 as refrigerant. The using cycle is about 30 years, yet the annual increment is pretty small.

Road Transport Refrigeration: Except for cold-storage containers, road transport refrigeration system includes those refrigeration system installed in van, truck, and tow truck. These kinds of refrigeration systems belong to discontinuous type. The sealed system uses eutectic plate and the open system uses liquid nitrogen, liquid CO_2 or solid CO_2.

In 1999, the sets of refrigeration tow trucks in using were estimated to be 300,000. While in 2000, it was estimated that in 15 countries of EU there were 120,000 pickup trucks, vans and eutectic systems, 70,000 medium trucks and 90,000 tow trucks, their average charges were 2, 5 and 7.5kg, respectively. In 2002, there were 1,200,000 road refrigeration systems in the world, 30% of which accounted for tow trucks, 40% for single truck refrigeration systems and the rest of 30% for dingus. The annually amount of maintenance accounts for 20-25% of the charge. The system which only need cold-storage function selecting HFC-134a as refrigerant, while R-404a and R-410a can be used in freezing system and other common refrigeration devices.

Railway Transport Refrigeration: North America, Europe, Asia, Australia and New Zealand all have railway transport refrigeration devices. Dry ice and ice are still used in discontinuous refrigeration system until now, while the continuous refrigeration system has used different refrigeration techniques. The refrigeration systems currently used in Asia primarily apply CFC-12 as refrigerant which is classified into the first level refrigeration (cold-storage) and the second level refrigeration (freezing or mixed use). For the sake of obeying the articles of law (EC No 2037/2000) about phaseout CFCs, the refrigeration systems in Europe have all turned to use HFC-134a. Some existing old systems in North America have turned to use HFC-134a as well, and new systems use HFC-134a and R-404a.

3.3.6 Centralized Air-conditioner (working temperature close to room temperature)

Large commercial centers are usually equipped with water-cooled centralized air-conditioners which include vapor compression type and absorption type. Based on the type of compressor, steam compressed centralized air-conditioners can be classified into centrifugal and cubage types.

Among the centrifugal centralized air-conditioners produced after 1995 in China, 30% of them used HCFC-123 and 70% for HFC-134a. Most of the screw type and scroll type used HCFC-22 as refrigerant。

(1) Steam Compressing Centralized Air-conditioner

Centrifugal air-conditioner: USA, Asia and Europe all can produce centrifugal centralize air-conditioners which mainly applied CFC-11, CFC-12, R-500, and HCFC-22 as refrigerant before 1993, among these refrigerants CFC-11 got the largest consumption. In 1993, it almost stopped using CFCs as refrigerant, due to the implementation Montreal Protocol. HCFC-22 was also barely used as refrigerant after 1990. Since 1993, most of the alternatives refrigerants are HCFC-123 and HFC-134a. HCFC-123 has relatively low effect to environment, and what's more, it can be used in the reconstructed centralized air-conditioner applied CFC-11 before. The maximum COP value of centralized air-conditioners using HCFC-123 as refrigerant is 7.8 (0.45kW/t). The operation pressure of the system using HFC-134a as refrigerant is higher than that of HCFC-123. The maximum COP value of centralized air-conditioners using HFC-134a as refrigerant is 6.6 (0.53kW/t). Centrifugal centralized air-conditioners can also use HCs and water as refrigerant。

HCs: HCs can be used as refrigerant of centrifugal chiller in petro-chemical factory. Since there are many dangerous chemicals, workers there have good security awareness. If accident happens, they can properly manage it in time. But, up to now, due to the combustible property of HCs, HCs can not be used as refrigerant in centrifugal chiller in other places.

Water: Water is rarely used as the refrigerant in centralized air-conditioner, because the cost is 50% higher than a traditional chiller. The increment of the cost results from the big volume and the complex compressor technology while using water as the refrigerant in central air-container.

Volume centralized air-conditioner: It always uses compressors types of screw, scroll, and reciprocating when producing volume centralized air-conditioners in many countries.

Screw type centralized air-conditioner: Most of which used HCFC-22 as refrigerant in the middle of 1980s. In the past several years, some air-conditioners of such type used HFC-134a as refrigerant. New refrigerant R-410a that needed high operation pressure was introduced in recently. Some countries in North Europe produced small quantity of screw type centralized air-conditioners which employed NH_3 as refrigerant. And attention must be paid to the irritating odor, toxicity, and flammability of NH_3.

Scroll type centralized air-conditioner uses HCFC-22, HFC-134a, R-410a and R-407c as refrigerants.

Reciprocating type centralized air-conditioners have two operation modes: water-cooled and air-cooled. Before carrying out Montreal Protocol, some small-size reciprocating centralized air--conditioners with the refrigeration capacity below 100kW used CFC-12 as refrigerant; a majority of the small-size reciprocating centralized air-conditioners and almost all the large-size reciprocating centralized air-conditioners used HCFC-22 as refrigerant. After carrying out Montreal Protocol, new reciprocating centralized air-conditioners used HCFC-22 and R-407c as refrigerants, and small part of them still used HFC-134a. Except for the refrigerants mentioned above, there were extremely small amount of water-cooled reciprocating centralized air-conditioners used NH_3 as refrigerant.

(2) Absorption-type central air conditioner

Since the absorption-type centralized air-conditioner is larger volume and more expensive than that of steam compression type. It is rarely used in western countries, only a few production in North America. Although the initial investment for absorption-type system is higher than steam compression type one, it has extremely obvious advantages: low power consumption and cheap operation expense. Therefore, it is widely used in Asian countries where the price of power is relatively higher. Asia countries, including Japan, China and South Korea, which are absorption-type central air conditioner's great use and production countries.

3.3.7 Alternative of HCFC-22 and HCFC-142b in XPS board Production

Some of the countries in the USA and Europe have started or already finished the ban of XPS boards foamed by HFCF-22 and HCFC-142b. Many factors should be integrally considered when selecting foaming agents, such as properties, impacts on environment, cost. Currently, although no perfect alternative has been developed, the primary ones are HFC-134a, HFC-152a, CO_2 and some other mixed foam agents, whose main properties are shown in the following table. The techniques when using these agents are exactly the same as those of former ones.

Table 3-4 Primary alternatives of foaming agents

	HCFC-22	HFC-134a	HCF-152a	CO2
Formula	CHF2Cl	CF3CFH2	CH3CF2H	CO2
Molecular weight (g/mol)	86.5	102.0	66.0	44.0
Boiling poing (℃)	-40.8	-26.4	-24.7	--
Psat at 25℃ (bar)	10.4	6.6	6.1	64.3
λ gas at 25℃ (mW/m.k)	11.0	13.6	13.4	16.6
Flammation limit (%vol)	--	--	3.7-18.0	--
ODP	0.05	0	0	0
GWP100yr	1,700	1,300	140	1

Since XPS boards are mainly used as insulation materials on walls, grounds, and cold rooms, the efficiency of heat exchange is the most important factor. Comparison between alternative and traditional foaming agents is present in the following Fig. This parameter of new agents is a little higher than those of traditional ones, but far smaller than that of air, therefore, these agents all can be applied as alternatives.

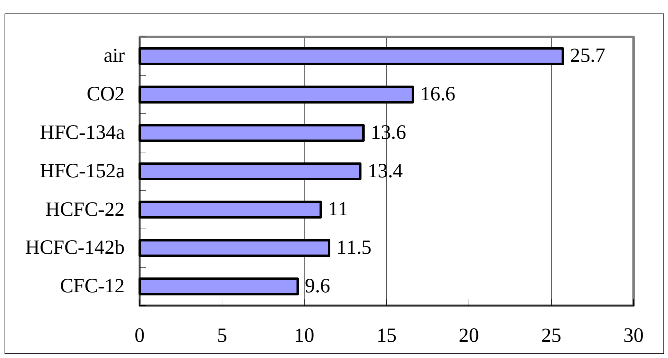

Fig. 3-1 Gaseous phase thermal conductivity of variable foaming agents at 25 ℃

(mW/m.k)

Gaseous components of foam changes as times pass by, air can diffuse into foam and meanwhile foam agent diffuse out until reaching the balance, therefore, the performances of XPS boards will change. Excellent foam agents should have stable and durable ability to keep constant temperature. Effective diffusion coefficient is usually used to indicate the diffusion property of the agents.

Table 3-5 Effective diffusion coefficients of variable chemicals

	HCFC-22	HFC-152a	HFC-134a	CO2
Effective diffusion coefficients (m^2/s)_	1.8×10^{-11}	1.6×10^{-10}	2.9×10^{-12}	1×10^{-10}
Relative value	1	8.9	0.2	5.6

From the two parameters listed above, HFC-134a is one of the best alternatives. However, its ability of solution is the maximal weakness, whose concentration can only be up to about 8wt%. This limits its application (such as low density XPS heat insulation plate). Moreover, GWP of HFC-134a is very high and may have an impact on global climate.

Currently used XPS production machinery can be retrofitted from use of HCFCs to CO2, HFC-134a, HFC-152, or ether, but this requires additional efforts for R&D. As the production of XPS in China is expanding rapidly, there is a good opportunity for providing incentives to industry to opt for alternative technology in new XPS production machinery when making investment decisions. A careful analysis of the incremental costs for shifting from HCFCs to alternatives would still be needed to determine the exact form of the incentives, which however is not provided in the present study.

3.3.8 Solvent Sector

The physical features of HFC-245fa are similar to those of HCFC-141b, while its compatibility is superior to HCFC-141b. The mixture of HFC-245 and alcohols can enhance its cleaning ability. In precise cleaning industry, HFC-245fa can be used to clean printed late boards, magnetic heads, relays, and kinds of communication, medical, and jewelry. The primary advantage of HFC-245 is that its ODP is zero and GWP is very low, which makes its impact on environment much weaker. However, its maximal sickness is the low boiling point, If using it to substitute HCFC-142b, the cleaning device should be reconstructed greatly. Moreover, the mixture of HFC-365mfc and alcohols can enhance its cleaning capacity. In cleaning industry, HCFC-141b can substitute HFC-365mfc in most occasions.

3.3.9 Substituting HCFC-141b in Foaming Industry

HFC-245fa is evaluated to be the best choice of HCFC-141b's alternatives. Numerous assessments have been carried on HFC-245fa, including the research on the compatibility of padding and food transportation conducted by American Household Associations of Manufactures (AHAM). Moreover, most of the primary electronics manufactures and their material suppliers have conducted their own assessment researches. The recent data suggests that: the efficiency of those refrigerators made by HFC-245fa foaming is equal to those made by HCFC-141b.

HFC-245fa is compatible to those metal, plastics and synthetic rubbers. Its total dissolvability in polyhydroxylated compound varies from good to excellent. The stability of the mixture of HFC-245fa and polyhydroxylated compound is quite similar to that of HCFC-141b system. As reported, better k-factors can be obtained in certain occasion. Compared the foams made by HCFC-141b with that by HFC-245fa, not only better k-factor is obtained, but also synthetic intension and space stability have been improved. The assessment from industries suggests that, compared with those made by non-ODS foaming reagent, the foams made by HFC-245fa have the best insulating property. HCFC-141b can be substituted by HFC-245fa in the application of variable kinds of sklero-polyurethanes and poly-fulminuric acid ester insulation materials, including those foams used in refrigerators and cooling closets, roofing, shroud and construction.

Beside the advantages of safety and environment protection, the insulation property of HFC-245fa is as good as that of HCFC-141b. The insulation property of HFC-245fa is better than other non-ODS products, like HCs and HFC-134a. HFC-245fa has significant effect on helping satisfy the increasing requirement of energy standards.

The gas phase heat conductivity of HFC-365mfc is the worst, only 1 mW/m.K higher than HCFC-141b, this property has been confirmed by the comparison experiment under or above room temperature. Therefore, HFC-365mfc can be one of the alternatives of HCFC-141b in foam industry.

3.4 Barriers to phasing out HCFCs in China

Nowadays, in China, although most enterprises have known the restrictions settled by the Protocol and some of them developed to produce products that apply R-407c or R410a to substitute HCFC-22 as refrigerant agents to meet the demand of international market and keep their own export share. From the overview, enterprises are primarily focusing on domestic markets and they haven't made a integral plan for phasing out HCFC-22.Without a sufficient consideration and preparation on consumption phase out of HCFC-22 and other HCFCs.

For HCFC-22 producers, currently, no limitation has been made on the production and investment on HCFC-22 and its production capacity and output keep a increasing trend. Although some of the enterprises have developed the alternatives of HFC, Most of them don't form a scale-effect, for one part poor technology and expensive cost, for another no market demand.

For HCFCs consumers, the market competition of their products is extremely serious, unless forcely regulated by the government, enterprises will not phase out the application HCFCs forwardly. Therefore, supports from policy, legislation, technology and financing are still needed for controlling and phasing out HCFC-22.

For other HCFCs products, production and consumption are still in the development stage. Without relevant pressure from international markets, the enterprises did not seriously consider alternatives, or available alternative technologies are not yet mature.

In the view of policy, according to the regulation by the Protocol, China is still allowed to use HCFCs for more than 30 years. Therefore, if market allows, enterprises will not phase it out in advance in the fear of harming their selves-development. While the competition in the domestic air–conditioner market is serious, profits remain at a low level. If the price of the new product is only a little higher, it can not enter the market successfully. Although China has issued a new standard of energy efficiency, it is not a compulsion standard. The advantages of energy efficiency from R410a can not be realized under the current regulation.

Patent for alternative is still a problem which results in a slightly high price of the alternative impaction its broadness and application.

The production of alternatives needs technique input, under the situation of no policy pressure and no market demand, enterprises would not forwardly invest in such areas. Financial support is in an urgent need.

Some barriers also exist in the application and broadness of new refrigerants. For those man-made refrigerant alternatives, like R407c or R410a, the technological requirements of air-conditioners' installation and maintenance is higher, which the current after-sales-service can not provide yet. For natural refrigerant alternatives, like HCs, the techniques for use in air-conditioners are not sufficiently available, safety is a significant issue, and therefore it is not yet suitable for wide application.

3.5 Proposals for Alternatives Development

Currently, the domestic refrigeration industry has already observed technology for phase out HCFCs. In room air-conditioner producers, some productions are compatible to R407c and R410a. At present technological condition, R410a, whose ODP is zero, HCFC-22 has a good application foreground, although its GWP value is pretty high, but its energy efficiency is excellent which can reduce the emission of green house gas and save energy. HCs has a good application foreground in future, but its application is limited by its safety problem. In commercial and industry refrigeration industry, although HCFC-22 is used widely at large, variable types of air-conditioners use different refrigerants, therefore, the alternatives are diversification.

For foaming industry, even now, the application of HCFC-141b substitutes CFC has not really been solved. The Industry Association shown a willing to develop those technologies that use HFC-245fa or HFC-365mfc directly, yet the primary obstacles are lying in the aspects of patent and price. Thus, most enterprises are appealing releasing patents, supporting alternative and providing proper financial support. At present, HFC-134a and CO_2 etc. are likely to substitute HCFC-22 and HCFC-142b in production of XPS boards.

In solvent industry, the possible choice to substitute HCFC-141b is HFC-245fa or HFC-365mfc, however, so far, there is no case of application in China.

In China, a huge international pressure is present on the controlling of HCFCs. For the sake of promoting the production and consumption of HCFCs, establishing a basis of implementing the Protocol, China should strengthen the development of alternative and its technology, at the current basis to choose key product for priority development and application. The principles China should stick to in the development and production of alternative include:

Sticking to the guideline of three synchronization about ODS production phasing out, consumption phasing out and promoting alternatives development and production. One of those basic guarantee of successfully phasing out ODS production and consumption is the suitable alternatives supply in the market. In other words, the collaboration of ODS control and phasing out and abundant market demand can also provide a capacious space for the development of alternatives. The maturation development of alternatives can in turn enhance the aim of phasing out ODS. Thus, the production of alternatives should be strongly reinforced. Firstly, ODS phasing-out strategy for variable industries should be satisfied, and meanwhile for international alternative market, sticking to the guidelines of synchronization of ODS production phasing out, consumption phasing out, and promoting alternatives developing.

Comprehensively considering the demand both at home and abroad, selecting high-qualified alternatives. Along with the carrying out of phasing-out activities, the request on variety, quality, and quantity of alternatives will be consistently increased. Thus, the development of alternatives should not only satisfy the demand of relevant industries suitable to the requirements of our existed domestic environmental policies, but also a comprehensive consideration about the production and variation of alternatives in international market and the environmental demand of the international society should be made. For the development of alternatives, besides considering the factors of technology and economy, the following principles should be confirmed: (1) adopting alternatives with GWP as low as possible or the alternative that has low integral green house effect; (2) adopting those chemicals with short life expectancy, but not persistent organic chemicals; (3) alternatives should have a good environment and health effect.

Emphasizing applied research and marketing broadness of alternatives. In the procedures of alternative development, applied research and marketing broadness of alternatives should be emphasized all the time. Let customers understand the purposes, usage, and advantages of alternatives. Due to the application of alternatives it would impose new requirements on the facilities and production technologies on consuming industries, therefore, applied research should be reinforced, demonstrating activities should be held regularly and the experience should be summarized, publicized, and popularized in time.

Exerting the function of policy management sufficiently. To encourage the development, production, and applicatin of alternatives on national policy level and provide policy assurance for distribution and use of alternatives. Due to alternatives have not acquired advantages on price and technical aspects, policy assistance should be provided, including standards of production, taxing, market entrance admission building a friendly policy environment for development, production, and use of alternatives. During the implementation of Montreal Protocol, the government of China has produced and enacted a series of policy and regulations and has achieved the expected effect. The current policies on ODS in China are seemly comprehensive, and yet some problems still exist. Some of the policies lack definite regulations on the penalty of convictions. Along with the the development, importing, and application of alternatives, many of those former technical standards and regulations should be amended and new policies and standards should be set up in order to secure the implementation of relevant policies and regulations successfully.

New alternative should possiblly use CTC as raw material. CTC is the primary material of CFC in China. Along with the phasing out of CFC, the production of CTC decreased from 65,000 MT (1997) to 36,218 MT (2003), the purposely production of CTC is decreasing by year. However, as the demand of dichloroethene and trichloromethane increased rapidly, the amount of CTC as by-product increased rapidly. According to the policy, the producer of by-product CTC must avoid the CTC used as raw material of CFC or ODS; they must assure that the by-product CTC only used as raw material of non-ODS or destroyed by the technology approved by Contracting Party. Therefore, the ODS alternative which used CTC as raw material should be developed first. There are steady sources of CTC and can save the cost of destroy. It can reduce the influence to environment by the burning of CTC.

Pay attention to the impact of development and demand of alternative by the energy policy. Raise energy efficiency is an important industry policy in China. Some industries including construction, refrigeration and etc. had or would publish new energy consumption standard and requirement on conservation of energy. It would affect the demand of alternative in these industries, which include the demand on its performance and quantity. Therefore we should pay a sufficient attention when establish the develop strategy of alternative.

Considering the influence of choosing alternative by Kyoto Convention properly. As "reduce the harm to human health and environment" is the ultimate goal of phasing out ODS, therefore, in the process of alternative development, GWP should be considered seriously. In some areas, high GWP alternative can be used as alternative when other alternatives can not satisfy the demand of security, quality, or may bring serious influence to human health. This application area should be restricted.

Chapter 4 Forecast of HCFCs Demand in the Future

Production and consumption of HCFC-22 covers more than 80% of the whole, and HCFC-141b covers 10% of the whole in China; within this HCFC-22 is increasing rapidly in parallel with the increase in room air-condition demand.; HCFC-141b is mainly used as foaming agent and solvent, and its forecasted demand of production and consumption approaches to the economy development. Therefore, trend of HCFC-22 and HCFC-141b demand and production development in the next 10 years is briefly forecasted as follows. Considering that HCFC-22 production methods are already mature in China and future development mainly depends on market demand but not the limitation of production capacity, the method for forecast is set up from bottom up top.

Usages of HCFC-22 in China contain ODS consumption and feedstock consumption. ODS consumption includes: (1) refrigerant in room air conditioning sector; (2) refrigerant in the industrial and commercial conditioning sector; (3) as component of blend foam in foaming industry; (4) a small part is used in other sectors. Feedstock consumption includes: (1) a large quantity for TFE/PTEF production; (2) a small part for other polymer production.

HCFC-141b is mainly used in foaming sector and solvent sector, and without any other usages. Consumption in foaming sector plays the leading role.

4.1 Methodology for the Forecast

The basic methodology used is: "Differentiate the exact purpose in each consumption sector, then specify the consumption amount purpose to purpose". Discriminate the purposes of HCFC-22 in a certain sector and according to the characteristic of certain sectors, analyze the consumption amount of HCFC-22 in each unit for producing or servicing, and then calculate the total consumption amount of HCFC-22 for this certain purpose by estimating the output of the new unit or the volume needing service. Based on the information available and integrated, for the HCFC-22 consumption demand forecast, we specify each purpose, take into consideration the historic data, the increasing rate and consuming characteristic of each purpose, estimate the demand of HCFC-22 consumption during 2005-2015, and then get the total consumption in China by summing up the consumption of each purpose and sector.

HCFC-141b consumption in the next 10 years is forecasted according to the developing trend of consumption amount (distribution consumption) in foaming sector and solvent sector in the past few years.

4.2 Consumption Forecast of HCFC-22 in Room Air conditioning Sector (ODS Consumption)

Room air conditioning sector in China can be divided into two parts: some for domestic consumption, almost all with HCFC-22 refrigerant; some for export, mostly with HCFC-22 refrigerant and a small part with R-410a and R-407c, and percent of R-410a and R-407c air conditioning will increase rapidly for the realization of control target for non-article 5 parties of Montreal Protocol. Since the import is too limited, the import data is neglected here. General structure of the sector is shown in Fig. 4-1.

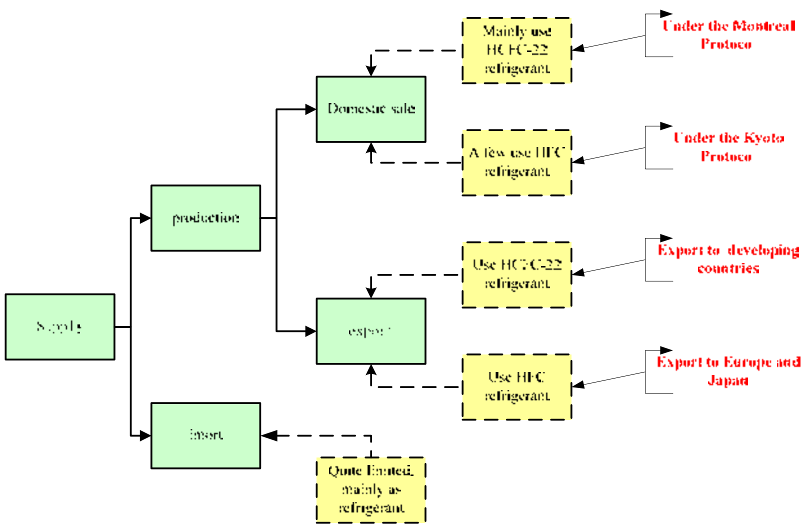

Fig. 4-1 Provision and distribution of room air conditioning with different refrigerant in China

4.2.1 Historic Situation of Room Air Conditioning Sector

Historic situation of room air conditioning production: Room air conditioning sector is the main HCFC-22 consumer in China. According to <China Statistical Yearbook 2006>, during 1991-1993, increasing rate of Room air conditioning production reached up to 144%; during 1994-1998, it was 23%; during 1999-2004, it was 41%. According to data from CHEAA (China household electrical appliances association), output of Room air conditioning in 2005 is 67,650,000 units. Sum up the annual output during 1995-2004, shown as the blue histogram in Fig. 4-2.

Historic situation of Room air conditioning sector export: Export of room air conditioning in China started from middle of the 1990s, and kept a rapid increasing after that. During 1995-2004, the average increasing rate of export is 59%, shown as the red histogram in Fig. 4-2. According to <China Statistical Yearbook> and CHEAA, room air conditioning export in China is 8,070,000 units, 16,440,000 units and 23,340,000 units in 2002, 2003 and 2004 respectively, and main countries and regions for export are shown in Table 4-1. Most of the air conditioning export use HCFC-22 refrigerant and only a few use R-407C and R-410a alternative refrigerant. Rate of air conditioning with alternative refrigerant will increase with the phaseout of HCFC-22. R-407C and R-410a air conditioning are mainly exported to Europe and Japan; export of air conditioning with non-HCFC-22 refrigerant will increase year after year.

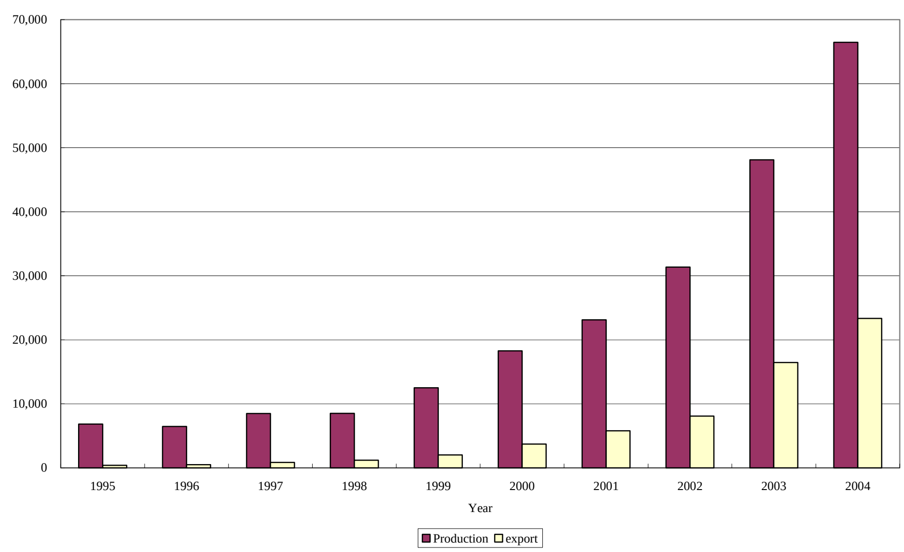

Fig. 4-2 Historic production and export of room air conditioning in China (1,000 units)

R-407C and R-410a are blends composed of HFCs, so with a zero ODP, but are controlled in Kyoto Protocol for the high GWP. Production and consumption of R-407C and R-410a is restricted after Kyoto Protocol becomes effective. For R-407C is non-azeotropic blends with a 6K temperature glide, and is not as steady as R-410a (azeotropic blends), so R-410a air conditioning account for most of the total export in 2005.

Table 4-1　Main Countries and Regions for Air Conditioning Export of China in 2002

Countries and regions	Number (1,000 unit)	Countries and regions	Number (1,000 unit)	Countries and regions	Number (1,000 unit)
Italy	426	Japan	1,252	USA	3,125
Greece	256	Hong Kong	599	Canada	152
Spain	222	Indonesia	172		
Turkey	103	Israel	117		
France	103				
Total in Europe	1,450	Total in Asia	2,942	Total in North America	3,278

Historic situation of Room air conditioning sector import: According to <Yearbook of China's Foreign Economic Relations and Trade>: number of air conditioning import in China is small all the time; and the consumption percent of air conditioning import is also small, with an average rate of 0.32% during 1995-2004. Thus, this study neglects the import data when calculating number of room air conditioning owned and for service.

Historic situation of number of Room air conditioning sector owned: According to CHEAA, scrap age of middle size and small size household electrical appliance is 8-12 years, and this study assume the average scrap age is 10 years and there is a certain scrap rate in each year. After the scrap at the end of each year, summation of the air conditioning in use is the number of room air conditioning owned that year.

4.2.2 Consumption Forecast of HCFC-22 in Room Air Conditioning Sector

Consumption forecast of HCFC-22 air conditioning in China: During 1999-2004, the average increasing rate of air conditioning consumption is 35%. This high increasing rate indicates that air conditioning in China is in a state of quick increasing, but not the long-term status. We assume that increasing rate of air conditioning consumption during 2005-2007 is 10%; during 2011-2015, for the gradual saturation of the air conditioning market in China, we choose an increasing rate equal to the average increasing rate of GDP (7%); during 2008-2010, the increasing rate is the average of the two rates in the two periods (8.5%).

Export Forecast of HCFC-22 Air Conditioning: According to control target of HCFC-22 consumption for non-Article 5 Parties to Montreal Protocol, each member has established policies for HCFC-22 air conditioning control. From Jul.1st 2002, EU prohibited use of HCFCs in fixed air conditioning produced after Jun.30th 2002 with a refrigeration capacity less than 100kW. Because refrigeration capacity of room air conditioning is about 3kW, EU prohibited the import and use of new room air conditioning with HCFC-22 from July 1st 2002. From Jan. 1st 2010, USA, Canada and Japan will prohibit use of HCFC-22 in new refrigerators, so the three countries will not import any refrigerators and air condition containing HCFC-22. Non-Article 5 Parties like EU, Japan, USA and Canada are main export countries of China, however recent years, export to developing countries also increases rapidly. Therefore we can foresee that export of HCFC-22 air conditioning to developing countries will quickly decrease by Jan. 1st 2010, while that to developing countries will continue increasing. According to historic data, average increasing rate of air conditioning export is 50% during 1995-2003; also according to policies of main export countries, number and increasing rate of air conditioning export will be zero during 2010-1015; so we assume the increasing rate to be 14% during 2004-2007 and 7% during 2008-2012.

Other correlative parameters: According to data from CHEAA, other parameters include: average filling amount of HCFC-22 for new air conditioning is 1.35kg/unit; servicing amount of HCFC-22 for one time is 1kg/unit; average scrap age is 10 years and there is a certain scrap rate in each year, but in the first two years scrap rate is zero.

Calculate expressions for consumption of HCFC-22 in air conditioning sectors:

(1) Calculate expressions for consumption of new air conditioning:

HCFC-22 amount for new AC at one year = (domestic consumption of AC at that year + export of AC at that year)* average filling amount of HCFC-22 per unit

(2) Calculate expressions for servicing amount:

Servicing amount of HCFC-22 at one year = servicing amount of HCFC-22 for each AC *

（Servicing amount of HCFC-22 closely related with the air conditioning owned at the same year)

(3) Calculate expressions for total consumption:

Consumption of HCFC-22 in Room air conditioning at one year = Consumption of HCFC-22 in new AC + Servicing amount of HCFC-22

According to the three expressions above and other correlative parameters, estimated HCFC-22 consumption as room air conditioning refrigerant during 2005-2015 is shown in Fig. 4-3. There is a shape decline for filling amount of HCFC-22 in new AC in 2010, which also causes the decline for total consumption of HCFC-22 in room air conditioning sector in 2010. (Total area stands for the total consumption amount). But consumption is likely to continue increasing later on.

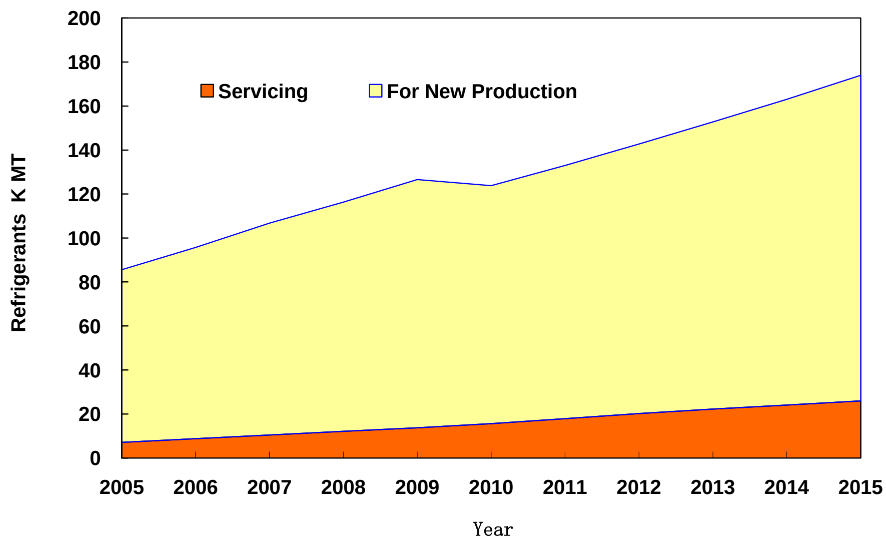

Fig. 4-3 Estimated H CFC-22 consumption for Room air conditioning

4.3 Consumption Forecast of HCFC-22 in Industrial and Commercial Sector (ODS Consumption)

In the phaseout of ODS in China, the industrial and commercial refrigerating equipment include: refrigeration with capacity more than 500 liters, such as commercial refrigerator, food showing cabinet, cold drink machine, ice maker, refrigerator car; central air conditioning; water chiller with refrigerate capacity more than 25kW; unitary air conditioning with refrigerate capacity more than 7kW.

4.3.1 Historic Consumption of Industrial and Commercial Refrigeration Sector

It is quite complicated and difficult to classify and statistic refrigerating equipment, for the widely use of industrial and commercial air conditioning sector. There are mainly five categories according to different purpose: commercial refrigeration, deepfreeze and refrigeration process, industrial refrigeration, transport refrigeration and central air conditioning.

Commercial refrigeration: Commercial refrigeration is springhouse and exhibitory cabinet for fresh food and drink, with two control temperatures for chilling and deepfreeze. Through investigating number of individual refrigerator devices (close), average cooling capacity, average filling quantity; number of small-size refrigerator devices (open, with one or two compressors, out of the selling areas), average cooling capacity, average filling quantity; number of central refrigerator devices, average cooling capacity, average filling quantity, we can sum up these parameters and get the general status of HCFC-22 in commercial refrigeration. However, this direct method is too complicated and difficult to do. So here, we try to set up an inquisition: to investigate number of supermarkets, total selling area for fresh and frozen food, type of the refrigerator devices and average filling amount of each type. We try to set up a relationship between consumption of HCFC-22 in commercial refrigeration and selling area in the supermarket. However, for the limit of data available, we take HCFC-22 consumption in industrial and commercial refrigeration instead of that in commercial refrigeration, and production value for trade and retail of food and beverage industry instead of selling area in the supermarket.

Deepfreeze and refrigeration process: Deep freezer in China is mainly used for food cold storage and refrigeration process. As the same to industrial and commercial refrigeration, we try to set up an inquisition to investigate annual consumption of frozen and deepfreeze food, and also the relationship between consumption of frozen and deepfreeze food and consumption of HCFC-22.

Industrial refrigeration: Industrial refrigeration contains refrigeration for special purpose and those of large size. These devices are often fixed on the spot after customized for their special use. In industrial refrigeration, evaporation temperatures vary from -70℃ -15℃, and corresponding cooling/warming capacity varies from 25kW-30MW (axle power). According to cooling capacity and requirement of different usages, compressors in this refrigeration can be reciprocating, screw rod or centrifugal type. Different statute in different countries causes the different technical development in industrial refrigeration. From 1st January 2001, HCFC-22 and HCFC-22 blends are prohibited in new devices in Europe.

Transport refrigeration: Transport refrigeration is mainly used for transporting frozen and deepfreeze food. Transport methods contain transporting by container, by sea, by fisher boat, by road, by railroad and by air. Compared with other refrigerator processes, technological requirements in transport refrigeration are higher. It is because that during the transporting, the refrigeration condition is relatively execrable and the refrigerant is easy to leak out. Container transporting is the most important son-sector, and number of containers is increasing rapidly. HFC-134a, R-404A and HCFC-22 are major refrigerants in the system, and R-407A is used in very few cases.

Central air conditioning (working temperature close to room temperature): Water-cooling central air conditioning is often used in large emporiums, containing vapor-compression and absorption central air conditioning. According to different types of compressor, vapor-compression type contains centrifugal type and volumetric type; volumetric type contains screw rod type, scroll type and reciprocating type.

Domestic demand, production capacity and export potential of central air conditioning are all increasing rapidly. Consumption of central air conditioning of centrifugal type increased observably in the 1990s. The central air conditioning of centrifugal type depended on import before 1995 and after then mainly on domestic production, 30% with HCFC-123 refrigerant and 70% with HFC-134a. Most of the screw rod and scroll type use HCFC-22 refrigerant. After 1999 when China canceled electricity limits for commercial purpose, amount of absorption type declined. At present, central air conditioning with fan heat pipes account for a large market of residential warming.

4.3.2 Consumption Forecast of HCFC-22 in Industrial and Commercial Refrigeration

In the "Sector plan for phasing out of CFC-11 and CFC-12 in China industrial and commercial refrigeration sector", according to sector strategy in 1995, China has promised to phase out ODS in industrial and commercial refrigeration sector by two stages and accomplish conversion to HCFC-22 refrigerant in the first stage (21 of the 24 items). Because there is no HFC-134a production in industrial scale and the special lube and service is poor in China, HCFC-22 technique is the best choice at present. China government will invest to accomplish technically conversion from HCFC-22 to non-ODS when feasible technique for non-ODS is mature.

HCFC-22 consumption in industrial and commercial refrigeration sector is the same as in room air conditioning sector, containing two parts: HCFC-22 filling amount for new AC and for service. Based on estimation by WANG Shiguo[1], estimated HCFC-22 consumption in industrial and commercial refrigeration sector during 2005-2015 is given in Fig. 4-4.

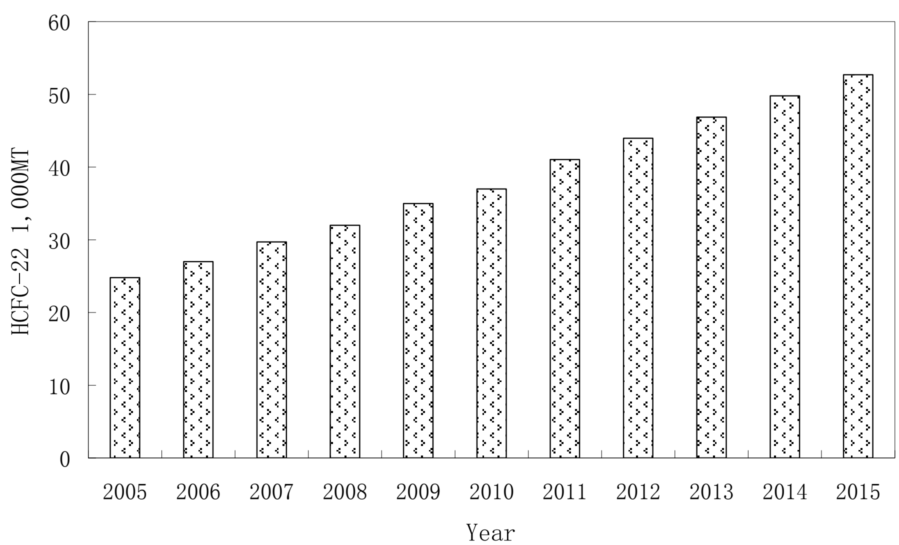

Fig. 4-4 HCFC-22 Consumption in Industrial and Commercial Refrigeration Sector (including new filling and servicing)

4.4 Consumption Forecast of HCFC-22 in Foaming Sector

HCFC-22 is mainly used for XPS (Expanded Polystyrene) board production, and demand of this heat preservation material increases rapidly as a result of the new standard for building energy saving in China. Through an elementary investigation, there are 150 producing lines with producing capacity of 10,000,000 m^3/year in China, production in 2005 is about 1,000, 000～3, 000, 000 m^3 with 5,000～10,000 MT HCFC-22 consumption as foaming agent; increasing rate of production is more than 20%.

XPS is a kind of rigid foam with closed cell structure through hot-extrusion process, and is composed of polystyrene resin or its copolymer with a few additives. It was developed in 1950s or 1960s. It has the excellent and constant adiabatic performance, particular strong resistance to steam osmosis performance, very high compressive strength, and is easy for machining and fixing, so is widely used all over the world. Owens-Corning Corp. invested and built a producing line with producing capacity of 100,000 m^3 in Nanjing, after its putting into production, it quickly exploited a new market share and got a high acceptance, also gained a good benefit. At present, the second producing line is to put into production. Besides, several Taiwanese enterprises also set up producing bases in Jiangsu and Beijing, their products are entering into the market.

During the several decades after XPS product is developed, XPS board is used in all kinds of building structures and accumulated mature experiences. It is used as heat preservation material in resident buildings, especially as roof heat preservation material, and there are also some successful applications in commerce and industry. For example: Osaka airport in Japan, Headquarters Building of McDonald's in America, Marineland in Florida, central tunnel in Norfolk city of Virginia, runway of Newton airport in Maine, large chiller of Marriott in Massachusetts, etc. XPS is also used in some new-style buildings in China, e.g. building of Bank of China and Oriental Plaza in Beijing, Coca Cola factory in Shanghai, Ice Cream Factory of Nestle in Guangzhou, etc.

Since the first producing line of XPS put into production in China in 2000, market share of XPS increased rapidly for its special adiabatic performance, low bibulous rate and higher producing efficiency, and there is also a certain developing potential.

Because the sector is in a developing stage, we can only do a simple forecast. Increasing rate during 2006-2010 is supposed to be 9% and that during 2011-2015 is 7%.

4.5 Consumption Forecast of HCFC-22 in Other Sectors (ODS Consumption)

In foaming sector, the primary alternative for CFCs foam is HCFC-141b, and a small quantity of HCFC-22 is used as component of transitional blend foam. However, the boiling point of HCFC-22 is obviously lower than that of CFC-11 (the primary CFCs foaming agent), and large investment in technique and device alteration is required to accomplish conversion from CFC-11 to HCFC-22, so HCFC-22 is not widely used at present. Now among Article 5 Parties, except HCFC-22 and CFC-11 used as foaming agent for rigid foam (used as heat preservation material in domestic refrigerator and air conditioning) in Latin America, HCFC-22 consumption as foaming agent in other countries is negligible. As a whole, consumption in this field is very limited, so we neglect the data here.

There is also little HCFC-22 consumption in fire-protection industry etc., but is neglected here.

4.6 Consumption Forecast of HCFC-22 for PTFE Production (Feedstock Consumption)

HCFC-22 is material for many fluorinated fine chemicals and mainly for PTFE. For the better character than other engineering plastic, PTFE becomes one of the most indispensable new materials used in petrol chemical industry, engine, electronic, aviation, biomedicine, construction, national defense and war industry and advanced science and technology, etc. PTFE, as the major fluorinated polymer, is high-tech product with high additive value, and produced only in few developed countries like America, Japan and Europe, and America is one-up in scale, varieties and sales. PTFE industry in China started in the 1960s, developed in 1990s, and developed quickly in the recent 10 years. In 2004, a new production device with capacity of 10,000-15,000 MT/yr was put into production. However, for the uneven distribution of fluorspar resources in China, 80% of the flour-chemistry industry centralized in Zhejiang, Jiangsu, Shanghai and Liaoning. PTFE product in China is mainly for domestic consumption and some for export. Increasing of domestic consumption depends on domestic market, and increasing of export depends on international market.

International market: American DEVOT consulting corporation pointed out that polymer department is in a five- year period of circulation and is to decline after the peak year 2007 or 2008. However, whether the Middle East could keep economy and polity steady, and China had the ability to carry out all the production plans both have an effect on the polymer market. For the good performance and low price, PTFE hold 50-60% of the total production capacity in the world, and the total demand will increase at the rate of 3-4% for the satiety terminal market. In the next 3-5years, increasing rate of PTFE demand in Asia is hopeful to reach 5-10%, and become the area with highest increasing rate. Therefore, we assume increasing rate of PTFE export in China is 4%, equal to the increasing rate of the world demand.

Domestic market: PTFE consumption holds more than 90% of the fluorinated polymer. However, since the undeveloped production technique and laggard checking measures can not meet the demand of technology and product quality control, PTFE produced in China is mainly used in chemical antisepsis and engine fields, and only few used in device and pipe lining or thruster, and even fewer in electric field (most depend on import). Therefore, we can see PTFE in China export a lot and import a lot for the difference levels and usages. Therefore, we use the apparent domestic demand in the report, which is the summation of domestic production and net import, and estimating the PTFE demand in future according to increasing rate in domestic market. According to historic status and developing trend, ZHU Shun forecasted that increasing rate of PTFE in the next few years is 10% in China.

Production process for PTFE and material conversion proportion for HCFC-22: PTFE is polymerized from TFE (no material transformation), production process for TFE is as follows:

$$\mathbf{2CHClF_2} \longrightarrow \underset{\mathbf{(TFE)}}{\mathbf{C_2F_4}} + \mathbf{2HCl}$$

According to the equation above, theoretic conversion proportion for TFE is: one MT TFE needs 1.73 MT HCFC-22. But there is a great deal of other by-products like CHF_3, $CClF_3$, C_3F_6 and C_4F_8, etc., so conversion proportion for TFE in China is about 2.0-2.1, while 1.8 in DuPont Company. In the report, we choose the average proportion: one MT TFE needs 2.05 MT HCFC-22.

As a whole, PTFE production and HCFC-22 consumption for PTFE production in 2005-2015 is shown in following fig.

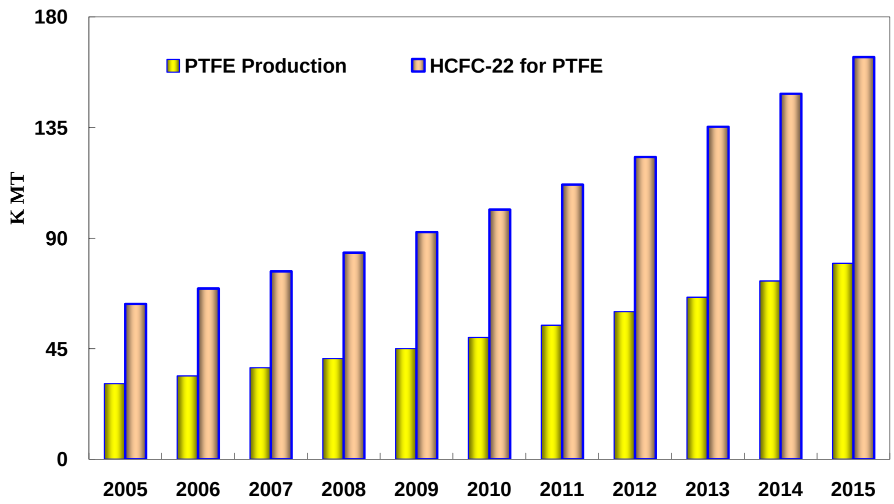

Fig. 4-5 PTFE production and HCFC-22 consumption as feedstock for PTFE in China

4.7 Consumption Forecast of HCFC-22 for Halon-1211 Production (Feedstock Consumption)

Halon-1211 is one of the synthetically products of HCFC-22, and is mainly used in fire fighting sector. The particularity of Halon-1211 is that it is in control list of Annex A in Montreal Protocol. According to “Sector plan for phasing out Halons in China Fire Fighting Sector” amended in 1997, Chinese government promise to phase out Halons on condition that Multilateral Fund is supported on schedule. The important measure for phasing out Halons is to execute permit and tradable output quotas, which can reduce the uncertainty in implementing the strategy. Quotas system together with fund support will encourage enterprises to phase out by inviting public bidding. The sector plan contains three stages:

The first stage, from when fund is warranted by Executive Committee of MLF until 2000. Annual production of Halon-1211 is to decrease from 9,950 MT to 3,980 MT;

The second stage, from 2001 to 2005, annual production of Halon-1211 will continue to decrease to 1,990 MT;

The third stage, from 2006 to 2010, the residual Halon-1211 of 1,990 MT is to phase out.

According to <Sector plan for phasing out Halons in China Fire Fighting Sector>, production of Halon-1211 is to be 1,990 MT in 2005, with 1,194 MT HCFC-22 as feedstock; after January 1st, 2006, there is no Halon-1211 production and also no HCFC-22 consumption as feedstock.

4.8 Total Forecast of Production and Consumption of HCFC-22 in the Next 10 Years

As a whole, HCFC-22 consumption as ODS, feedstock and total consumption in the next 10 years is shown in the figure below. It shows that under the existing society, economy and policy status, phasing out HCFC-22 containing equipment from 2010 in the major export countries of China, which would cause a decrease in refrigerators production and HCFC-22 consumption, HCFC-22 consumption as ODS, feedstock and total consumption before 2015 will continue increasing. It is obvious that in the next 10 years, China will be one of the most important countries of HCFC-22 consumption and production, and management and control in China holds the balance.

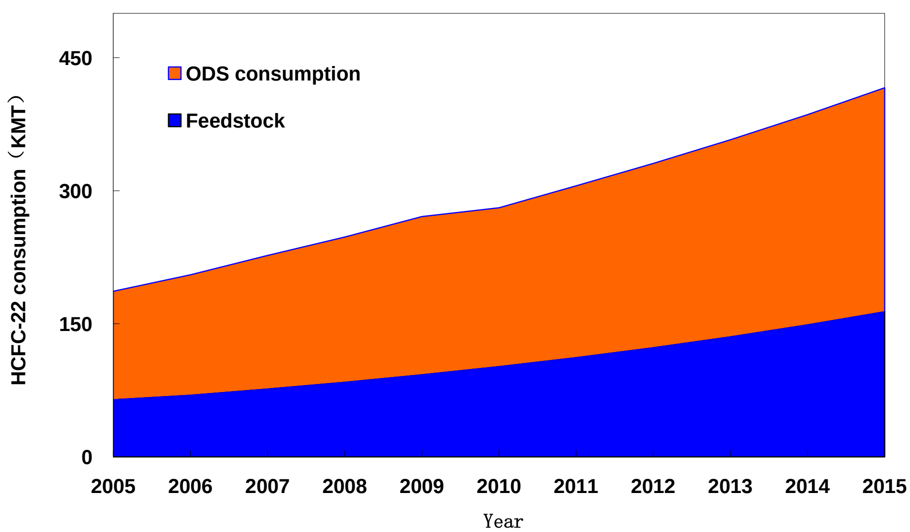

Fig. 4-6 HCFC-22 consumption as ODS and feedstock and total consumption in China

Note: summation of the area is the total consumption of HCFC-22 in China.

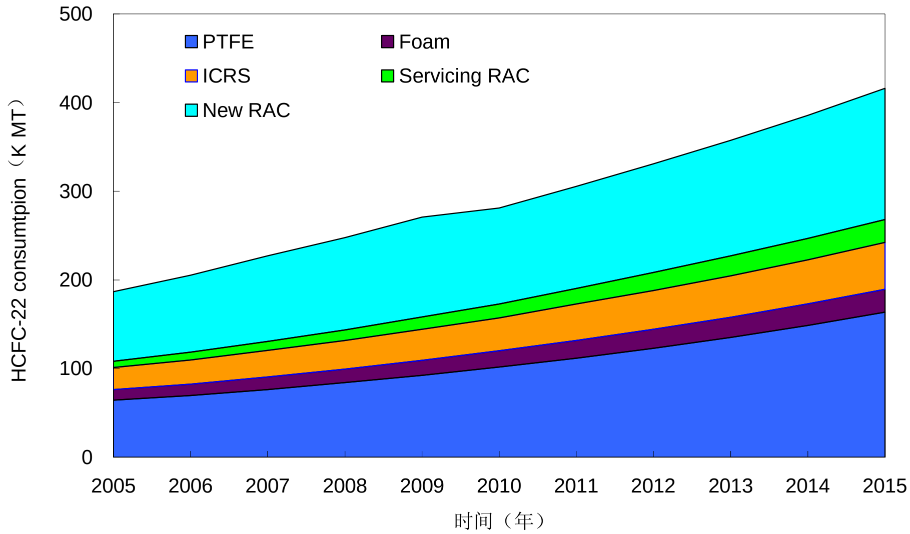

Fig. 4-7 Forecast consumption demand in different HCFC-22 sub-sectors

Summation of consumption, export and production is in following Fig. It shows that HCFC-22 export increases slowly, and mainly exports as feedstock to America and Korea; annual increasing rate of HCFC-22 production during 2004-2015 is up to 10.2%. There is hardly any HCFC-22 import in China, so production is summation of the export and consumption, which is shown as the total area in Fig. 4-8.

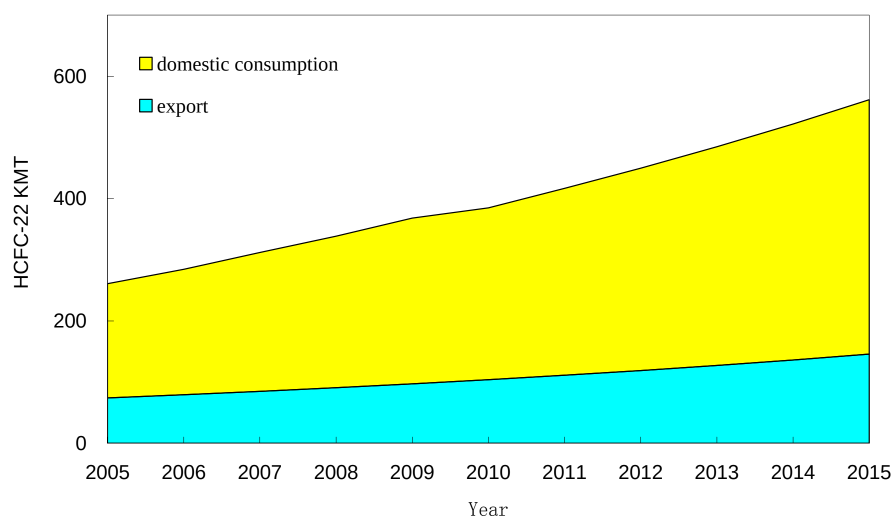

Fig. 4-8 HCFC-22 Consumption, Export and Production in China

4.9 Environmental Effect Caused by HCFC-22 Production and Consumption in the Next 10 Years

Because HCFC-22 is both ODS and greenhouse Gas (thereafter GHG), with a GHG by-product HFC-23, both of which may cause serious effect to the environment when let off to the atmosphere. In order to calculate the effect, first calculate the amount of HCFC-22 and HFC-23 let off through expressions; then calculate ODP and GWP of HCFC-22 and HFC-23 let off, ODP and GWP here shows environmental effect caused by HCFC-22 and HFC-23 actually let off to the atmosphere in the year. We neglect feedstock leakage when calculating release of HCFC-22, it is because that: first there is no reified control target or measures for the leakage in Montreal Protocol, second is lack of inquisitional data. When calculating release of HFC-23, the parameter 1.5% is based on methodology AM0001 in CDM item (releasing rate of HFC-23 in enterprises lack of monitoring data will adopt 1.5%); according to IPCC, rate of HFC-23 let off is 3-4% without reduce measurement; also according to data given by producers in “China-Italy: The workshop of China HFC-23 CDM project global”, we can affirm that actual amount of HFC-23 in HCFC-22 producers in China is 3%, therefore we choose 3% for calculation in the study.

Environmental effect of HCFC-22 production and consumption is in Fig. 4-9 according to the method above. It is obvious that global environmental effect by HCFC-22 production and consumption is stronger and stronger during 2005-2015. In 2015, GWP of relevant let off will be 409,000,000 MT CO_2.

Emission of HCFC-22 = Servicing amount in refrigeration sector + leakage amount in foaming sector + leakage amount of feedstock during transportation and producing process

Emission of HFC-23 = Production of HCFC-22 * 3% - Disposal amount in CDM item

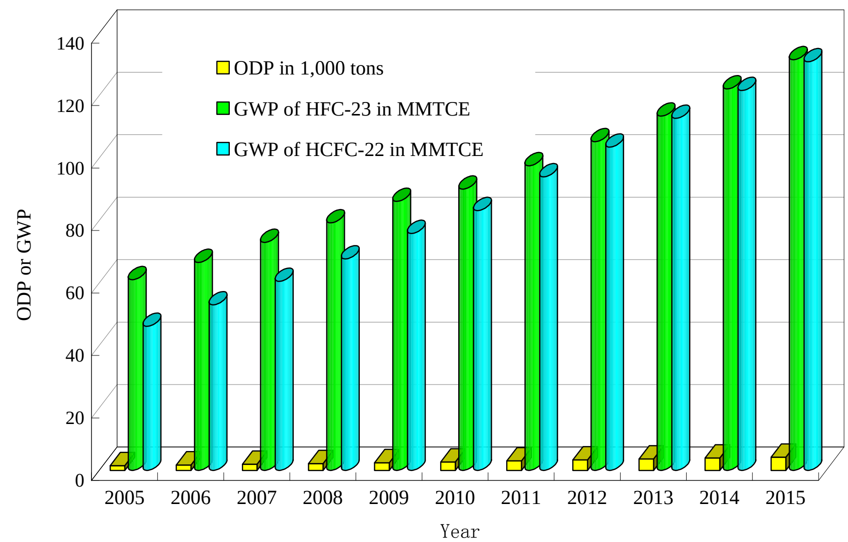

Fig. 4-9 Environmental Effect Caused by HCFC-22 Consumption in China

4.10 Consumption Forecast of HCFC-141b

Consumption forecast in foaming sector

From sales data of producing enterprises, HCFC-141b consumption as foaming agent increased from 4,638 MT in 2000, 7,748 MT in 2001, 10,669 MT in 2002 to 18,271 MT in 2003. Through an elementary investigation of data in 2005 and 2006, consumption (sales) above continues increasing, but with a slower increasing rate. Because there is no sufficient data support in the sector, the study simply adopts the projected increasing rate of national GDP to estimate the development in this sector. Increasing rate of 8% during 2006-2010 and 6% during 2011-2015 are used to estimate the consumption of HCFC-141b in foaming sector.

Consumption forecast in solvent sector

Market share of HCFC-141b as solvent in China is low. According to data for 2000 to 2003, consumption of HCFC-141b is less than 1,000 MT, calculated with the same parameters above.

Summarization of consumption in the two sectors is in the figure below.

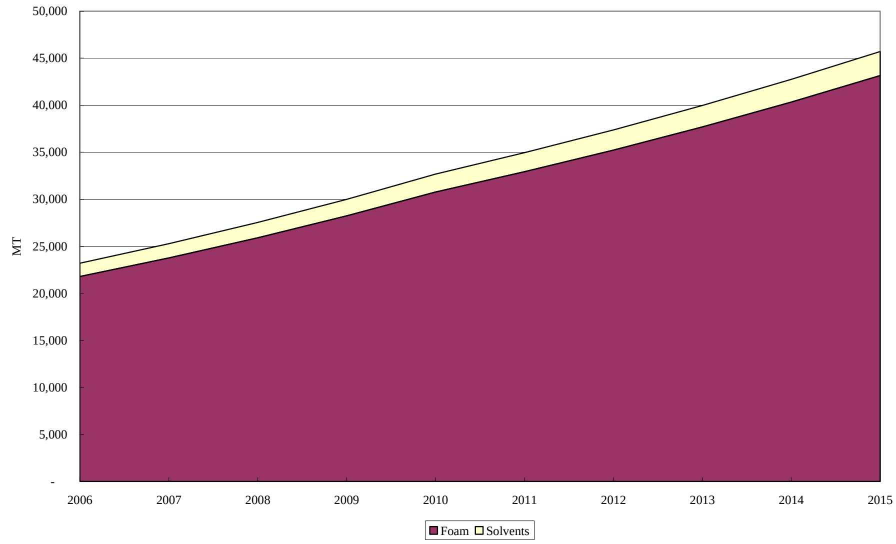

Fig. 4-10 Demand of HCFC-141b in the next 10 years

4.11 Brief Summary

4.11.1 Summarization of the Estimation

Without the restriction of the Montreal Protocol, forecasted consumption of HCFC-22 and HCFC-141b would be increased in the next 10 years in China. It is estimated that the HCFCs consumption would be increased from 140,000 MT (~ 8,900 ODP tons) to 210,000 MT (13,000 ODP tons) in 2010 and 300,000 MT (18,000 ODP tons) in 2015 respectively.

4.11.2 Shortage of the Estimation Result

In fact, HCFCs production and consumption during 2005-2015 is likely to be lower than estimated for the five factors below, which may cause production and consumption less than that in the protocol in Article 5 Parties. Prescription in Montreal Protocol for Article 5 Parties is ‘to have the maximum production and consumption without any limits”; but actually, control in non-Article 5 Parties is inevitable to have indirect effect on HCFCs production and consumption in Article 5 Parties.

(1) In the next few years, whether there is MLF support or not, many producers especially MNC in Article 5 Parties may reduce production of HCFCs, even to close some relevant production devices.

(2) Non-Article 5 Parties will prohibit import devices containing HCFCs with the development in phaseout process. Article 5 Parties such as China and India, who export the devices, have to turn to non-HCFCs technique in order to keep their market quotient, which also quicken the process of conversion to non-HCFCs technique in air condition consumption at home.

(3) The quick decline of HCFCs consumption in non- Article 5 Parties will result in a rationalization production that only minority producers have the devices for HCFCs production. This will cause a price rising which can quicken the conversion to non-HCFCs technical in Article 5 Parties; of course, there will be no effect if Article 5 Parties set up large-scale production of HCFCs. At present, China has already had strong production capacity, up to 319,500 MT in 2004, so there would not be great effect on HCFCs production and consumption in China.

(4) HCFCs trade between parties and “non-parties” is prohibited in Beijing Amendment. Non-parties refer to countries with HCFCs consumption but have not ratified Copenhagen Amendment or countries with production but have not ratified Beijing Amendment, and HCFCs trade is prohibited there. By March 2005, among the 189 countries ratifying Montreal Protocol, there are still 23 countries have not ratified Copenhagen Amendment and 98 countries have not ratified Beijing Amendment. Now in countries and regions with large production and consumption like USA, Japan and EU have already ratified the two amendments, and China ratified only Copenhagen Amendment but not Beijing Amendment. In 2002, export of HCFC-22 exceeded 40,000 MT and HCFC-141b is 13,000 MT, 72% export to Korea and Thailand and other non-parties of Beijing Amendment, and 27% export to Korea, 28% to parties like America and Japan, export to America is mainly for feedstock consumption.

(5) Besides, some of the Article 5 Parties do not take measures according to the control target in Copenhagen Amendment, instead they may set up control project in domestic ahead of schedule or restrict dependence on transition alternative or take multilevel for phasing out during 2016-2040.

Chapter 5 Scenarios Analysis

According to the above demand prediction of HCFCs, this chapter will discuss how to control and reduce the HCFCs consumption demand before the 2016 on the premise that relevant sectors could develop as usual through scenario analysis, and the phase out after 2016 is simply discussed.

As Montreal Protocol only controls the ODS consumption use of HCFCs, the control strategy in this research pays most attention on four industries as room air-condition, commercial refrigeration, foaming and solvent. Here the control scenarios are mainly for room air-condition industry because it covers more than 60% of the total consumption. The reasons why only room air-condition is chosen conclude: it's hard to exactly predict the trend of commercial refrigeration industry due to the complex sorts of its equipment, the lack of its basic data, the dependence on the importation of its compressors and the restriction on its substitution time that the substitution schedule of overseas refrigeration has given; though HCFC-141b has been used in foaming sector for a long time, the scale is small, as to HCFC-22 and HCFC-142b, they have been used in foaming sector since the past five years; HCFC-141b used in solvent sector is in a smaller scale with a total consumption of thousands of Mt.

In addition, in term of the emission speciality and experiences of Europe and USA, the HCFC-22 consumption of room air-condition sector always phases out the latest. Therefore taking the phase out of room air-condition sector as the basic of HCFC-22 phase out in China in this research is actually good for the safe implementation of China.

5.1 Scenario Design

The prediction precondition of consumption and production in the Chapter 4 of this report is to suppose that China has taken no additional measures to control the increasing of HCFCs and just obeys to the requirements of Montreal Protocol. Actually, China is able to take different administrative and technical measures to control the increasing trend of production and use of HCFCs. As follows:

- Encourage or force the adoption of substitution technology in different industries;

- Encourage or force the carry-out of correlative technical policies such as the energy efficiency to limit HCFCs products' demand;
- Limit the production capacity and output of HCFCs as the ODS usages;
- Enact correlative technical criterions to require the reduction of HCFCs leak to reduce HCFCs' demand;
- Require the reclamation and recycle of HCFCs, etc.

In order to adopt and carry out the above administrative and technical measures successfully, China should take some correlative prophase preparations in the support of all aspects. Such as:

- Frame the national scheme or plan;
- Carry out substitution demonstration projects;
- Frame the phase-out plan of relative industries;
- Carry out reclamation and recycle demonstration programs;
- Carry out relative awareness and training activities;
- Study on making relative policies and statutes, etc.

5.1.1 Probable Scenarios of HCFCs' Demand Control before 2016

Based on available information at present, scenarios could be set up as follows:

Table 5-1 HCFCs Phase-out Control Scenarios before 2016 Year

Scenarios	Chemical Production Management	Manufacturing Production Management	Imports and Exports Management	Development of substitutions	Reclamation and Recycle
A(Prediction Scenario in Chapter 4 of this report, BAU)	Just registration management. Freeze output in 2016 according to Protocol and carry out management using production quotas.	No requirements at present. Freeze consumption in 2016 according to Protocol and carry out consumption management.	Carry out permit management based on Protocol.	No requirements at present.	No requirements at present.
B (Development-Restricted Scenario. Control the increasing rate of HCFCs' demand and decrease freezing output and consumption levels; freeze output and consumption in 2016 according to Protocol)	**Objects:** (1)Restrict new production capacity of ODS use from 2012; (2) Freeze output in 2016 according to Protocol and carry out management using production quotas. **Activities:** (1)Study on developing substitutes;(2)Manage HCFCs productions;(3)Study on making management policies.	**Objects:** (1)Restrict new production capacity of ODS use in several consumption industries from 2012;(2) Freeze consumption in 2016 according to Protocol and carry out consumption management;(3)Limit outputs of some products with indexes as energy efficiency and leak rate. **Activies:** (1) Study on developing substitutes;(2)Study on	Carry out permit management based on Protocol.	**Objects:** Develop and apply substitution techniques to satisfy phase-out needs to ensure successful phase-out of HCFCs production and consumption. **Activities:** (1)Develop demonstration projects in some industries such as room air-condition, foaming and solvent;(2)Frame	**Objects:** Reduce HCFCs demand and emissions and save resources. **Activities:** (1)Develop reclamation and recycle demonstration programs;(2)Frame technical criterions about reclamation and recycle;(3) Activities as awareness and training, etc.

		framing technical statues about energy efficiency and leak rate;(3)Choose some industries to enact bans;(4)Study on framing management policies;(5)Activities as awareness and training, etc.		industry phase-out plans to achieve freezing object;(3) Activities as awareness and training, etc.	
C(Development-Strictly Controlled Scenario. Control the increasing rate of HCFCs' demand at furthest and decrease freezing output and consumption levels)	**Objects:** (1) Restrict new production capacity of ODS use from 2010; (2) Freeze output in 2016 according to Protocol and carry out management using production quotas. **Activities:** (1)Study on developing substitutes;(2)Manage HCFCs productions;(3)Study on making management policies.	**Objects:** (1)Restrict new production capacity of ODS use in most consumption industries from 2012;(2) Freeze consumption in 2016 according to Protocol and carry out consumption management;(3)Limit outputs of some products with more strict indexes as energy efficiency and leak rate;(4)Phase out several sub-industries with mature substation techniques in advance. **Activities:** (1) Study on	Carry out permit management based on Protocol.	**Objects:** Develop and apply substitution techniques in full scale to satisfy phase-out needs to ensure successful phase-out of HCFCs production and consumption. **Activities:** (1)Develop demonstration projects in all industries;(2)Frame and carry out industry phase-out plans to achieve freezing object;(3)	**Objects:** Reduce HCFCs demand and save resources. **Activities:** (1)Develop reclamation and recycle demonstration programs;(2)Frame technical criterions about reclamation and recycle;(3) Require some industries to develop reclamation and recycle;(4)Activities as awareness and training, etc.

		developing substitutes;(2)Study on framing technical statues about energy efficiency and leak rate;(3)Develop substitution activities and choose some industries to enact bans;(4)Study on framing management policies;(5)Activities as awareness and training, etc.		Activities as awareness and training, etc.	
D(HCFCs Consumption Freeze in Advance and Accelerated Phase-out Scenario. Freeze output and consumption at the 2012 year's level in 2013 and step down output and consumption thereafter)	**Objects:** (1) Restrict new production capacity of ODS use from 2009; (2) Freeze output in 2013 and carry out managements using production quotas. **Activities:** (1)Study on developing substitutes;(2)Manage HCFCs productions;(3)Study on making relative management policies.	**Objects:** (1)Restrict new production capacity of ODS use in all consumption industries from 2010;(2) Freeze consumption in 2013 and carry out consumption management;(3)Limit outputs of some products with more strict indexes as energy efficiency and leak rate. **Activities:** Besides activities in Scenario C,	**Objects:** (1)Carry out permit management based on Protocol;(2)Reduce export to limit the HCFCs production demand. **Activities:** (1)Reduce export quotas step by step according to the subdivisions of products and fields	**Objects:** Develop and apply substitution techniques in full scale as soon as possible to satisfy phase-out needs to ensure successful phase-out of HCFCs production and consumption. **Activities:** (1)Develop demonstration projects in all	**Objects:** Reduce HCFCs demand and save resources. **Activities:** (1)Develop reclamation and recycle demonstration programs;(2)Frame technical criterions about reclamation and recycle;(3) Require some industries to develop reclamation and recycle;(4)Activities as awareness and

		still should: (1) Develop substitutions and stop production and sale of open and half-open refrigerators including HCFCs step by step;(2) Develop substitutions and stop the use of HCFC-22 and HCFC-141b as vesicant and solvent step by step;(3)Develop products with high energy efficiency and limit the production and sale of HCFC-22 air-condition with low energy efficiency.		industries;(2)Frame and carry out industry phase-out plans with more power to achieve freezing object;(3) Activities as awareness and training, etc.	training, etc.

Based on the above proposed scenarios, demand of HCFCs is predicted as follows:

Table 5-2 HCFCs Main Demand Predictions as ODS Use in Different Scenarios
3 (Including domestic consumptions and exports)

Scenarios	2005	2010	2015
A (Prediction Scenario in Chapter 4 of this report)			
HCFC-22(MT)	122,000	179,000	252,000
HCFC-141b(MT)	21,000	33,000	46,000
ODP(tons)	9,020	13,475	18,920
B (Development-Restricted Scenario)			
HCFC-22(MT)	122,000	165,000	210,000
HCFC-141b(MT)	21,000	30,000	38,000
ODP(tons)	9,020	12,375	15,730
C (Development-Strictly Controlled Scenario)			
HCFC-22(MT)	122,000	158,000	186,000
HCFC-141b(MT)	21,000	30,000	31,000
ODP(tons)	9,020	11,990	13,640
D (HCFCs Consumption Freeze in Advance and Accelerated Phase-out Scenario)			
HCFC-22(MT)	122,000	158,000	158,000
HCFC-141b(MT)	21,000	30,000	30,000
ODP(tons)	9,020	11,990	11,990

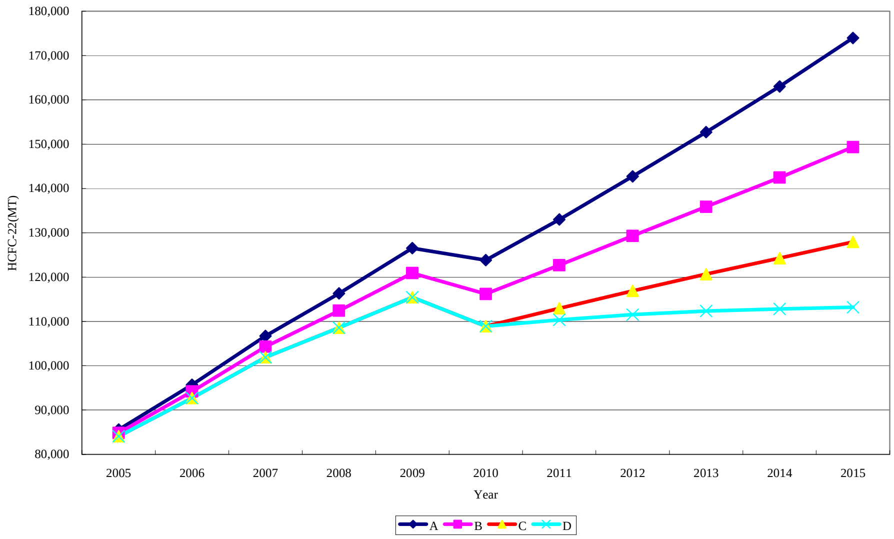

Fig. 5-1 HCFC-22 Demand Predictions in China Air-Condition Industry in Different Scenarios

5.1.2 HCFCs Stepwise Phase-out Scenarios after 2016 Year

The phase-out plan totally complying with Montreal Protocol (See Fig.1-1) is the slowest boundary scenario of HCFCs consumption phase-out for the Article 5 countries. From the point of view of reducing environmental impact, the quicker of the ODS phase-out speed, the better. Compared to the BAU Scenario, other scenarios try to accelerate HCFCs phase-out at different degrees and different time.

BAU Scenario A, (Baseline, to continue the above Control Scenario A, named Scenario A for short in the following text): Strictly complying with the requirement of Montreal Protocol; China's slowest scenario of HCFCs consumption phase-out (Boundary Scenario).

Jan.1st 2016: Freeze at the 2015 year's level predicted by BAU Scenario.

2016~2039 Year: Keep the total consumption of HCFC-22 in air-condition industry at the 2015 year's level.

Jan.1st 2040: Phase out 100% of HCFCs consumption.

Slow-speed Scenario B, (Slow Phase-out, to continue the above Control Scenario B, named Scenario B for short in the following text): Complying with the control trend of the above Scenario B, limit consumption step by step.

Jan.1st 2016: Freeze at the 2015 year's level.

2016~2039 Year: Phase out step by step according to Function $y=a_1x^2+b_1x+c_1$. Compared to linear and geometric phase-out, the characteristic of this scenario is that the phase-out speed is slow at first and fast at last with a relative slow speed in whole.

Jan.1st 2040: Phase out 100% of HCFCs consumption.

Fast-speed Scenario C, (Fast Phase-out, to continue the above Control Scenario C, named Scenario C for short in the following text): Complying with the restrict control trend of the above Scenario C, strictly limit consumption step by step.

Jan.1st 2016: Freeze at the 2015 year's level.

2016~2039 Year: Phase out step by step according to linear and geometric function.

Jan.1st 2040: Phase out 100% of HCFCs consumption.

Scenario D, (Phase-out in Advance, to continue the above Control Scenario D, named Scenario D for short in the following text): Complying with the above Scenario D, freeze in advance and phase out the whole HCFCs consumption before 2035 year step by step.

Jan.1st 2014: Freeze at the 2013 year's level.

2016~2035 Year: Phase out step by step according to Function $y=a_2x^2+b_2x+c_2$. Compared to the linear and geometric phase-out, the whole phase-out speed is relative fast.

Jan.1st 2035: Phase out 100% of HCFCs consumption.

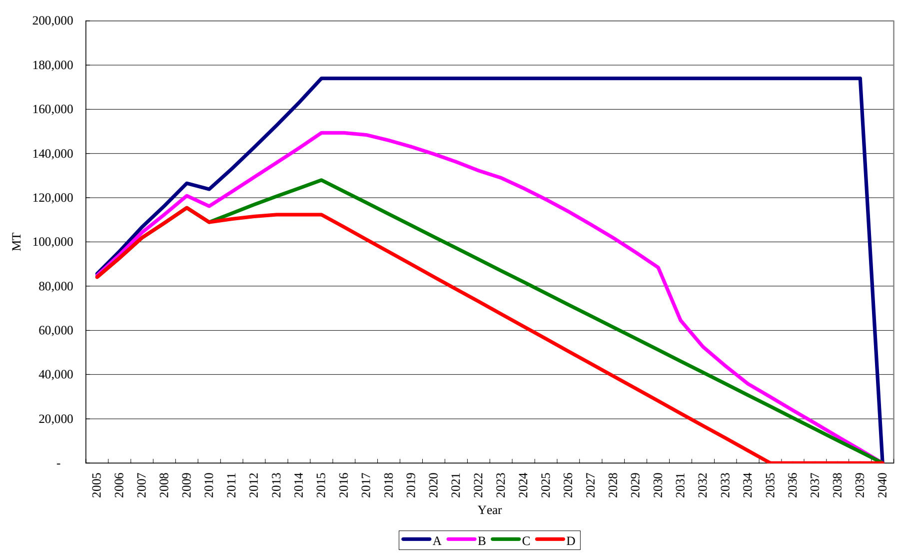

Fig. 5-2 HCFC-22 Consumptions in China Air-Condition Industry in Different Scenarios

(HCFCs' Accumulative Level in Other Industries is equivalent to the above Fig.)

5.2 Analysis of Incremental Costs in Room Air-condition Industry

The substitution in room air-condition, industrial and commercial refrigeration, foaming and solvent industries will result in incremental costs. Based on the available data, this chapter analyses the incremental costs in room air-condition industry.

5.2.1 Definition and Impact Factors of Incremental Costs

The definition of Incremental Costs (IC) by GEF is that: The relevant costs are incremental rather than total. The cost of GEF eligible activity should be compared to that of the activity it replaces or makes redundant. The difference between the two costs -- the expenditure on the GEF supported activity and the cost saving on the replaced or redundant activity -- is the incremental cost. It is a measure of the future economic burden on the country that would result from its choosing the protocol implementation supported activity in preference to one that would have been sufficient in the national interest. According to this definition, the incremental costs in this research mainly means the cost which the end consumers of room air-conditions in China need to assume in addition while changing the refrigeration in room air-condition industry in China from HCFC-22 to non-ODS chemicals.

According to the guidelines about incremental costs in GEF documents and taking into account the main reason of HCFC-22 substitution activities in China that is to implement the protocol, the incremental costs to implement the protocol equals to the costs to implement the whole phase-out activity. Therefore, the correlative incremental costs are primarily defined as the incremental costs in the process of HCFC-22 substitution activity, which mainly include introducing costs of substitute/substitution techniques, rebuilding and operating costs of substitution equipment and training costs, etc.

Incremental costs analysis is based on the present substitution techniques and foundation establishments. There are many impact factors including present consumptions of HCFC-22 and its substitutes, historical changes of HCFC-22 consumptions, room air-condition servicing, reclamation and recycle of HCFC-22 and public participation in room air-condition industry, etc. See the detail analysis of each factor in the following paragraphs.

HCFC-22 historical consumptions and its consumption increasing trend in the uncontrolled scenario: Room air-condition industry is the main consumer of HCFC-22 in China as ODS use. During the year 1994 and 1998, the annual average increasing rate of room air-condition productions comes to 23%; during the year 1999 and 2004, the annual average increasing rate of room air-condition productions comes to 41%; in 2004, the production of room air-conditions in China comes to 66,460,000. As the HCFC-22 consumptions in room air-condition industry and the quantity of air-conditions show the strong positive relevancy, it could be predicted that the consumptions of HCFC-22 and its increasing trend would be stupendous in the uncontrolled scenario. Obviously, in the phase-out process, the demand of HCFC-22 in room air-condition industry will be supplemented by its substitutes and the more demand of HCFC-22, the more demand of those substitutes, which means it will be more and more difficulty to implement the phase-out with different incremental costs.

Control and phase-out schedule: The phase-out schedule is one of the key impact factors to incremental costs. It impacts on the phase-out incremental costs in two aspects. First, the earlier to adopt refrigeration substitutes, the higher the incremental costs of rebuilding techniques, and the techniques are not mature enough; contrarily, the later to adopt refrigeration substitutes, the lower the incremental costs of rebuilding techniques which are more mature. Secondly, the demand of substitutes is directly related to the phase-out rate, and the development of substitute production ensures the phase-out of HCFC-22. Only when the substitution techniques and production capacity of substitutes are well-developed can the phase-out of HCFC-22 consumptions and productions be implemented successfully; otherwise, there would be lack of products in the market. The faster phase-out and the more investment in developing the substitution techniques and production capacity of substitutes, the more incremental costs; on the other hand, the slower phase-out and the less investment in developing the substitution techniques and production capacity of substitutes, the less incremental costs. And the phase-out also has obvious benefits on the environment and healthiness which will be more when the phase-out is faster.

Substitution techniques: Substitution technique is another key factor to impact on the phase-out incremental costs. The substitution techniques for the HCFC-22 production in room air-conditions include artifacts HFCs and natural substances such as HCs, NH_3 and CO_2. As different substitution techniques need different phase-out incremental costs, the society's demand and adoption of different substitution techniques will impact on the incremental costs.

Policy: Policy is one of the important factors to impact on the phase-out incremental costs. Policies can impact on both the production and the market of HCFC-22 and its substitutes. For instance, reduce or release taxes on substitutes of HCFC-22 and restrict the consumptions and productions of HCFC-22 and so on.

5.2.2 Assumptions and basis of incremental costs calculation

When calculating the incremental costs between per R-410a/R-407C room air-condition and per HCFC-22 air-condition, 6 factors are considered in this research as follows:

(1) Suppose that the profit of each air-condition does not change while producers replace refrigeration and the increasing cost of each R-410a/R-407c air-condition is assumed by the end consumers;

(2) The consumption of air-conditions is relative to consumption demand rather than air-conditions' prices, which means that consumers would not reduce their purchase because of the increasing prices;

(3) Suppose that the prices of refrigeration keep unchangeable, which means that the prices of HCFC-22 and its non-ODS substitutes won't change;

(4) Most product lines of HCFC-22 room air-conditions can be used to produce R-410a/R-407c air-conditions, so the rebuilding of product lines only needs to add some new equipment such as refrigeration filling machine;

(5) Take the year 2005 as the base year.

The substitute R-290 in room air-condition industry is also developing at present. Compared to R-410a/R-407c, the alteration of producing process of R-290 compressors is less. But the refrigeration capacity of R-290 is worse than HCFC-22, which means its compressor is larger by 20% if the same refrigeration capacity is needed and the price of each 100 yuan. Besides, the price of R-290 in China is 200 yuan/kg. The use of R-290 may save more energy than use of R-410a; however, our research workgroup lacks relative energy-saving data at present. And the existing data shows that these two substitution techniques share the similar costs. Based on the actual conditions in China that there have been already a lot of producing practices for R-410a/R-407c and there is no Split type Room Air-Condition in the market, R-410a/R-407c technique is adopted in this incremental cost computation.

5.2.3 Incremental Costs Calculation

On one hand, in the process of changing the refrigeration in room air-condition industry from HCFC-22 to R-410a/R-407c, producers of air-conditions need to introduce techniques, change product lines (including replace new refrigeration filling machines and other equipment) and replace lubricants in addition to buying new compressors with more capacity of stress and changing plastic pipes. These incremental costs would be assumed by the end consumers of air-conditions at last not by the producers because the prices of R-410a/R-407c air-conditions are generally higher than those of HCFC-22 air-conditions by 30% (the data from Ningbo Aux Group), so the profit of each air-condition for producers changes little as producers just pay the financial cost rather than the economical cost. Therefore, the increasing cost for producers to produce a R-410a/R-407c air-condition instead of a HCFC-22 one will be calculated and taken as the additional cost which the end consumers should pay, supposing that the profit of each air-condition for producers keeps unchangeable when changing refrigeration.

On the other hand, consumers should also pay additional price differences between R-410a/R-407c and HCFC-22 when servicing after they purchase R-410a/R-407c air-conditions.

All in all, the total increasing cost of each R-410a/R-407c air-condition equals to the summation of above two increasing costs, and the product of this total increasing cost and domestic consumptions of such air-conditions equals to the total incremental cost of phase-out HCFC-22 in China that the end consumers would assume.

5.2.3.1 Calculation Formula of Producers' Increasing Financial Cost

Theoretically, the total increasing financial cost for air-condition producers to produce one room air-condition can be calculated as Formula 5-1. IC^1 is the total incremental substitution cost of HCFC-22 air-condition producers with the unit Yuan, including four parts:

$$IC^1 = \sum_{i=1}^{t} \frac{IC_{1i} + IC_{2i} + IC_{3i}}{(1+r)^i} + \sum_{i=1}^{t} \frac{IC_{4i} + IC_{5i}}{(1+r)^i} + \sum_{i=1}^{t} \frac{IC_{6i} + IC_{7i} + IC_{8i}}{(1+r)^i} + \sum_{i=1}^{t} \frac{IC_{9i}}{(1+r)^i} \quad \textbf{(5-1)}$$

The first part, the increasing one-off investment cost of room air-condition corporations during the process of using substitutes:

IC_{1i} : When the year i, the cost for air-condition producers to introduce techniques (unit: Yuan);

IC_{2i} : When the year i, the rebuilding cost of production equipment of air-condition producers (unit: Yuan);

IC_{3i} : When the year i, the training cost for air-condition producers to train labors to use new refrigeration techniques (unit: Yuan);

The second part, the increasing operating cost of room air-condition corporations during the process of using substitutes:

IC_{4i} : When the year i, the increasing (or saving) water and electricity cost during the production of air-conditions (unit: Yuan);

IC_{5i} : When the year i, the increasing (or saving) labor cost during the production of air-conditions (unit: Yuan);

The third part, the increasing cost of raw and processed materials during the process of using substitutes:

IC_{6i} : When the year i, the total increasing cost after room air-conditions are filled with substitute refrigeration, its value equals to the product of incremental cost of each air-condition and quantity of air-conditions, and the incremental cost of each air-condition can be calculated as Formula 5-2;

IC_{7i} : When the year i, the increasing cost of using new lubricant (unit: Yuan);

IC_{8i} : When the year i, the increasing cost of using compressors with the higher capacity of stress and using other raw and processed materials (unit: Yuan);

The forth part, the cost to propagandize and popularize the use of air-conditions with new refrigeration:

IC_{9i} : When the year i, the cost to propagandize and popularize the use of air-conditions with new refrigeration (unit: Yuan).

Due to the data's availability and the each part's different contributions to the whole incremental cost of one room air-condition, three parts have been included in the calculation of the incremental cost of each air-condition filled with substitute refrigeration (for the first time) including the one-off investment cost, the increasing cost of a room air-condition filled with substitute refrigeration and the increasing cost of using a R-407c/R-410a compressor rather than a HCFC-22 one. See Formula 5-2.

$$IC_{6i} = n_{1i}(m_1 p_1 - m_0 p_0) + n_{2i}(m_2 p_2 - m_0 p_0) \quad (5\text{-}2)$$

n_{1i} : When the year i, the production of R-407c room air-conditions (unit: set);

m_1 : The quantity of R-407c filled in each new air-condition (unit: kg);

p_1 : The price of R-407c (unit: Yuan/kg);

m_0 : The quantity of HCFC-22 filled in each new air-condition (unit: kg);

p_0 : The price of HCFC-22 (unit: Yuan/kg);

n_{2i} : When the year i, the production of R-407c room air-conditions (unit: set);

m_2 : The quantity of R-410a filled in each new air-condition (unit: kg);

p_2 : The price of R-410a (unit: Yuan/kg).

5.2.3.2 Relative Training Activities for Servicing Brought by Adopting Substitutes

One suit of training equipment in training center will cost 45,000yuan, which includes vacuum pump, manifold, measure meter, tube, pack carrier leakage monitor, steel cylinder to fill refrigeration and equipment to refill. It's suggested that each training center own two suits of training equipment and the direct training cost of each participator will be nearly 1,000yuan, including three-day room and board costs and other direct cost of each participator(including consumptions, evaluation and operating authentication).

Besides the direct costs, there are still some indirect costs relative to training activities. As the 20 training centers are located all around the whole countries, it's necessary to set up a central regulating institution to make plans and check the preparation of training objects in each center, offer guidance and supports during the trainings' preparation and operation, help offering training materials and give training to trainers by National Training

Center, etc. The management cost of each training participator is about 400yuan and the extra cost (if there is) should be paid by air-condition producers who participate.

The cost of training the trainers is predicted to be 160,000yuan. And the cost of building National Training Center is computed under the condition that there are five suits of equipment inside at the price of 45,000yuan per suit. In addition, to compile the training materials is also included with the two parts of adapting existing materials and translating them into Chinese, each of which could cost 160,000yuan.

SEPA is developing a web system to offer local officers the training of ozonosphere protection policies. And this system will be extended further to offer air-condition servicing technique training. The training materials will be uploaded onto the present web after finishing compilation, which will help young servicing technicians study techniques. And the extra cost to design such web training is about 160,000yuan.

The cost to strengthen trainings in domestic vocational schools is based on offering training equipment to them directly, which is equivalent to the cost of offering equipment to a new training center. In addition, to update the existing training materials may cost 160,000yuan.

The design, preparation, making and distribution of each booklet or poster may cost 15 Yuan and 20 Yuan, respectively. The awareness seminars in order to promote the public consciousness will cost 800,000 Yuan.

Develop and increase awareness for good servicing operation standards.

The design and evaluation cost of each activity (including inviting experts, holding international awareness seminars and printing materials) is listed in the table of incremental cost.

The management information system includes: Track and record each training activities and awareness activities which are held to promote the public consciousness; Collect the information about the participators and those servicing corporation beneficiaries and set up and maintain the relative database; Monitor the reclaim and reuse activities; Maintain the database for HCFCs which are reclaimed and recycled from scrapped equipment; Store and accumulate some relative information, etc. The cost of the whole MIS is 3,000,000yuan including the cost of hardware, software and setting up, operating and maintaining a database. In order to monitor these activities, there should be a stable group of experts if needed. The cost will be 16,000 if to monitor these activities strictly. And it's estimated that there may 50 out of 800~1,000 training tutorials need strict monitoring.

5.2.3.3 Increasing Servicing Cost of Room Air-condition Consumers

After the room air-condition consumers buy air-conditions, they should pay additional price differences between the substitute refrigeration and original one each time when they need servicing, which is the increasing servicing cost of room air-condition consumers. See Formula 5-3.

$$IC^2 = \sum_{i=1}^{t} \frac{N_1(M_1 p_1 - M_0 p_0) + N_2(M_2 p_2 - M_0 p_0)}{(1+r)^i} \qquad \textbf{(5-3)}$$

IC^2 : The increasing servicing cost of room air-condition consumers (unit: Yuan);

N_1 : When the year i, the quantity of room air-conditions which need servicing (unit: set);

M_1 : The quantity of R-407c needed when servicing one air-condition (unit: kg);

M_0 : The quantity of HCFC-22 needed when servicing one air-condition (unit: kg);

N_2 : When the year i, the quantity of room air-conditions which need servicing (unit: set);

M_2 : The quantity of R-410a needed when servicing one air-condition (unit: kg).

The meanings of other parameters are the same as Formula 5-1 and Formula 5-2.

5.2.3.4 Calculation Formula of the Total Incremental Cost

The total incremental cost equals to the sum of the increasing financial cost of air-condition producers and the increasing servicing cost of air-condition consumers. Supposing that the profit of air-condition producers keeps unchangeable, the incremental cost will be assumed all by the end consumers of air-conditions at last. The calculation result of Formula 5-4 is the total incremental cost.

$$IC^{*} = IC^{1} + IC^{2} \qquad \textbf{(5-4)}$$

IC^{*} : The total incremental cost paid by the end consumers of room air-conditions in China.

5.2.3.5 Key Input Parameters of the Mode

Table 5-3 Key Input Parameters of Incremental Cost Calculation in Room Air-condition Industry

Content			
Scenarios	A	B	C
The 2010 year, productions of HCFC-22 room air-conditions in China (unit: thousand sets)	73,300	64,600	57,700
The 2010 year, consumptions of HCFC-22 in China room air-condition industry (unit: kiloton)	103	90	81
The 2015 year, productions of HCFC-22 room air-conditions in China (unit: thousand sets)	102,800	78,709	63,780
The 2015 year, consumptions of HCFC-22 filled in new air-conditions in China room air-condition industry (unit: kiloton)	144	110	89
The incremental cost of rebuilding a product line with the capacity of 500,000 (unit: thousand yuan)	750		
Price of HCFC-22 (unit: yuan/kg)	10		
Price of R-407c (unit: yuan/kg)	78		
Price of R-410a (unit: yuan/kg)	100		
Average price of HCFC-22 compressor (unit: yuan/set)	400		
Average price of R-407c/R-410a compressor (unit: yuan/set)	200		

The supposed electricity saved by each R-410a air-condition per year[2]	55kw/hr		
Electrovalence	0.6yuan		

The computation parameter for incremental cost that is brought by the promotion of servicing level is given in the part 5.3.3.3.

5.2.4 The Incremental Costs and Electricity-Saved Costs in Different Scenarios in Room Air-condition Industry (before 2016 year)

Production equipment rebuilding: Suppose that until 2015, China existing air-condition producers rebuild their HCFC-22 product lines: 1/4 rebuilt in Scenario B, 1/3 rebuilt in Scenario C and 1/2 in Scenario D. Then the accumulated cost will respectively be 45,000,000yuan, 60,000,000yuan and 90,000,000yuan.

Training and awareness: Hold training and awareness activities at different levels, and the cost in Scenario B, C and D will respectively be 3,185,000yuan, 8,275,000yuan and 15,590,000yuan.

Based on the above scenarios and parameters, the incremental costs in Scenario B, C and D in room air-condition industry are shown in the following table.

[2] Wu Chen, Mark W. Spatz, Honeywell, The comparison of R410A and R22 in the Application of household air-conditions.

Table 5-4 Incremental Costs of Production Process in Scenario B, C and D in Room Air-condition Industry

(At the price of 2005 year)

Extra Demand of R-410a Air-condition(thousand suit)				Extra Cost of Compressor(thousand yuan)			Extra Cost of Refrigeration(thousand yuan)		
Scenarios	B	C	D	B	C	D	B	C	D
2007	1,551	3,074	3,074	310,206	614,773	614,773	139,593	276,648	276,648
2008	2,520	4,965	4,965	504,095	992,934	992,934	226,843	446,820	446,820
2009	3,631	7,106	7,106	726,190	1,421,163	1,421,163	326,786	639,523	639,523
2010	4,899	9,524	9,524	979,711	1,904,702	1,904,702	440,870	857,116	857,116
2011	6,610	12,741	14,655	1,321,918	2,548,285	2,930,976	594,863	1,146,728	1,318,939
2012	8,509	16,261	20,145	1,701,761	3,252,228	4,029,090	765,792	1,463,502	1,813,091
2013	10,613	20,106	26,020	2,122,558	4,021,213	5,204,072	955,151	1,809,546	2,341,833
2014	12,939	24,301	32,307	2,587,895	4,860,267	6,461,303	1,164,553	2,187,120	2,907,586
2015	15,508	28,874	39,033	3,101,643	5,774,782	7,806,540	1,395,739	2,598,652	3,512,943
Total	66,780	126,952	156,828	13,355,979	25,390,345	31,365,553	6,010,190	11,425,655	14,114,499

Compared to the incremental cost of production process in room air-condition industry, the cost of production equipment rebuilding, training and awareness only holds 1% of the former.

The largest HCFC-22 consumer, household Air-conditioners for export and domestic markets, incurs incremental costs mainly for the purchase of compressors and refrigerants. The price changes of compressors and refrigerants are therefore the determining factor, deciding when this industry will replace HCFC-22. At present, the Chinese Air-conditioner industry judges accelerated phaseout scenario (such as scenario C and D) to be unfeasible because of their anticipation of these prices.

5.3 Environmental Benefits of Different Phase-out Scenarios in Room Air-condition Industry (Extra Reduction and Energy Saving)

5.3.1 ODP and GWP Reduction

Suppose Scenario A as the baseline, and there are 4 aspects of environmental benefits brought by Scenario B, C and D compared to Scenario A, three of which are about extra reduction as follows: (1)The demand of HCFCs decreases; (2)The decreased demand of HCFC-22 results in the demand decreasing of CHCl3 and production reduction of its by-product CTC; (3)The decreased demand of HCFC-22 also results in the emission reduction of its by-product HFC-23. And the other environmental benefit is the energy saving due to the promotion of operating efficiency of refrigeration equipment after substitutions.

Suppose that to produce 1Mt HCFC-22 needs 1.5Mt CHCl3 and 13Mt CHCl3 produces 1Mt CTC; and suppose that to produce 100Mt HCFC-22 produces 3 Mt HFC-23. The total GWP value reduced by the decreased HCFC-22 production means the GWP value reduced by the abated emission of its by-product HFC-23.

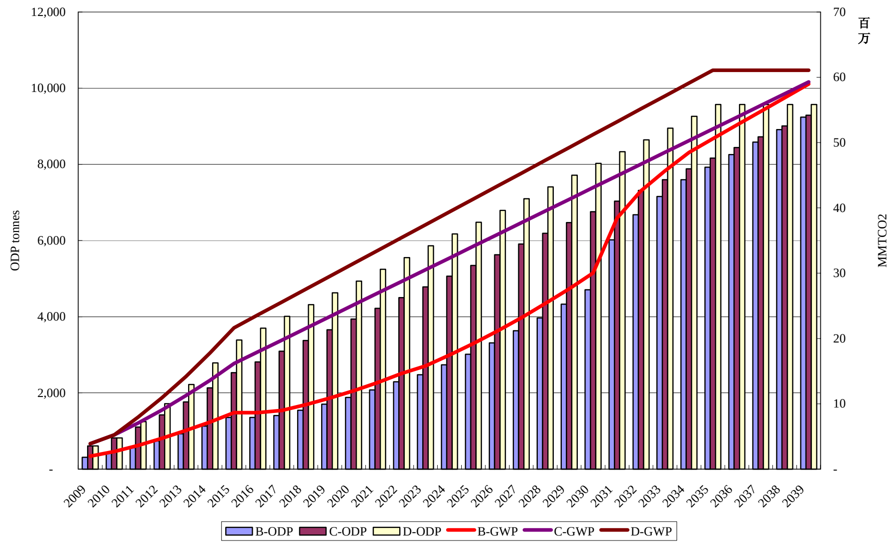

Fig. 5-3 Reduction of ODP and GWP per Year Resulted from Decreased HCFCs Demand in other Scenarios Compared to Scenario A

3 The accumulated data of the above reduction (2007~2040) is in the following table.

Table 5-5 Accumulated Reduction of ODP and GWP Resulted from Decreased HCFCs Demand in other Scenarios Compared to Scenario A

	B	C	D
HCFC-22(MT)	2,113,717	2,828,971	3,340,965
HCFC-22(ODP tons)	116,254	155,593	183,753
CTC (MT)	243,077	325,332	384,211
HFC-23(MT)	63,412	84,869	100,229
HFC-23(GWP tons)	741,914,776	992,968,791	1,172,678,592

6 ### 5.3.2 Electricity Saving (Benefits Before 2016 Year)

Due to the extra use of R-410a room air-conditions, the electricity-saved cost in different scenarios is listed in the following table.

Accumulated Extra R-410a Air-conditions (thousand suit)				Electricity Saving per Air-condition per Year (thousand yuan)		
Scenarios	B	C	D	B	C	D
2007	2,495	4,954	4,954	82,346	163,477	163,477
2008	5,016	9,919	9,919	165,522	327,311	327,311

2009	8,647	17,024	17,024	285,343	561,803	561,803
2010	13,545	26,548	26,548	446,996	876,079	876,079
2011	20,155	39,289	41,203	665,112	1,296,546	1,359,690
2012	28,664	55,550	61,348	945,903	1,833,163	2,024,490
2013	39,277	75,656	87,369	1,296,125	2,496,664	2,883,162
2014	52,216	99,958	119,675	1,723,127	3,298,608	3,949,277
2015	67,724	128,832	158,708	2,234,899	4,251,447	5,237,356
Total	237,739	457,730	526,747	7,845,372	15,105,097	17,382,644

This estimate for the reduction in electricity consumption is based on the currently available Air-conditioner models. It is likely that future advances in Air-conditioner technology will lead to higher savings. In addition, Air-conditioners using Hydrocarbons such as R-290 could achieve higher efficiencies than those with R-410a.

5.4 Brief Summary

To adopt Scenario B, C and D will respectively reduce the accumulated demand of HCFC-22 by 110,000MT (6,000MT ODP), 210,000MT (11,000MT ODP) and 250,000MT (14,000MT ODP) in room air-condition industry just before 2016 year. In Scenario B, the manufacturing incremental cost (including compressor system and refrigeration) comes to 14.4 billion yuan (based on the price of the year 2005), and the electricity-saved cost by substitutions comes to 5.6 billion yuan (based on the price of the year 2005) with the reduction of HFC-23 emission about 38 MMT GWP; and in Scenario C, the manufacturing incremental cost (including compressor system and refrigeration) comes to 27.5 billion yuan (based on the price of the year 2005), and the electricity-saved cost by substitutions comes to 10.8 billion yuan (based on the price of the year 2005) with the reduction of HFC-23 emission about 72MMT GWP; and in Scenario D, the manufacturing incremental cost (including compressor system and refrigeration) comes to 33.4 billion yuan (based on the price of the year 2005), and the electricity-saved cost by substitutions comes to 12.4 billion yuan (based on the price of the year 2005) with the reduction of HFC-23 emission about 87 MMT GWP.

No matter which scenario would be adopted, the extra control cost compared to the baseline scenario is obvious and at the same time, there will be three aspects of extra environmental benefits: First, the reduction of HCFCs and CTC emission is helpful to the protection of ozonosphere; Second, reduction of GHG emission including HFC-23, HCFCs, etc; Third, decrease the energy and resource demand due to the promotion of energy efficiency.

In the above four scenarios, Scenario A, which strictly complies with the present requirement of the Protocol, has the lowest direct control cost but also has some problems: (1)Both of its ODS and GHG emissions are too large to satisfy the domestic and international requirements for environmental protection; (2) It could not activate to rebuild and upgrade HCFCs techniques enough to satisfy the relative requirement in National Eleventh Five-Year Plan such as “Advance in Industrial Structure Optimization Upgrade”, “Construct a Resource-saving and Environmental Friendly Society”, etc. Scenario D is the most active and is beneficial to environmental protection as only the reduction of HFC-23 emission is amazing without the reduced GWP value by the reduced HCFC-22 emission in this report. If taking both benefits of helping ozonosphere protection and reducing climate change into account, Scenario D is undoubtedly a most active one; but there are some problems: (1) The preparation of substitution techniques is deficient as there have been no technique researches and demonstration programs at the national levels yet; (2) It’s difficult to control even cut the increase of the relative HCFCs chemical production and use industries in a short time as they are all increasing fast at present.

Compared to Scenario A and D, Scenario B and C could satisfy the kinds of present requirements better. However, Scenario C calls for higher level of requirements in available capital, degree of executing laws, substitution techniques and impact on chemical industries. Thus to adopt Scenario B is safer. The conditions to implement Scenario B as follows:

Government Level:

- Revise National Project as soon as possible and implement National HCFCs Phase-out Plan;
- Limit the building of new ODS production capacity before 2012;
- Organize and set up demonstration projects as soon as possible and develop the whole-industry phase-out in some industries step by step;
- Prompt the research, development and application of substitutes and substitution techniques as soon as possible;
- Study on making relative technique statutes about energy efficiency, leakage rate,

reclaim and recycle;

- Study on framing other management policies; making industry phase-out plan and choose some industries to enact bans;
- Develop activities such as awareness and training.

Industry Level:

- Develop activities such as awareness and promotion seminars widely;
- Support to organize substitutions;
- Support governments to develop relative researches and make relative management policies and technical policies;
- Organize corporations to develop voluntary activities to limit or reduce production and use of HCFCs.

Corporation Level:

- Develop substitutes and substitution techniques actively;
- Try best to reduce production and use of HCFCs and the leakage during production and use;
- Hold substitution activities actively and reduce production and use of HCFCs step by step.

International Level such as Montreal Protocol:

- Supply sufficient financing to develop demonstration projects;
- Support technique transfer and reduce the substitution techniques' obstacle at furthest;
- Supply financing and experts to develop technical assistance activities.

The respective merits of scenarios B, C and D depend strongly on the costs of replacing HCFC-22 in Air-conditioners. The overall recommendation should therefore be considered in light of potential and expected technology advances. If the costs for R-410a and R-290 and their compressors decline, then the relative merit of scenarios C and D increase. Besides, most producers believe that the servicing system needs to be enhanced widely for R-410a and R-290 Air-conditions.

Chapter 6 Recommendation Strategy for the Long Term Management

Analyzing Chinese strategy on long term control of HCFCs, China may be faced with the challenges as below:

(1) China has become the largest country of ODS production and consumption, so the future work on ODS phase out is quite arduous. After 1995 when developed countries had completely phased out the major ODS as Halon and CFCs, they have started to phase out HCFCs, and more than 50% of the total HCFCs consumption have been phased out already. At present, China has become the largest country of ODS production and consumption either calculated by ODP or actual substance. Especially the increase in use of HCFCs, covering quite a large proportion of the total production and consumption of ODS, has attracted much attention of the international community.

(2) Sectors relevant to HCFCs phase out are quite extensive. Sectors relevant to production include chloro-alkali production, methane chloride production and PTFE production, etc. In the sectors relevant to consumption, the room air conditioning sector alone reached production levels of 60,000,000 units per year valued at 90 billion RMB. The Chinese economy will keep a relatively high increasing rate (about 7.5%), on one hand, this increasing rate may cause a continual sharp increase of products relevant to HCFCs and may augment the pressure for ODS phase out. On the other hand, how to keep relevant sectors developing as usual while phasing out ODS production and consumption is a key point for Chinese implementation safety. Therefore, phase out of ODS may have effect on macro economy development, economic increasing rate, manner for production and consumption, and social employment, etc.

(3) There are close relationships among international environmental protocols. On one hand, large quantity of HFC-23 will release during HCFC-22 production, whose greenhouse effect has exceeded all the other HFCs of intentionally production, and has got the international attention. On the other hand, some relatively perfect ODS substitutes also are control substances in Kyoto Protocol for their GHG characteristics. How can Chinese implement the protocol effectively and safely, not increase GHG emission in large quantity

when protecting the ozone layer and avoid huge economic expense and social effect is an urgent issue to be solved. So Chinese should systematically consider the joint implementation of Montreal Protocol and Kyoto Protocol on the point of view of national benefit.

(4) Alternative substances/technologies are seriously lagged and some alternatives are facing with a problem of second phase out. In order to phase out ODS production and consumption, developed countries have developed tens of ODS alternative products and technologies such as HFC-134a, HFC-152a, HFC-143a, HFC-125, HFC-225ea, HFC-227, cyclopentane and PFCs etc., which have monopolized the market, and new alternative products and technologies are being in developed and generalized. Although some alternatives like HFC-134a have developed in China in recent years, the situation of seriously dependence on foreign products and technologies does not change, most HCFCs alternatives are still at a quite high price due to the patent protection. Moreover, HFCs consumption have been limited in developed countries since 16th Feb. 2005 when Kyoto Protocol came into effect, however in China technical research and application of alternatives for HFCs products have not started yet.

(5) Although schedule for HCFCs control starts at 2016 in China, for the huge quantity of HCFCs used in refrigeration sector, the future demand for servicing must be considered, and there will be large quantity of obsolete HCFCs before 2040 if not dealt with properly. This will cause a huge management cost and financial demand.

(6) As a result of the increasing trend of ozone layer depletion and greenhouse effect of some ODS and their alternatives, target of HCFCs phase out may be advanced.

(7) Because awareness for HCFCs phase out is not yet widespread, most enterprises still do not comprehend the requirements of HCFCs phase out and therefore could not yet make any provisions for conversions and funding. All of the above will bring resistance against the phase out.

(8) Chinese government has devoted large human resource to the management for implementation the phase out of ODS as CFCs and halon, but the management is still in a passive position and sometimes work is developed only aiming at the short term target. So the government should develop work considering capacity-building, system improving and plan making to face the lack of management on HCFCs.

For all the factors above and combine with the scenario analysis in chapter 5, we suggest that China adopt scenario B above to control production and consumption of HCFCs. That is to control the increasing demand of HCFCs on a certain extent to decrease the freezing level in 2016, then gradually phase out HCFCs production and consumption as ODS after 2016.

Suggested strategy on HCFCs control is as follows:

6.1 Strategy Objective

6.1.1 Key objective

The Ozone layer depleting has been one of the most important global environmental issues. To implement the Montreal Protocol effectively will help China to protect the ozone layer, reduce GHG emission, prevent the global warming and advance sustainable development.

China will take the responsibilities prescribed in Vienna Convention and Montreal Protocol. With financial support and technology transfer affiliated with the Montreal Protocol, China will integrate the demand for the implement into the relevant plans of the government, improve relevant management system, establish and implement relevant policy and essential action measures for the implementation to achieve the control objectives in Montreal Protocol:

- Try to control de increasing demand of HCFcs, and freeze the HCFC consumption by 2016 at level of 2015 and phase out the consumption by 2040.

Implementing the Convention/protocol will help China to promote clean production, structure regulation of production, resource effective utilization, develop cyclic economy, search for perfect alternative product and methods, cultivate new points of economic growth, create more employment opportunities, raise environmental awareness amongst the general public, encourage public participation and promote changes to a sustainable development modality.

China will take relevant strategies and measures on consumption control for different chemicals and different sectors stage by stage, that is to control ODS consumption with high ODP value, high emission rate and easy to substitute preferentially, and then establish a strategy fitting the Chinese situation.

6.1.2 Preferential fields

Key objective of the study on strategy for HCFCs control is to freeze the HCFCs consumption by 2016; relevant preferential fields are as follows:

- With the requests of Montreal Protocol, establish and improve policy and regulation and strengthening the capacity-building of the institutions;
- Promote study, development and application of alternative product and technology;
- Establish financial safeguard mechanism and develop demonstration projects to promote the phaseout of HCFCs;
- Recovery, recycle and reuse;
- Strengthen international cooperation;
- Develop capacity-building to ensure the implementation of the HCFCs strategy;
- Establish long-term implementation policy framework and effectiveness control mechanism.

6.1.3 Detailed objectives

In order to implement the Montreal Protocol and control HCFCs production, consumption and releases as ODS effectively, and according to the implementation schedule in the Montreal Protocol, the production and consumption situation and the technical, economic and management feasibility, China has set up detailed objectives into two stages: short term objective is to freeze by 2016 and long term objective is phase out HCFCs by 2040.

Short term objectives:

- To carry out dynamic registration system for production, consumption, import and export and emission data by 2008.
- To adjust industrial structures to phase out outdated products and technologies, and encourage the new products and technologies;

- To promote study, development and application of alternative product and technology;
- To set up recovery system for retired HCFCs equipments by 2010;
- To set up labeling system for large size equipment containing HCFCs, registering and tracking management of the equipment by 2010;
- To confirm phaseout schedule for each sub-sector through demonstration and reevaluation by 2010;
- To control the new building, expanding and rebuilding projects relevant to HCFCs production capacity development by 2012;
- To implementation auditing with clean production system to control HCFCs emission by 2015;
- To establish and improve recovery system for HCFCs, and carry out imperative recovery in some key sectors by 2015.

Long term objectives:

- To prohibit HCFCs consumption as solvent for any purpose by 2020;
- To prohibit HCFC-141b consumption as foaming agent by 2020;
- To prohibit production of open and half-open refrigerators with relative medium-term emission stage by stage by 2020;
- To prohibit production of refrigerators with HCFCs stage by stage by 2030;
- To prohibit HCFCs consumption as ODS by 2040.

6.1.4 Relationship between Study on strategy for HCFCs control and Kyoto Protocol

Implementation of the study on strategy for HCFCs control is linked to the activities under Kyoto Protocol, so some of the action plans in the strategy should be combined with the Kyoto Protocol. Besides, in the National Guideline of eleventh-five plans, it is pointed out that China will “promoting the optimization and upgrading of industrial structure”, and “building resource-saving and environment-friendly society”; firstly proposing”, both will be propitious to HCFCs reduction and control in China.

6.2 Suggested Implementation Measures

For the implementation of the strategy objective on HCFCs control, Chinese government will strictly carry out relevant regulations and policies to exert the effect of the existing environmental protection management system and to combine the objective of HCFCs control and phase out with target of “promoting the adjustment of industrial structure” and “building resource-saving and environment-friendly society” in the National Eleventh Five-year Plan Outline; adequately exert the effect government leading and market promotion; perfect environmental protection regulations and policies further more, strengthen preferential prevention and increase the execution of law; encourage HCFCs emission control to combine with promotion of cleaner production and the full use of resources; adopt international advanced technology and experiences and encourage self-innovation; promote the development and application of alternative product and methods and adjustment of industrial structure by environmental standards and technical standards.

During the implementation, we should positive aspects of central government, local and enterprises, perfect and strengthen management agency for implementation, provide the necessary financing support and improve the implementation ability. Strengthen the supporting system for decision-making, including: the established national leading group for ozone layer protection and the project management office (PMO); establish technical support and scientific decision-making mechanism, and develop technical consultation and evaluation report aiming at regulations and policies, environmental impact assessment, technical guideline of cleaner production, alternative technologies evaluation, emission standards and technical guideline, etc.

Establish and perfect regulation and policy system, bring the phase out and control of HCFCs into the regulation and policy system and strengthen the execution and executive group. Adopt economic measures suit for the market economy system to control, reduce and phase out HCFCs production, consumption and emission, strengthen policy leading and regulation control on HCFCs control and stick to the principle of preferential prevention; develop sustainable dissemination, education and training and improve the social environmental awareness and activity criterion.

Make effort on the social investment for the implementation and take the phase out and control of HCFCs as the point, to promote the adjustment of industrial structure and increasing fashion conversion in relevant fields and bring along the development in relevant industries through financing conformity, technology optimization, management improvement and market exploration.

As to production of HCFCs, control the production scale, improve technical level in the sector, avoid aimless expansion of production scale and reduce HCFCs emission during the production by establishing technical admittance system, environmental impact assessment system, auditing of cleaner production, standards for HCFCs emission control, production quota system and product quality criterion; reduce the difficulties from the implementation in the future.

As to relevant consumption sectors of HCFCs, we should control and reduce HCFCs leakage and emission by product quality criterion and technical standards; phase out HCFCs consumption by different chemicals, sectors and products, preferentially control consumption of HCFC-22 and HCFC-141b in high emission sectors like foam and solvent; promote technology of high-sealed and leakage prevention; reduce and control HCFCs emission from the source. Promote cleaner production, and in accordance with requirement of resource-saving and recycling economy in the Eleventh Five-year Plan Outline, carry out compelling phase out system on old technics and products with high emission; control HCFCs emission by environmental impact assessment, technical guideline of cleaner production, auditing of cleaner production and emission standards.

As to large-size refrigeration equipment with HCFCs, we should strengthen the superintendence, establish register systems, strengthen normative management on servicing and refrigerant replacing and establish refrigerant recovery system to reduce the emission.

As to development of alternative products and methods, we will introduce and adopt advanced technology and encourage self- innovation based on national technical development. Besides, phase out and control of HCFCs should be carried out at the same time with development of alternative products and technology, in order to meet the domestic demand and ensure the implementation of the activities.

China will strive for international support and ensure the domestic financing demand by governmental financial arrangement and investment of enterprises. In order to promote the financial efficiency and reduce implementation risks, the government will develop activities on HCFCs control by demonstration projects.

In order to ensure the implementation of the Protocol and program activities of ODS phase out roundly after the achievement of CFCs and Halons phase out in 2007, we will revise "National plan for ODS phase out in China" when appropriate, and establish sector plan or project for HCFCs control in accordance with specific situation in relevant sectors.

The leading group for ozone layer protection is in charge of the leading and harmonization of implementation of strategy for long-term HCFCs control, SEPA in charge of the detailed programming of the strategy and relevant ministries and commissions in charge of fulfillment of detailed activities in relevant sectors.

6.3 Action Plans

6.3.1 Strengthen institution and its capacity building

Action 1 Capacity building for member units of the leader group

Clearly defining the responsibility of member units to implement the Convention and Protocol; Strengthening the capacity of technical support of departments and its directly subordinate departments and agencies to develop policies and regulations, data research, information exchange and communication, as well as supervision and management; for the demand of implementation of the Convention, training technical support personnel of each department and affiliated agencies.

Action 2 Capacity building of the Project Office

Organizing and improving the functions and responsibilities of the Project Office; Implementing staffing; Implementation necessary training of the staff; For implementation the Convention, such as information, policies and regulations, alternative technics, project preparation, performing and management, as well as other technical assistance, strengthening infrastructure construction of the Project Office; based on the existing management information system, perfecting the ODS management information systems for establishment and operation of the effective and long-term management mode.

Action 3 Strengthen the capacity building of relevant institutions of localities, sectors and associations

For the responsibilities of implementation the Convention, strengthening the survey of basic information, management of information, establishment of the policy and law, constituting of the programming, capacity building of relevant supervision and management, as well as training for relevant personnel.

According to priority of the emission control and combined with “promote the optimization and upgrading of industrial structure” put forward by the " National Guideline of eleventh-five plans”, strengthening capacity-building of data research, information management, technology assessment, self-discipline standards and norms, programming development, propagandizing and training in different industries, as well as training the relevant personnel.

6.3.2 Establish and perfecting relevant laws and regulations

Action 1 Bring implementation requirements into the establishment or revise the relevant laws and regulations

Combined with the programming of laws establishment of the “National eleventh-five plans”, gradually establishing and revising the laws and regulations relevant to ODS management; standardizing the environmental activity; intensifying laws and regulations for the priority of management and prevention, and resource saving; establishing the relevant regulations about HCFCs production, consumption, import and export, emission, recovery, as well as standards on production and products.

6.3.3 Establish and perfect relevant standard system

Through the establishment and improvement of standard system, develop, revise and improve management of technical standards of HCFCs; implement HCFCs management, and gradually restrict production, consumption and emissions of HCFCs.

Action 1 Revise or establish HCFCs emission /leakage standard for the key sector or product

For key sectors or product, asses HCFCs emission of the various technics/products at home and abroad, and establish and revise HCFCs emission standard.

Action 2 Bring HCFCs sector into the auditing system of cleaner production

When revising the audit system of cleaner production, bring the related HCFCs industry into it, such as the regulations of auditing programming of the key enterprises, as well as the category of toxic and hazardous substances for the audit.

Action 3 Establish the standard, technical policy and requirement of cleaner production for relevant industry

Establish standard of cleaner production and develop technical manual for environmental impact assessment, as well as other technical policy and requirement for relevant industry by 2010.

Action 4 Establishing the technical requirement for recovery in relevant sectors

Establish the technical standard and guideline for HCFCs recovery in relevant sectors by 2012.

6.3.4 Control capacity building for HCFCs production and encourage alternative product/technique

Action 1 Revise "Category for adjustment of industrial structure"

According to the schedule, outdated and obsolete technologies and products, as well as alternative products and technologies still under development shall be listed in "eliminate categories" and "encouragement categories", respectively of the "Catalog for the adjustment of the industrial structure" to promote industrial structure adjustment.

Action 2 Control new building, extending and rebuilding relevant to HCFCs production capacity building

In accordance with environmental impact assessment system (technical manual for EIA) and “category for adjustment of industrial structure”, control the new building, expanding and rebuilding projects relevant to HCFCs production capacity development.

6.3.5 Establishing and perfecting the dynamic registration system for production, consumption, import and export and emission data

Action 1 Establish the dynamic registration system

By 2008, establish and perfect HCFCs production and consumption quota management system, management on HCFCs production and consumption; and establish and perfect the dynamic registration system for production, consumption, import and export, and emission data to fulfill the requirement of the data report of the Parties.

Action 2 Gradually establish the label system for large equipment containing HCFCs, register and track the equipment management

Bye 2010, gradually label and register large equipment containing HCFCs, and track the management of equipment.

6.3.6 Research and establish relevant economic policy and environmental protection investment mechanism

Action 1 Research on economic policy

Based on the "State Council’s decision on strengthening environmental protection” and in order to promote cost effectiveness of the implementation, evaluate the socio-economic impact assessment for the control of HCFCs, and establish prices, taxation, trade, incentives, green procurement policies for HCFCs control.

Action 2 Policy study on alternative product and technics through market mechanism

Assess the advanced international experience, research, establish and improve independent innovation and promote policy for development and application of alternatives products and methods, including the environmental labels, the green procurement, encouraging, and promoting capacity building to create effective demand for alternative products, then to promote the industrialization of relevant environmental protection and adjustment of the related industrial structure, and product competitiveness in the international market.

Action 3 Research on the mechanism of environmental protection investment

In accordance with implementation of the Kyoto Protocol, research on the impact of HCFCs and HFCs control on the society, technology and economy; estimate the financial demand of implementation; study, develop and improve the investment and financial mechanisms of government, enterprise, local and international finance for environmental protection.

Action 4 Research on recovery system of retired equipment containing HCFCs

In accordance with recycling economy and the existing work on electrical appliances, study on the recovery system of the retired equipment containing HCFCs.

6.3.7 Research, development and promotion of alternative product and technics

Establish the assessment method for alternative product and technics, and encourage the research and development on the economic alternative product and technics.

6.3.8 Public information, awareness and education

In accordance with the "National guideline on environmental information and education", establish action plans on information, education and training; edit and publish some scientific literature for the general public to disseminate the knowledge about protection of the ozone layer; use the network platforms, as well as television, newspapers, or other media to publicize the knowledge about protection of the ozone layer, the environmentally sound alternatives and technics, and legislation and policy; continually organize the recognition activities, establish relevant contributions award to recognize the contribution of advanced organizations and individuals.

6.3.9 Decree the ban timely to phase out HCFCs used in different sectors/product

According to different chemicals, sectors and stage of the phase out process and considering the GHG emission control, ODS consumption with high ODP value, high emission rate and easy to substitute should be controlled preferentially as in following table.

Table 6-1 Target of strategy on long term management of HCFCs (as ODS consumptiom)

Controlling measure	Management on consumption	Management on production	Management on import/export	Remark
2004.1.1			Each party should prohibit import any HCFCs from any non-parties.	
2012.1.1	Limit new additional production capacity of HCFCs in room air conditioning and industrial and commercial refrigeration sectors	Limit additional HCFC production capacity		In 2015, HCFCs consumption in room air conditioning will be the key factor for incremental cost of emission reduction
2014.1.1	Label large size refrigeration equipments containing HCFCs.			For phasing out HCFCs by 1st January 2016 in China, the relevant refrigeration equipment should be labeled and registered for tracking management
2015.12.31	Benchmark number	Benchmark number		Consumption control in the Montreal Protocol: Article 5 Parties should insure that its annual HCFCs estimated consumption should be no more than the estimated consumption in 2015 during 12 months and the following 12 months since 1st January 2016; production controlling: since January 1, 2016, Article 5 Parties should use the estimated average production and consumption amount in 2015 as the benchmark
2016.1.1	Consumption control for industrial and commercial refrigeration: some large refrigeration units with low energy efficiency and HCFCs consumption in solvent sector.	Freeze production.		

2020.1.1	Consumption control of room air conditioning: phase out 50% of HCFCs consumption Consumption control of foaming sector: phase out all the HCFC-141b consumption.			Industrial and commercial refrigeration mainly use unseal or semi-unseal compressor, so the refrigerant is of medium-term emission; all the room air conditioning use the closed compressor, and the refrigerant is of short-term emission. So the leak probability of refrigerant in industrial and commercial refrigeration is higher, and phase out should be ahead of schedule.
2030.1.1	Consumption control of room air conditioning: phase out 100% of HCFCs consumption. Consumption control of industrial and commercial refrigeration: phase out 100% of HCFCs consumption. Consumption control of foaming sector: phase out all the HCFCs consumption.	Phase out 70% of production		The production of phase out should be behind consumption to meet the need of consumption
2040.1.1	Prohibit new produced HCFCs to be used in servicing process, and totally phase out HCFCs consumption	Totally phase out HCFCs production.		Montreal Protocol: Article 5 Parties should insure that the estimated consumption of HCFCs should be no more than zero during 12 months and the following 12 months since 1st January 2040

6.3.10 Measures on HCFCs emission/leakage control

Action 1 Train relevant personnel

In accordance with the demand of technical guideline of cleaner production and guideline of maintaining, train relevant personnel in different regions and sectors.

Action 2 Measures on HCFCs emission/leakage control during production

According to the regulation of the "auditing measures on cleaner production" and the "regulation on auditing process of cleaner production for key enterprise", the enterprises of key industry should carry out imperative cleaner production to control the HCFCs emission/leakage during production and processing.

Action 3 Measures on HCFCs emission/leakage control during servicing process

According to the demand of recovery methods in relevant sectors, HCFCs emission should be controlled during servicing process. Recovery, reuse and destruction also can reduce HCFCs emission.

6.3.11 Develop demonstration projects

Action 1 Develop demonstration of cleaner production

In accordance with the requirement of technical guideline of cleaner production and the national plans on recycling economy and resource-saving, develop the demonstration of cleaner production appropriately.

Action 2 Assessment of alternatives

In accordance with requirement of the Montreal Protocol, regularly assess the alternatives and issue the assessment report.

Action 3 Develop demonstration of substitution in different sectors according to order of priority of control

Develop demonstration of substitution in foam sector, solvent sector, industrial refrigeration and commercial refrigeration, which will accumulate the experiences for thoroughly phasing out HCFCs.

6.3.12 Establish plans for HCFCs phase out

Action 1 Assess and update the strategy

By 2010, assess the effect of strategy implementation; integrating with the international experience, adjust and revise the strategy to make it fit for of the actual industry development and technical advancement.

Action 2 Establish plans for HCFCs phase out

By 2015, reassess the alternative product technics; assess the effect of policy management in China; summarize the foreign experience; analyze the impact of HFCs control; analyze the impact of HCFCs control on the society and economy in China, especially the effect of production control in 2016; establish the plans for HCFCs phase out.

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[1] Wang Shiguo. CFCs Substitution and Conversion Implemented by Chinese Industrial and Commercial Sector[J]. Fine and Specialty Chemicals, 1999,22:35-36