ACHEMASIA 2004 organized in Beijing, China: The most comprehensive exhibition and congress for the process industries

DECHEMA Society for Chemical Engineering and Biotechnology is a non–profit scientific and technical society based in Frankfurt on Main, Germany. It was founded in 1926. Meanwhile it has over 5,000 private and institutional members. DECHEMA is an interdisciplinary platform for scientists, engineers and technologists. The society is dedicated to the support of research, teaching and technological progress in chemical engineering and biotechnology. DECHEMA serves as a network for technology transfer between research and industry, especially SMEs.

RAPID GROWTH IN PHARMACEUTICALS

The pharmaceutical industry in China has been developing fast since the country's reforms and opening–up to foreign investment. Production of pharmaceuticals has increased in value by 16.6% annually from 1978 to 2002, making this one of the fastest–developing sectors of the Chinese economy. In the first three quarters of 2003, pharmaceutical production increased by 20.0% and sales increased by 17.2%. The demand for chemical equipment and know–how is tremendous. Pharmaceutical technology was one of the main points of the 6th ACHEMASIA International Exhibition–Congress on Chemical Engineering and Biotechnology.

Growth above the global average, but profits under pressure

The pharmaceutical industry in China is driven mainly by the medical needs of the country's 1.3 billion people. The industry has grown rapidly since China's reform and opening–up to foreign investment. During the 8th Five–Year Plan (1990–1995) growth in pharmaceuticals peaked at 22% per year. During the 9th Five–Year Plan (1996–2000), average annual growth was 17%.

The total value of the Chinese pharmaceutical industry in 2001 was 277 billion RMB, or 2.9% of GDP; by 2002 this had risen to 330b RMB, or 3.2% of GDP, and was increasing at 18.8% annually. For comparison, the average growth rate of the pharmaceutical industry worldwide is 13%.

Sales of medicines increased at 21.7% annually from 1990 to 2001, reaching 126 billion RMB in 2001.

Among the various branches of the pharmaceutical industry, figures for 2002 show that pharmaceutical equipment grew faster than average, at 28%, and so did the manufacture of active ingredients (21%); growing at below–average rate were traditional Chinese medicine (16%), biotech–based pharmaceuticals (16%), sanitation materials (15%) and medical equipment (12%).

According to the licensing authorities, in 2001 there were 5,146 pharmaceutical companies in China. These included more than 1,700 foreign companies and joint ventures (the 20 largest international pharmaceutical companies have all invested in China). A further 1,100 companies are owned by the state.

China's 5,000 or so pharmaceutical companies include about 4,000 manufacturers of active ingredients, 1,100 traditional Chinese medicine companies and about 200 biotech firms. By the end of 2001, Chinese manufacturers were producing around 1,500 different conventional drugs, with an output of 430,000 t/y, second only to the USA.

Traditional Chinese medicine has become more strictly classified and controlled, with delivery mechanisms now including injection, intravenous bolus and aerosol. More than 8,000 individual traditional Chinese medicines are now available, classified into 40 basic types, and production has reached 370,000 t/y.

Biotech firms in China manufacture more than 300 products including bacterins, toxoids, antisera, blood products and diagnosis reagents, including 20 products based on recombinant gene technology.

More than 11,000 types of medical equipment are manufactured in China. These include equipment for computed tomography (CT) and magnetic resonance imaging (MRI). Most pharmaceutical companies in China are relatively small; the combined sales of the top 60 companies account for only 35% of total sales.

Pharmaceutical manufacturers are concentrated in eastern China, and this uneven geographical distribution is becoming more pronounced. Ten provinces account for two–thirds of total pharmaceutical sales, and eight of these ten provinces are in the east.

Both imports and exports of pharmaceuticals are increasing. Imports in 2001 were worth $4,532 billion, an increase of 5.4% on the previous year, but 2001 exports were worth $5,864, an increase of 16.6%. Active ingredients and finished drugs account for more than half of both imports and exports.

Not all this growth, however, has translated into increased profits. In 1992 most companies reported lower profits than in the previous year, and overall profit margins grew by only 0.6% while costs increased by 6.2%.

The domestic retail market for medicines is doing well, with annual growth of over 10%. Together with continuing improvements in China's medical insurance system, this has encouraged investment in the retail market. Drugstore chains are showing the fastest growth in the medicines retail sector, and competition is increasing.

Optimism in the first three quarters of 2003

According to the latest data from the National Statistics Bureau, the pharmaceutical sector continued to grow rapidly in the first three quarters of 2003. Average capacity utilisation during this period was 94%.

Table 1. The pharmaceutical industry continued to grow rapidly in the first three quarters of 2003 (source: National Statistics Bureau)

Index	Value (100m RMB)	Annual Growth rate (%)
Pharmaceutical production	2801	+19.8
Additional value provided by the pharmaceutical industry	863	+24.5
Sales	2104	+17.2
Exports	253	+19.8
Profit	191	+28.5
Profit margin	9.2%	+0.8%

Performance in the third quarter of 2003 was below than in the second quarter. Sales fell by 3.8%, and profits by 9.3%. For one group of 24 companies, growth fell by 23%.

There are two main reasons for this apparent slowdown. First, the SARS outbreak created abnormally high demand for medicines in the second quarter of 2003. Second, the price of basic medicines continues to fall.

Overall, the industry remains in excellent shape. Although growth is slowing somewhat, the quality of both products and management continues to improve.

Current highlights by sector and product type

Medical equipment is one area of the pharmaceutical industry in China that is not currently performing as well as it could. Chinese companies manufacture many thousands of types of medical equipment, but in terms of technology they are well behind the world leaders. For instance, 90% of the country's electrocardiographs and 100% of top–grade medical imaging equipment are currently imported. World sales of medical equipment are estimated at $200 billion, with 7% annual growth, so this is a market in which Chinese companies could do well.

The market for SARS vaccines began to develop rapidly almost immediately after the SARS virus was recognised in March 2003. The average world market for vaccines is estimated to be growing at 10% annually, but the Chinese domestic market is growing at 15%.

According to Wang Hexiang, secretary–general of the China Preventive Medicine Association, investment in vaccines and other medicines related to the immune system was 800 million RMB in 2002 and 1,200 million RMB in 2003. Many companies, both Chinese and foreign, are trying to cash in on this market. GlaxoSmithKline, the largest vaccine supplier to the World Health Organisation, is very active in the Chinese market. China National Biological Products Corporation, the country's biggest vaccine manufacturer, is investing 500m RMB to establish the largest vaccine R&D centre in China.

Demand for propanoic acid in China already outstrips supply, and is set to increase considerably. Current production capacity is around 1,000 t/y, but actual output is only about 200 t/y. Increasing production of vitamin B6 and drugs such as naproxen and tolperisone will require an increase in either domestic production or imports of propanoic acid.

Chinese production capacity for gamma–butyrolactone is increasing by around 10% annually. More than 20 companies in China now produce a total of 16,000 t/y of gamma–butyrolactone, but domestic demand is around 18,000 t/y. The markets for 1,4–butylene glycol and butanoic anhydride are also developing fast.

Gamma–butyrolactone can be used to treat prostate cancer. The growth in demand for this drug reflects the way the pharmaceutical market is changing as China's population ages. Drugs for prostate hyperplasia, a disease mainly of older men, made up more than 70% of the pharmaceutical market in the genito–urinary sector over the last three years.

Though this percentage is decreasing, total sales of treatments for prostate hyperplasia are increasing rapidly. For instance, sales in the Beijing area grew by 37% in the period 2000–2002. In the same period, total sales of drugs for genito–urinary conditions grew by 43% (excluding alpha–blockers such as terazosin and prazosin), while average growth for all pharmaceuticals was 17%.

Demand for other common medicines against age–related conditions, including antivirals and antibacterials, and drugs to treat conditions of the bile duct, metabolism, circulatory system, tumours and the immune system, will also increase.

Demand for vitamin B12 in China has grown fast in recent years. As late as the 1980s demand was only 200 kg/y, but it has now reached 1,200 kg/y and is growing at more than 10% annually. Consumption has increased as vitamin B12 has become an accepted part of basic medical care in China. Thanks in part to its availability in over–the–counter multivitamins, more than 90% of the

population in many large Chinese cities now take vitamin B12 as a supplement.

Other reasons for the growing popularity of vitamin B12 include: an increase in blood diseases caused by pollution; the new applications for vitamin B12 emerging from R&D, especially for diseases of the nervous system; and, as an additive in food and animal feeds. This application is still relatively small but is increasing fast.

WTO membership: challenges and opportunities

China's accession to the World Trade Organization has brought new challenges and new opportunities to the pharmaceutical industry.

In the long term, WTO membership will improve the quality and competitiveness of the pharmaceutical industry, with benefits including:

- development of the Chinese pharmaceutical regulatory system through collaboration with foreign organisations;
- positive effects on R&D and intellectual property rights;
- more international resources for the Chinese pharmaceutical industry;
- promotion of exports for the more competitive parts of the Chinese pharmaceutical sector, including generic drugs, traditional Chinese medicine and some types of medical equipment;
- better management of Chinese pharmaceutical companies.

In the short term, however, China faces three main challenges:

- import duties for medical products will fall from the current 20% to 5.5–6.5%, in line with other WTO members. This will have different effects on different parts of the pharmaceutical industry;
- pharmaceutical patents will be enforced more rigidly;
- competition from foreign companies in the wholesale and retail markets will increase, and many Chinese firms are not prepared for this.

The following sections discuss these in more detail.

WTO membership will have a small but positive effect on the export of basic pharmaceuticals. This sector is a very important export area: China is the world's largest producer of penicillin and the second–largest producer of vitamin C, for which it supplies about 30% of the international market.

The manufacture of these drugs depends on imported raw materials, so WTO membership will reduce production costs by lowering import duties. This will boost exports, especially in view of the fact that Chinese production of basic medicines currently exceeds demand and prices are falling.

However, Chinese exports of basic medicines are currently limited mainly by competition from India and other low–cost producers. This sector is characterised by low added value, so large companies tend to perform best, yet most Chinese manufacturers are small. India is a particular threat because of its more advanced position in GMP certification. In conclusion, the effect of WTO membership on this sector will be fairly small.

Chinese manufacturers of pharmaceutical active ingredients will suffer because WTO membership will reduce the price of imported drugs. Chinese companies will not be able to fight back by increasing exports, because only around 10% of them have the GMP accreditation necessary to produce drugs for export.

In general, Chinese manufacturers of active ingredients suffer from lack of technology and innovation. Even those products that are direct copies of Western drugs lag a long way behind the originals, and Chinese companies produce only 4,000 drug types compared to 150,000 in the USA.

Current healthcare reforms in China could reduce the demand for imported drugs, because these relatively expensive products are rarely approved by the state health insurance system. However, this will not stop foreign manufacturers attacking the Chinese market in other ways, such as by setting up joint–venture companies and adjusting their sales strategy accordingly.

Traditional Chinese medicine (TCM) is in steady demand at home, and has increasing potential in the export market as it becomes accepted by both consumers and regulatory authorities abroad. TCM exports currently make up only 3% of the international market – a much lower figure than for Japan and Korea. WTO membership offers great scope for increasing TCM exports, especially for well–known TCM companies such as Tongrentang and Yunnanbaiyao.

If this is to happen, however, Chinese companies and regulators need to get to grips with safety and standardisation. These are serious issues in the export market, and there is a very real danger that the domestic TCM market will come to be dominated by imported products, rather than the other way round. Indeed, in 1999 the value of imported TCM exceeded the value of exports.

In medical equipment, WTO access will affect low–tech and high–tech products differently. Low–tech equipment accounts for 30% of the value of Chinese pharmaceutical equipment production, and is generally competitive in the export market. WTO membership will therefore be good for exports of these products.

Higher–tech medical products generally lag behind their foreign competitors, so most of these are sold within China. Lower import duties for equipment such as CT and MRI scanners will damage this domestic market by making imports more competitive.

The rapid development of China's pharmaceutical industry depends to a great extent on copying Western drugs, and WTO membership will have an important effect on this. Low investment in R&D means that around 97% of the pharmaceuticals manufactured in China are copies of products developed abroad. Of the 1,500 new medicines developed during the 8th Five–Year Plan, only two have truly innovative molecular structures.

This is bad news for Chinese manufacturers, because WTO accession commits China to protecting the patent rights of foreign pharmaceutical companies. Anyone infringing a pharmaceutical patent will be liable

to fines of $400 million – 1,000 million, and a product licence for a patented medicine will cost $5 million – 6 million.

China has offered full patent protection to foreign companies since January 1993, and more limited protection since 1986. However, many companies did not take advantage of this earlier legislation, so there is a legal loophole that allows Chinese companies to copy many products without a licence.

The law in question is the Medicine Administrative Protection Statute of 1992, which says that holders of foreign pharmaceutical patents taken out between January 1986 and January 1993 could apply to the Chinese government for protection. As long as these products had not yet been sold in China, the government would grant a period of seven–and–a–half years during which Chinese companies were not allowed to copy them.

Many products that remain important in gene therapy, including EPO, recombinant insulin, recombinant G–CSF, GM–CSF, interleukin–2 and interferon, were developed before 1993 and were not registered under the Medicine Administrative Protection Statute. This means that Chinese companies may legally carry on making them without a licence.

The conclusion is that WTO membership will make relatively little difference to the current and previous generations of drugs, but that new products are a different matter. In the future, Chinese manufacturers will only be allowed to develop their own new products, which will be expensive, or to make old drugs that are out of patent, which means fierce competition and low profits.

The final challenge from free trade concerns competition from foreign manufacturers within China. At present, Chinese companies are not ready for direct international competition; they are characterised by small size, poor management, low productivity, high costs and rigid administration. Until now the government has prevented direct foreign competition, but with WTO membership this situation will change.

Trends include steady growth, GMP and biotech

Under the 10th Five–Year Plan the Chinese pharmaceutical industry is on track to increase sales by 12% annually until 2005. The need for this is driven mainly by China's increasing population and rising standard of living.

Sales of medicines in China are forecast to reach $14 billion by 2005 and $24 billion by 2010, at which point China will be the fifth–largest medicine market in the world after the USA, Japan, Germany and France.

An important change currently under way is the Chinese government's move to ensure that all pharmaceutical plants meet GMP (Good Manufacturing Practice) and GSP (Good Supply Practice) standards by 30 June 2004.

Forcible GMP compliance, administered by the National Medicine Supervising Bureau, is intended to restrict the number of pharmaceutical manufacturers and improve product quality. Its effects will be severe, because to convert a standard production line to GMP status costs an estimated 40 – 200 million RMB.

Of China's 5,000 pharmaceutical companies, 2,585 had at least one GMP approval by October 2003. Nearly 30% of these approvals were gained between June and October 2003.

World sales of biotech–based medicine have risen at an average annual rate of 30% since 1995, but by 2000 investment was starting to fall and the industry was in some trouble. In China, biotech investment by joint–stock companies fell from 700 million RMB to 596 million RMB. Slow product development, falling profits and lack of capital are hitting the biotech companies.

Thanks in part to more stringent proof of effectiveness required by the FDA in the USA, and to the launch of several new biotech–based drugs, investor confidence has started to recover. It now seems as if the industry hit bottom at the end of 2002, and since then the situation has improved.

The SARS epidemic in 2003 was a big shock to both the economy and society, but it also provided opportunities for the bio–pharmaceutical industry.

Biotech–based pharmaceuticals in China were worth about 20 billion RMB in 2002, or about 6% of the total pharmaceutical industry. This share is predicted to rise to 12% in the years to come.

Traditional Chinese medicine (TCM) offers around 2,000 kinds of herbal medicine and 3,300 other traditional remedies. The citizens of developed countries are increasingly discovering benefits in a "natural" approach to medicine, while 60% of Asians already use herbal medicines. As a result, world demand for herbal and other natural medicines increases daily.

Experts predict that demand for traditional medicines in African and Arabian countries will increase by 10–20% annually for the next 5–10 years, and that sales in these countries will reach $10 – 20 billion. On the same reckoning, global sales of traditional medicines will reach $200 – 300 billion.

The next 40 years is therefore a key period for China to expand its production of traditional medicines and to promote them across the world. China currently has just 5% of the global market in traditional medicines, and the target is to increase this share to 15% by the end of the 10th Five–Year Plan in 2005. Aiding this growth are the current efforts to standardise and rationalise the systems used to classify and prepare TCM.

Basic medicines, the retail market and OTCs

Basic pharmaceuticals are the mainstay of the industry in China. China is now the world's second–largest producer of basic medicines, and the largest producer and exporter country of penicillin, beta–lactam and vitamins.

Chinese output of basic pharmaceuticals reached 562,000 t in 2002, an annual rise of 11%, and made up 22% of global sales. Exports in this sector increased by 28% to $2.99 billion, and accounted for 52% of China's total pharmaceutical exports.

As the big foreign companies transfer the manufacture of basic pharmaceuticals to China, the

country's strength in this sector will grow. However, India is a serious challenger in this regard. Indian pharmaceutical companies also have low production costs, and in many cases they have better technology and are more competitive than their Chinese counterparts. Ultimately, Chinese manufacturers can only survive through innovation.

Another growth area is the medical retail sector. Traditional Chinese medicine companies, large pharmaceutical manufacturers and many other private companies have all invested heavily in the retail sector, and are waiting for correspondingly high profits. Competition is fierce.

Table 2. Investment by Chinese companies in the medical retail sector

Company	Investment	Goal
999	1.3 billion RMB	8,000 shops by 2005
Shanghai Huayuan	1 billion RMB	700 shops by 2003
Lizhu	200-300 million RMB	1,000 shops
Beijing Tongrentang		600 shops by 2005
Shenzhen Yizhi		21,000 shops up to 2005

As a result of this and other competition, plus government control, prices of medicines are falling from their previously very high levels. According to the National Statistics Bureau, the government has cut the prices of more than 200 medicines 10 times since 1997. Price cuts increase the demand for medicines, but whether such increases are enough to maintain manufacturers' profits is debatable. It seems that in its future policies the government may be prepared to balance the benefits to industry of maintaining prices against the benefits to consumers of cutting them.

A new law, the New Medicine Examining Statute, encourages innovation by controlling prices and protecting intellectual property. First, it extends the protection period for new medicines; in some cases this period is now 12 years instead of eight. Within the protection period, only licensed companies can produce the drug in question.

Second, profit margins for new medicines are allowed to be higher than those for other products, so that their manufacturers can more quickly recoup the costs of R&D.

Third, the government is reducing bureaucracy by contracting–out the licensing of new medicines and production plants. This will stimulate investment, improve R&D and cut the time to market for new medicines. The government will now concentrate its efforts on patent protection, which will also aid innovation.

OTC (over–the–counter, or non–prescription) medicines are growing at the fastest rate in the world, and although per–capita sales are still below the world average, this is set to change by 2005. OTC sales in China were $250 million in 1990, $1,010 million in 1994 and $1,300 million in 1996. The current figure is 24 billion RMB (20% of all pharmaceutical sales), and demand is forecast to rise to 60 billion RMB by 2005. This would make China one of the world's biggest markets for OTC drugs. Demand for OTC pharmaceuticals in China is stimulated by changes in the healthcare system. As people become more responsible for their own medical treatment, they will buy more OTC products.

Current investment projects in China

World's largest ephedrine programme

In March 2003 Shanghai Shiye Group agreed to invest 70 million RMB in a joint venture with Aike Corporation, a subsidiary of Chifeng Pharmacy Group, to create a world–class R&D and manufacturing programme for ephedrine and related products. The project is due for completion in 2005.

Shanghai Shiye Group is traded on the Shanghai stock exchange and has net capital of more than 1440 million RMB. Its main business is biotech–based medicine.

Hebei Zhuoda and US firm to build medicine exhibition centre

Hebei Zhuoda Group agreed in June 2003 to collaborate with Huamin Group, a US company, to create an "international medicine park" for pharmaceutical trade exhibitions.

"Medicine valley" programme for Haikou

A project costing 7 billion RMB will transform the Haikou area into a centre for medical R&D, production, wholesale and export. The "medicine valley" programme will create five new biomedical R&D centres clustered around the national biotech laboratory in Hainan. The development will also attract big pharmaceutical manufacturers and wholesalers, and will aim to export 20% of the pharmaceuticals produced locally.

Baxter and Xi'an Libang create joint venture

US company Baxter, one of the world's top 500 firms, signed an agreement in October 2003 with Xi'an Libang Group to establish a joint venture company in Xi'an. The new company, Baxter–Libang Xi'an Pharmacy Ltd., will use an investment of $10 million to build a 10,000–m^2 plant to produce intravenous anaesthetics.

Baxter has been active in the Chinese pharmaceutical market for many years. Xi'an Libang Group is concerned mainly with new biotech–based medicine.

East Soft Group to invest 800 million RMB in pharmaceutical imaging park

East Soft Digital Medicine Ltd., an affiliate company of the East Soft Group, will invest 800 million RMB to build a "digital pharmaceutical industry park" in Shenyang. The 130,000–m^2 park will produce around 50 types of medical imaging equipment.

East Soft Digital Medicine is China's only manufacturer of colour imaging equipment for ultrasound, CT, X–ray and MRI. Its market share for CT scanners in China is second only to that of the US company GE.

Tasly pharmaceutical industry park set for 2005 opening

The Tasly Traditional Pharmaceutical Industry Park, which is supported by Tasly Group, is set to open on schedule in 2005. As well as being a general model of modern high–tech industry, the park will host China's largest pastillation plant. The project dates from June 2003, when Tasly agreed to invest 2 billion RMB in the Tianjin Beichen Science Park.

Medical equipment industry park in Ningbo attracts over 300m RMB

The Ningbo Medical Equipment Industry Park, the first of its kind in China, opened in September 2003 at Wangchun Industry Park, Ningbo, Yinzhou province. Specialising in medical equipment as well as pharmaceutical manufacturing, the park has already attracted investment of more than 300 million RMB.

Onlytime enlarges ammonium sulphate plant

Fine–chemical giant Degussa and Guangxi Nanning Onlytime Meishi Medicine Ltd. have agreed to invest $13.5 million in expanding an ammonium sulphate plant at their Onlytime subsidiary. Work at the plant in Nanning, Wuming, began in September 2003.

Onlytime is a biomedical company part–owned by Degussa and Ruimikesi of France, the world's second–largest producer of amino acids.

When the project is complete, Onlytime will be the largest producer of pharmaceutical–grade amino acids in China. The company currently supplies nine types of amino acid, and exports to Europe, the USA and other countries in southeast Asia.

Yunnanbaiyao invests in transdermal technology

In September 2003, Yunnanbaiyao announced that it is to invest 50 million RMB in a new plant for transdermal drug delivery systems at a greenfield site in Wuxi. Total investment is eventually planned to exceed 100 million RMB.

China's environment, today and tomorrow

China has come to realise that increased spending on environmental protection can bring net economic benefits by creating a strong domestic environment industry and encouraging exports. Water and air pollution are the main targets at the moment. The environmental services sector is currently strong, but has plenty of room for growth. This will in turn stimulate the environmental equipment sector, which is growing rapidly but currently suffers from too many small companies, outdated manufacturing technology and not enough R&D. By 2010 China aims to be competing strongly in the world market for environmental equipment.

A coherent approach to environmental protection

Environmental protection in China has seen big changes in the past 20 years. As in many developed countries, the emphasis has moved from end–of–pipe pollution control, based on individual plants and processes, to a coherent and consistent strategy of pollution prevention based on entire drainage areas or other geographical regions.

China now has a national strategy for environmental protection, whose enforcement has moved away from local administrative orders, as in the past, towards laws, taxes and other economic incentives. Yet with GDP below $300 a head, China cannot work overnight miracles with its environmental performance. Steady progress guided by well–planned strategies is the way ahead.

The increasing emphasis on environmental protection has created plenty of opportunity for the environmental industry in China. During the 9th Five–Year Plan (1996–2000), annual investment in environmental protection totalled 346 billion RMB, or 0.93% of GDP. In 2001 the corresponding figures were 106 billion RMB and 1.1% of GDP, and by 2002 the fraction of GDP had reached 1.33%.

Experience from developed countries shows that environmental investment of 1–1.5% of GDP is enough to stop pollution from getting worse, but not enough to improve the situation. To reverse the environmental decline will require an annual investment of 2–3% of GDP. This increased investment will pay off. Chinese research in the period 1995–2000 showed that an increase in environmental spending from 0.7–0.8% to 1–1.5% would decrease GDP by only 0.06%, while at the same time reducing the annual costs attributable to pollution by more than 100 billion RMB. Higher environmental spending, of course, also stimulates the growth of the Chinese environmental protection industry.

The next five years will bring big challenges to environmental protection as the Chinese economy continues to grow rapidly. A realistic target will be to stop existing pollution from getting any worse, and to improve environmental decision–making.

THE ENVIRONMENTAL INDUSTRY IN CHINA TODAY

According to several studies by the China Environment Industry Association, the environmental industry is developing fast. Since 1988, the number of environmental protection companies has increased by a factor of six, and sales and profits are also increasing fast (Table 3). The environmental industry is growing faster than Chinese industry as a whole.

Table 3. Key figures for the environmental protection industry in China

Year	1988	1993	1997	1999	2000
Number of companies	2529	8561	9090	9380	18144
Number of employees (10,000)	32.1	188.2	169	154.3	317.6
Fixed assets (100m RMB)	30.3	450.1	720.1		8484.7
Sales (100m RMB)	37.9	311.5	459.2	693.1	1689.9
Sales per employee (10,000 RMB)	0.94	1.66	2.72		5.32
Profit (100m RMB)	8.3	40.9	58.1	about 77	166.7
Ratio of profit to GDP (%)	0.25	0.9	0.71		1.9
Ratio of output in the environmental industry to total national output (%)	0.25	0.9	0.71	0.84	0.77

The largest of the various sectors of the environmental protection industry is the provision of environmental services, which accounts for 38% of total sales and around 30% of total profits. The other sectors are the manufacture of environmental protection products, waste recycling, the manufacture of clean products and the protection of nature.

Environmental protection products cover equipment and materials for detecting, disposing and controlling pollution and other environmental problems. In 2000, total sales for this sector were 24 billion RMB and profits were 3.2 billion RMB. Equipment for controlling and disposing air and water pollution accounted for three–quarters of both sales and profits in this sector.

Environmental protection services refer mainly to the provision of environmental technology and consulting, management of pollution control equipment, resource recycling, and financial and management services relating to the environment. With the exception of the latter group, this sector in 2000 produced sales of 64.3 billion RMB and profits of 5.0 billion RMD. Exports in this sector for 2000 were worth $1.4 billion and imports $1.7 billion.

The Chinese environmental protection services sector has plenty of room for growth. The sector is currently dominated by resource recycling; without recycling, environmental services would account for only 11–13% of the Chinese environmental industry, whereas the corresponding figure for the world environment market as a whole is around 50%.

Current investment in environmental protection is forecast to boost the market for environmental services by 15–21 billion RMB a year. 2.5–6.5 billion RMB/y of this is attributable to project management and plant design, and 10–12 billion RMB/y to construction.

Waste recycling refers to the recycling of industrial waste, including solids, liquids and gases. According to the National Environmental Statistics Gazette published by the National Environment Bureau, the production value of waste recycling of solids, liquids and gases in 2000 was 20.8, 3.0 and 1.9 billion RMB respectively. The combined production value for recycling of all three waste types had grown to 38.6 billion RMB by 2002.

Clean products is a wide–ranging area of environmental friendly products that includes non–toxic and biodegradable materials etc. The total production value in this sector was around 26 billion RMB in 2000.

Protection of nature includes the setting up of nature reserves and schemes to rehabilitate areas that were formerly polluted. This sector was worth around 28 billion RMB in 2000.

Problems and opportunities

The Chinese environmental protection industry is growing fast and has great potential, but it also faces certain difficulties. First, the market is not yet truly competitive.

At the local level, protectionism is common; many projects are either not publicly tendered, or are subject to corruption following the tender process. This has a discouraging effect on suppliers.

Second, Chinese companies lag behind foreign manufacturers of environmental protection equipment. This is not always because of a lack of research; much of China's R&D in environmental protection can stand comparison with that in the rest of the world, and some technologies – notably bag filters, electrostatic precipitators and noise control – are highly competitive in the world market. However, most companies in the environmental sector are too small to do much R&D, so this work falls on the increasingly cash–starved universities. The result is the lack of innovations and the technology level of many products is 10–20 years behind that in developed countries.

Manufacturing technology, too, is relatively old–fashioned. This means that Chinese equipment does not score well in areas such as automation, integration, reliability, standardisation and packaging. As a result, high–tech environmental equipment will depend on imports for a long time to come.

Third, the industry is badly structured. It is full of companies that are too small to do their own R&D or to take advantages of economies of scale. Large companies account for less than 3% of the total number, and even the largest of these has sales of only 300 million RMB. 65% of the large companies are joint ventures with foreign organisations.

Partly as a result of having many small manufacturers, there is much unnecessary duplication of products. According to one study, out of more than 3,000 products, 20% perform so badly that they should never have been marketed, and a further 40% need improvement. Some types of equipment are flooding the market, while other products are in short supply.

Fourth, the agencies responsible for enforcing environmental regulations are not as effective as they should be, and there is a shortage of competent consulting companies.

On a more optimistic note, the National Environment Bureau prepared a National Environmental Programme as part of the 10th Five–Year Plan (2001–2005). According to the programme, the investment in environmental protection during the 10th Five–Year Plan is 700 billion RMB, representing 1.3% of GDP and 3.6% of total capital investment. The total investment breaks down into 270 billion RMB for water pollution, 280 billion RMB for air pollution, 90 billion RMB for solid pollution, 50 billion RMB for protecting ecosystems, and 10 billion RMB for basic construction. Most spending is on environmental protection in the narrow sense – environmental protection products and services, plus waste recycling – and the discussion below concentrates on these areas.

A programme of 1,137 "core items" distributed across all the provinces of China should absorb 262 billion RMB of the total 700 billion RMB investment. Ten of these core items, costing a total of 145 billion RMB, are especially important (Table 4).

Table 4. Of the more than 1,000 core environmental projects in the 10th Five–Year Plan, ten are described as key items

Key core items	Total investment (100m RMB)
"Three rivers and three lakes" water treatment plant	317
Sanxia reservoir region water treatment plant	146
Water from south to north (east line) cleanup	88
Bohai clean ocean project	16
"Two controlling region" power station desulphurisation	120
Beijing "clean water and blue sky" project	536
National nature reserves and ecology protection plans	30
Dangerous waste disposal	195
Construction of a national environmental monitoring network	25
Science and technology innovation programme for the environment	13

Water treatment

Managing and reducing water and air pollution are the two biggest issues within the narrow definition of environmental protection. The amount of water pollution discharged to the environment was estimated at 14.5 million t/d of COD in 2000, and the goal is to reduce this by 5 million t/d.

In municipal wastewater treatment, a key aim is the continuing development of systems for capacities of more than 200,000 t/d and less than 100,000 t/d. Technologies being studied include aerobic and anaerobic processes, including moving–bed and membrane systems, and equipment for removing nitrogen and phosphorus. For industrial wastewater treatment, standardisation and improvements in equipment quality are important. Other development fields include high–COD wastewaters, oil separation, wastewater streams containing salts and heavy metals, and the production of high–purity and sterile water.

Saving water is equally important, and here the focus is on power stations, fibres and textiles, petrochemicals, papermaking and metallurgy. Technologies under development include ash slurry handling at high concentrations, dry scrubbing systems for waste gases, water–saving systems for textile washing and dyeing, and recycling of cooling water and process water. Desalination, dry cooling towers and water–free processes are also being researched.

The water pollution programme of the 10th Five–Year Plan involves a total new investment of 250 billion RMB. Around 98 billion RMB of this is forecast to be spent within the environmental protection industry. Annual spending is 4–4.5 billion RMB for municipal wastewater treatment and 15 billion RMB for industrial wastewater treatment.

Air pollution control

Flue gas desulphurisation (FGD) is a primary objective in China's efforts to control air pollution. SO_2 emissions in 2000 were estimated at 20 million t/y, and the goal under the 10th Five–Year Plan is to reduce this figure by 4.6 million t/y as well as cutting dust emissions by 5 million t/y.

FGD processes under development range from systems suitable for coal–fired power stations of 200 MW and larger, down to small boilers and domestic stoves.

China is already relatively advanced in the design of bag filters and electrostatic precipitators (ESPs) for the control of smoke and particulates. ESP development aims to increase the range of applicability of this technology, so that it can handle high particulate concentrations, high temperatures and corrosive gases, and generally to make ESP systems more versatile.

For bag filters, the plan is to develop systems for gas flows of more than 100,000 m^3/h and temperatures up to 250°C, with a working life of more than three years. Bag filters and ESPs with integrated FGD systems are set to replace less–effective cyclones for flue gas cleaning.

To reduce vehicle exhaust emissions, China is promoting sales of small cars with modern gasoline engines, three–way exhaust catalysts, fuel injection and lean combustion. For diesel engines the emphasis is on new high–pressure systems and exhaust catalysts.

Technologies are also being developed for the disposal of toxic and smelly industrial waste gases.

Air pollution control accounts for 182 of the 1,137 core items in the National Environmental Programme and 37% of the total budget. Of the 182 projects, 84 are for clean energy (48 billion RMB), 47 are for district heating (23 billion RMB), and the remaining 51 are for pollution control (26 billion RMB).

Total demand for flue gas cleaning equipment (ESPs, bag filters, cyclones, wet FGD systems and others) is estimated at 6.6 billion RMB a year during the 10th Five–Year Plan. Other FGD systems will account for a further 8 billion RMB a year. Incinerators, scrubbers and other equipment for disposing of toxic gaseous waste will be worth about 6.7 billion RMB a year.

Solid waste

Solid waste management covers both municipal and industrial (hazardous and non–hazardous) wastes. For the former, China plans to develop new technology and equipment for waste collection, sorting, compaction, pretreatment, incineration and flue gas cleaning. For landfill, new developments include systems for gas handling and leachate cleaning, sealing membranes and instrumentation. For composting, the aim is to develop new systems for both large and small installations.

For toxic waste, high–temperature incineration is the main planned disposal route. Several purpose–built toxic waste incineration plants are envisaged.

To improve the utilisation of natural resources, the plan is to develop processes for extracting metals, including gold, silver, iron, thulium, columbium, vanadium and titanium, from other ores and minerals. Also in development are new ways to use the minerals that are co–extracted with coal, new uses for aluminite, pyrite and diatomite, and the conversion of mining waste into building materials.

New technologies for the coal industry include circulating fluidised bed (CFB) systems for coke combustion, used both to generate electricity and as a source of blocks for the building industry. Coke can also

be used to replace some or all of the clay used in making cement.

Coal ash can be used in a similar way to build roads, railways and dams, and to make concrete. Other ideas based on the use of waste include making structural materials from other types of process industry waste, recycling of alkali in the pulp and paper industry, integrated plants to produce alcohol by fermentation, and better use of waste heat and pressure.

In recycling, there is a need for technology and equipment to dismantle electronic equipment and cars, and sort the resulting materials. Other applications are in recycling paper, glass, plastics, rubber and batteries, with equipment for collecting, classifying, washing, crushing, packing, transporting and recycling waste.

Altogether, 192 projects in integrated waste disposal are planned, among them 172 city rubbish disposal items, with a total investment of 21.2 billion RMB. Furthermore China plans to build eight plants for hazardous waste disposal and 113 plants for medical waste disposal, at a total cost of 19.5 billion RMB during the time of the 10th Five–Year–Plan.

The future of the environmental industry

By 2005 the environmental protection industry will have a much more competitive structure dominated by large companies. Product technology and quality will be better, and comparable with the performance of 1990s equipment from Europe and the USA.

By 2010 this time lag is expected to be less than ten years, and China will possess several large companies and groups with advanced technology and considerable R&D muscle. By this time China will be an important exporter of environmental equipment, technology and services, and the environmental industry will contribute significantly to the national economy.

Table 5. Predictions for the growth of the Chinese environmental industry

Year	1993	1997	2000	2005		2010	
	Production value (100 million RMB)	Production value (100 million RMB)	Production value (100 million RMB)	Production value (100 million RMB)	Annual growth rate (%)	Production value (100 million RMB)	Annual growth rate (%)
Manufacture of environmental protection equipment	104.0	182.1	236.9	580	13	850	8
Environmental technology services	11.1	57.8	129.4	370	25	710	14
Waste recycling	169.3	181.4	757.1	350	7	500	7
Protection of nature	27.1	16.3	285.4	230	36	310	6
Manufacture of clean products		21.6	281.1	220	33	430	14
Totals	311.5	459.2	1689.6	1750	16	2800	10

To make this future a reality, certain changes have to happen. The first of these is the establishment of a multi–faceted investment system that taps into the enthusiasm of government, companies, foreign investors and Chinese citizens. Relying on state support is no longer enough.

Second, the provision of environmental services needs to develop somewhat in advance of the environmental equipment industry. Environmental services, which include technology, consulting and marketing, are forecast to increase at an average rate of 25% a year from 2001 to 2005 and at 14% a year in the following five years, reaching sales of 37 billion RMB by 2005 and 71 billion RMB by 2010.

Thirdly, clean production and a life–cycle approach to economics need to become widespread in industry. Work on these topics has already started, notably in the provinces of Liaoning, Jiangsu, Guangxi and Guizhou. In Jiangsu, profits from around 100 companies using clean production techniques reached 260 million RMB before 2000.

Continued and sustainable growth in the Chinese environmental protection industry requires co–operation between government, companies and international partners. The government needs to continue its progress towards consistent and comprehensive environmental regulatory systems, quality standards, and laws to govern competition and protect the rights of companies. It also needs to support the environmental industry through investment and by creating appropriate tax regimes.

Companies, meanwhile, need to review the opportunities for entering the environmental market, to create new, better and cheaper products, and to grow in size and R&D capacity.

China also needs to continue importing the best equipment from abroad, both to take advantage of its performance while domestic manufacturers catch up, and to provide performance benchmarks. Chinese companies must learn from their competitors abroad, while of course respecting intellectual property rights.

Many apparent contradictions – environment versus development, trade versus development, buyer versus seller – turn out to depend on each other to the extent that they can never be separated. In the environmental field, China needs to create a win–win situation through industrial development. Key targets include:

1. A strategy and legal framework for the environmental industry, so as to promote growth and encourage companies from abroad to contribute investment and technology.

2. Encourage trading conditions for environmental technology that are favourable to both sides, with lower import duties for high–tech and environment–friendly technologies.

3. Training in marketing, management, design, production, insurance and finance.

Appendix: current environmental projects

The main environmental projects currently in progress, or scheduled for the next two years, are specified in the following Tables. These lists, which are by no means exhaustive, show how quickly investment is taking place in China, especially for projects related to water pollution. At the moment pollution control projects dominate, though in the longer term, ecological management and other aspects of environmental protection in the wider sense have a bright future in China.

Table 6. Current projects: water treatment

Company	Project	Investment (1000 RMB)	Notes	Status
Beijing Enfei Environ- ment Ltd	Liangxiang wastewater treatment plant	71,610	New project	Started
Tianjin Chuangye Environment Ltd	Beicang wastewater treatment plant	371,000	New project	Started
Handan City Planning Water Disposing Ltd	First phase of wastewater treatment plant	338,870	New project	Started
Baoding City Planning Ltd	Second phase of Baoding water treatment project	496,520	New project	Report in progress
Shijiazhuang Water Disposing Department	Shijiazhuang wastewater treatment project (supported by the World Bank)	938,810	New project	Started
Jincheng Water Disposing Department	City wastewater treatment plant, capacity 100,000 t/d	172,000	New project	Report approved, now in design phase
Shunyi Zhanqian 414 Project Command	Shunyi water from north and east to south and west project	300,000	New project	Started
Benxi Steel Ltd	Water-saving project	174,980	New project	Report approved, project designing
Haerbin Construction Committee	Haerbin Hejiagou treatment plant	1,680,000	New project	Report in progress
Liaoning Anshan City Construction Bureau	Second phase of the city's second wastewater treatment plant, capacity 200,000 t/d	388,400	New project	Report in progress
Wuhu Shanjiang Chemical Ltd	Clean production project supported by ADB	410,000	New project	Commissioning

Table 7. Current projects: solid waste

Company	Project	Investment (1000 RMB)	Notes	Status
Daxing Environment Service Center	Capacity 300 t/d	46,000	New project	Report approved, now in design phase
Tianjin Taida Environment Ltd	Electricity generating by combusting in Shuanggang	570,000	New project	Report approved, now in design phase
Baotou Environment Department	Rubbish disposing item, capacity 1200 tons per day	107,000	New project	Report in progress
Jilin Baicheng Construction Bureau	Synthesized items of rubbish and dejecta disposing	85,910	New project	Commissioning
Jixi Environment Bureau	Second enlarging item of rubbish disposing factory	167,000	Enlarging	Commissioning
Shanghai Environment Technology Ltd	Linan rubbish combusting item	97,920	Enlarging	Report in progress
Hangzhou Lvneng Environment Ltd	Lvneng environment electricity generating item (the 8th Five-Year Plannational item)	215,800	New project	Commissioning

Table 8. Current projects: air pollution

Company	Project	Investment (1000 RMB)	Notes	Status
Dalian Cement Groups	Ash removal plant	89,950	Expansion	Commissioning
Shanghai Waigaoqiao Ltd	FGD	800,000	New project	Report approved, now in design phase
Zhejiang Feida Environment Technology Ltd	Wet lime/limestone FGD plant	160,000	New project	Report in progress
Fujian Longjing Environment Ltd	Dry desulphurisation plant using imported technology	162,400	New project	Commissioning
Jingdezhen Jiaohua Coal Gas Factory	Water-free extinguishing plant for 60 t/h of coal	179,800	New project	Report in progress

Table 9. Current projects: clean energy

Company	Project	Investment (1000 RMB)	Notes	Status
Dongdian Maolin Wind-power Ltd	30 MW demonstration wind farm	196,610	New project	Commissioning
Wuhu Guanghua Groups	Expansion of 600 m^2 solar water heating plant	199,680	Expansion	Report in progress
Shanghai Windpower Ltd	Wind farm	192,000	New project	Report approved, now in design phase