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AUSTRALIA–JAPAN RESEARCH CENTRE
ANU COLLEGE OF ASIA & THE PACIFIC
CRAWFORD SCHOOL OF ECONOMICS AND GOVERNMENT

CHINA AND EAST ASIAN ENERGY: PROSPECTS AND ISSUES

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China and East Asian Energy: Prospects and Issues
Volume II

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Peter Drysdale, Kejun Jiang and Dominic Meagher (eds)

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PREFACE

This collection of papers in two volumes is the second in a series on *China and East Asian Energy*, a major project which is an initiative of the East Asia Forum in conjunction with the China Economy and Business Program in the Crawford School of Economics and Government at the Australian National University (ANU). The first volume was published in April 2007.

The research program is directed at understanding the factors influencing China's energy markets. It also involves high-level training and capacity building to foster long-term links between policy thinkers in China and Australia. It provides for regular dialogue with participants from the energy and policy sectors in the major markets in East Asia and Australia. The backbone of the dialogue is an annual conference, the location of which has thus far alternated between Beijing and Canberra.

The objective is to advance a research agenda that informs and influences the energy policy discussion in China, Australia and the region.

This special edition of the Asia Pacific Economic Papers brings together papers presented at the second conference in the series. Due to their number and length, papers from that second conference are published across two volumes of the Asia Pacific Economic Papers. This volume includes the first half of the papers, while the next volume includes the second half. The third conference in the project is scheduled for July 2008.

Peter Drysdale, Kejun Jiang and Dominic Meagher
Canberra and Beijing
January 2008

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We are especially grateful to Trevor Wilson, without whom this volume would not have been completed. Special thanks are also due to Sue Matthews for her meticulous attention to detail in editing and to Minni Reis and Aylwen Gardiner-Garden for preparing the volumes for publication.

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ABBREVIATIONS

$ are US dollars unless otherwise specified
RMB are Renminbi (Chinese Yuan)
Tons always refers to metric tons unless otherwise indicated

ACC	advanced clean coal
AIM	Alternative Investment Market
ASEAN	Association of South East Asian Nations
AP6	Asia-Pacific Partnership for Clean Development and Climate
APEC	Asia Pacific Economic Cooperation
APP	Asia Pacific Partnership
Bbl	barrel
BOF	Basic Oxygen Furnace
CBM	coal bed methane
CCS	carbon capture and storage
CDM	Clean Development Mechanism
CFB	circulating fluid bed
CMM	Coal mine methane
CNOOC	China National Offshore Oil Company
CO_2	Carbon Dioxide
CPCNPC	National Congress of the Communist Party of China
DC	Direct Current
DOE	United States Department of Energy
DNAs	Designated National Authorities
E&P	Exploration and Production
ECEDTC	Eastern China Electricity Dispatching and Trading Center
EECPs	Early entrance co-production plants
ERI	Energy Research Institute (of China)
ETS	Emissions Trading Scheme

EU ETS	European Union Emissions Trading Scheme
FBDC	Fluidised Bed Desulphurisation Combustion
FYP	Five Year Plan
GDP	Gross Domestic Product
GHG	Green House Gas
GW	Giga-Watt (10^9 Watts)
ha	Hectare
HC	Hydro Carbons
IEA	International Energy Agency
IGCC	integrated gasification combined cycle
IPAC	Integrated Policy Assessment Model for China
IPCC	International Panel on Climate Change
IPO	Initial Public Offering
KEPCO	Korea Electric Power Corporation
KOGAS	Korea Gas Corporation
KNOC	Korea National Oil Corporation
KW	Kilo-Watt (10^3 Watts)
kV	kilo-Volts
LIFAC	Limestone Injection into the Furnace and Activation of Calcium Oxide
LNG	liquefied natural gas
LPDME	liquid phase dimethyl ether
LPG	Liquid Petroleum Gas
LPMEOH	liquid phase methanol
m^2	square metres
m^3	cubic metres
MHP	Magneto-hydrodynamic
MLTECP	China Medium and Long-Term Energy Conservation Plan
Mt	Million Tons
Mtoe	Million Tons of Oil Equivalent
MW	Mega-Watt (10^6 Watts)
NDRC	National Development and Reform Commission
NEDO	New Energy Development Organisation (in Japan)
NEDTC	Northeast Electricity Dispatching and Trading Center
NERC	Northeast Electricity Regulatory Commission
NDRC	National Development and Reform Commission
NO_x	Nitrous Oxides

OH	Hydrogen Monoxide
OPEC	Organisatino of Petroleum Exporting Countries
PFBC	Pressurised Fluidised Bed Combustion
PJ	Petajoules
PNG	piped natural gas
R&D	Research and Development
SCEDC	Southern China Electricity Dispatching Center
SCETC	Southern China Electricity Trading Center
SEPA	State Environmental Protection Administration
SERC	State Electricity Regulatory Commission
SO_2	Sulphur Dioxide
tce	tons of coal equivalent
TOU	time-of-use
TRP	Top-pressure Recovery Turbine
TSP	Total Suspended Particulates
TWh	Terra-Watt Hours
UNFCCC	United Nation's Framework Convention on Climate Change
u tons	micro tons

1 INTRODUCTION

DOMINIC MEAGHER

In 2007 climate change moved to the forefront of international politics. The United Nations Secretary General, Ban Ki-Moon, described turning the 'climate crisis into a climate compact' as the 'moral challenge of our generation'.[1] Yet progress towards agreement is painfully slow. At the centre of this challenge is China.

China is already the world's second largest energy consuming nation, and according to some estimates has already surpassed the United States as the world's largest emitter of green house gases (GHGs). That China adds 'a new coal fired power station every week' has been so often repeated that it has become conventional wisdom. That conventional wisdom has frequently been exploited, giving credence to the notion that any efforts the rest of the world make will pale into insignificance next to the tremendous expansion that China is undergoing. Yet clarity and understanding regarding exactly what is happening in China is scarce.

The papers collected in these two volumes seek to elucidate one aspect of China's growth: energy. Understanding China's energy prospects and the issues surrounding them are critical for a number of reasons.

Most important, from the perspective of long-term sustainable development, is the impact on the global environment of China's seemingly insatiable thirst for energy. According to the UN Framework Convention on Climate Change reporting, around 85 per cent of total GHG emissions come from the energy sector.[2]

For China, a clearer understanding of its energy prospects and issues is central not only to its sustainable development, but also to the much heralded goal of achieving a harmonious society.

And for Australia, insight into China's energy prospects and issues is critical to strategic investment and policy decisions. Australia is a key supplier of uranium to China, as well as a major exporter of high quality coal and liquid natural gas (LNG). Australia has also exported entrepreneurs, scientists and engineers with expertise in renewable energy.

Within this context, this second collection of papers under the Crawford School of Economics and Government's *China and East Asian Energy Project* brings together leading researchers on China and East Asia's energy issues.

In **Chapter 2**, Kejun Jiang and Xiulian Hu, of the Chinese Energy Research Institute (ERI), present scenarios for China's energy demand and supply to 2020. The ERI is China's national body responsible for conducting energy research, and is situated in the National Development and Reform Commission (NDRC). Energy forecasting conducted in the ERI uses a sophisticated approach to energy demand and supply modelling in China, called the Integrated Policy Assessment Model for China (IPAC).

Their model takes into account various assumptions about the development and deployment of numerous technologies relevant to energy demand and supply in China. It also allows modellers to make alternative assumptions about the policy environment. This chapter showcases improvements made on the model over the previous year—particularly by incorporating a major focus on the consumption of energy in buildings.

Jiang and Hu also present a detailed analysis of the policy environment in China relating to energy. Owing to the rapidly changing nature of China's policy frameworks, it is often difficult for outsiders to gain a proper perspective on the content of China's policies at any given time. This chapter goes a long way to providing clarity on China's energy policies.

Chapter 3, also by Jiang and Hu, moves the analysis to the environmental impacts of China's energy consumption. Coal (the 'dirtiest' major source of energy) provides the majority of China's energy supply, a situation which is almost certainly not going to change in the near future. Jiang and Hu present forecasts of China's emissions of each of the major GHGs through to 2030. They also detail a number of other environmental consequences of China's energy use.

In this chapter, Jiang and Hu provide as well a detailed picture of strategies available in China for mitigating the environmental impact of energy. These strategies are broken into four broad categories: legal strategies (at both national and local levels); fuel substitution strategies (to promote alternative energy); technological strategies (clean coal technologies, improving energy efficiency at the consumption end, and a discussion of potential gains across several key industries and in transport and construction); and market strategies (development of international markets and the use of taxes and special funds).

In **Chapter 4**, Tony Beck takes the analysis to the international level, asking what international institutions can best manage GHG emissions. He outlines two broad approaches. The first is a market-based approach, represented by the Kyoto Protocol and its Clean Development Mechanism (CDM). The second is a technology-focused plurilateral approach, represented by the Asia-Pacific Partnership for Clean Development and Climate (AP6).

Chapter 5 reproduces a paper authored by Warwick McKibbin commissioned for this project on *China and Northeast Asian Energy Issues*, but first appearing in Song and Garnaut, 2006.[3] The chapter details the McKibbin–Wilcoxen Blueprint—a model for establishing a market for carbon emissions. The McKibbin–Wilcoxen Blueprint has three key features. First, it is conceived of as a national system, not a global system (although it can easily become a global system). The rationale for such an approach is to avoid difficult and time consuming international negotiations.

Second, it establishes a long-term carbon price, based on 100-year licences to emit 1 ton of carbon equivalent each year. The quantity of such permits available is set by the long-term emission targets of the government and would be fixed in supply (similar to real estate). Finally, there is a complimentary short-term (10 year) market which the government can use to smooth the price transition of emissions. The chapter details the rationale and results of the model and looks at the impact of its implementation in China.

China's international procurement of energy has, especially over the last 2–3 years, been creating considerable consternation, particularly in Washington. In **Chapter 6**, Zhao Hongtu discusses China's energy procurement. One of the main areas of contested opinion is whether international acquisitions by China's energy firms represent a national procurement strategy driven by the central government or simple profit-maximising behaviour by enterprises in China's energy sector, and the implications of either situation for China and the world. Many Chinese analysts tend to believe that no such national procurement strategy exists. They point to several failed international bids for oil acquisition as evidence of the absence of a governmental strategy for foreign energy procurement. In contrast, most Western analysts not only believe that China has such a strategy, but also that the government is diligent in carrying it out.

The next two chapters compare China's energy prospects to those of Korea and Japan. In **Chapter 7**, Jin-Woo Kim describes Korea's experience in securing energy supplies. In **Chapter 8**, Takeo Suzuki discusses how Japan diversified its energy source from predominantly relying on imported oil.

The next two chapters focus on China's electricity sector. In **Chapter 9**, Zhaoguang Hu provides a very insightful analysis of the institutions and structure of China's electricity market. Hu discusses the market reforms in China's electricity sector and the privatisation of the industry. He also describes how the newly privatised electricity market is regulated.

While Hu goes to lengths to present a comprehensible picture of China's electricity regulation and institutions, in **Chapter 10**, Edward Cunningham provides a very different picture. He describes energy governance at the national level in China as fragmented, incoherent and dominated by *de facto* decisions at the local level. Meanwhile, at the industry level, dramatic capacity expansion has taken place and greatly diversified ownership rights; while at the firm level of power production, hybrid corporate energy actors are emerging, born from partnerships between traditional electricity firms and nuclear, non-traditional, and upstream resource firms seeking to hedge against rising fuel costs and to 'diversify around' disjointed central price controls. Cunningham does an excellent job of not only making it clear why it is so hard to wrap the mind around China's energy regulations, but also manages to do just that.

In **Chapter 11**, Yuhong Hu focuses on the development and outlook of China's coal sector. This paper begins by discussing the role of coal in China's energy sector, and then looks in detail at the state of China's coal reserves, considering separately each of the 13 major coal bases set for future development. It then provides an analysis of China's coal market, considering the rising demand for coal in China and the supply-side response, as well as the impacts on China's international trade in coal. The paper concludes with a brief outlook of the prospects for China's coal industry.

The final chapter, **Chapter 12**, by Xingshan Zhu and Jianhong Yang, focuses on China's gas industry. Zhu and Yang introduce China's gas production capacities and the state of installed and planned gas distribution infrastructure. They then describe developments in the demand and consumption of gas in China. The chapter then analyses the structure of China's gas industry, and how gas contributes to China's national energy strategy. Recent reforms to the regulatory framework of the gas industry are discussed, focusing on the pricing mechanism. Finally, consideration is paid to the relationship between China's gas industry and the global industry.

Notes

1 Text of speech available at http://www.un.org/apps/news/infocus/sgspeeches/search_full.asp?statID=161

2 United Nations Framework Convention on Climate Change, 2006. *Key Greenhouse Gas Emissions Data* for 1990–2003.

3 Song and Garnaut (eds), 2006, *The Turning Point in China's Economic Development*, Asia Pacific Press, Canberra

2 SCENARIOS FOR CHINESE ENERGY DEMAND AND SUPPLY TO 2020: NATIONAL POLICY AND PLANNING, ENERGY DEMAND IN BUILDINGS AND CLEAN COAL TECHNOLOGY

JIANG KEJUN AND HU XIULIAN

Introduction

This paper focuses on key factors affecting China's energy scenarios: energy consumption in buildings and the development of clean coal technologies. Due to rapid energy demand growth and significant environmental problems, many policies and programs have been established in China over the last two years.

This paper begins by introducing energy policies in China that impact the future energy demand pathway. Due to the occurrence of serious energy shortages since 2003, a series of national policies and plans have been announced. These include the '11th Five Year Plan' (FYP), the 'Renewable Energy Development Plan', the 'Energy Conservation Plan', and the 'Energy Conservation Program'.

One of the most remarkable policy objectives is contained in the 11th FYP: to reduce energy intensity by 20 per cent during the plan period (2006–10). Because of these recent policy and planning changes, recent studies on energy scenarios to 2020 have focused mostly on assessing the expected impact of the most recent national energy policies and plans. Recent studies also focus on the availability of energy resources, clean coal technology, and sectoral energy demand analyses.

Results from our study show the importance of coal use in China. Coal will still provide more than 50 per cent of China's energy to 2030, meaning that development and utilisation of clean coal technology is crucial for China's low-energy demand and carbon future. This paper analyses the development of clean coal technology and presents scenarios for forecasting.

Large-scale coal extraction and combustion have already severely impacted the environmental capacity of coal mining areas. Air pollution in both urban and rural areas has become increasingly serious. Coal production in 2004 was over 1.8 billion tons, equal to nearly 50 times the level at the time of the establishment of the People's Republic of China.

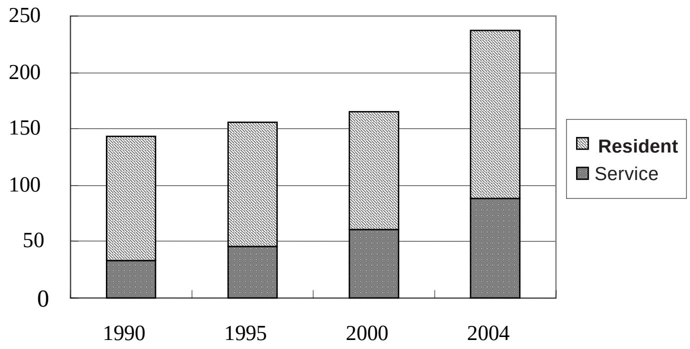
However, coal is expected to remain the major source for energy in China for the next several decades. The coal industry plays an important role in China's economy. We provide a detailed analysis of coal, especially clean coal technologies, in China.

Since the 1970s, the Chinese government has focused its efforts on environmental protection; however this has been constrained by both economic capacity and the level of technical development. The government's resources have been insufficient for the task. The following five points reflect the most significant impacts of directing insufficient resources to environmental protection:

- First, land resources have been damaged by coal exploration. Up to 2004, about 48,000 hectares (ha) of land had collapsed. On average, 0.2 ha becomes collapsed per 10,000 tons of coal extracted. The rate of land collapse has increased by more than 20,000 ha per year. Despite this, the rate of recovery is now only about 20 per cent.
- Second, coal exploration has damaged water resources and caused pollution. For example, 19 per cent of water resources in bedrock was polluted to some extent in North China in 2004.
- Third, accumulated coal stone occupies land and has damaged river beds. Accumulated coal stone from coal production reached 3 billion tons in 2005, increasing at a rate of 150–200 million tons per year. A large portion of coal stone is therefore burned as waste, emitting carbon dioxide (CO_2).
- Fourth, methane is emitted during the coal mining process. Coal mining accounts for around 10 per cent of total methane emission from anthropogenic sources. In China methane emissions from the coal industry account for one-third to one-quarter of total methane emissions from coal mining in the world.
- And finally, coal combustion is a major source of air pollution in China. Sulphur dioxide (SO_2) emissions were 19.5 million tons in 2001, around 85 per cent of which were emitted from coal combustion. Acid rain has occurred in more than one-third of China's land area.

Increasing energy use in buildings (including urban residential, rural residential and the service sector) is one of the major driving forces for rising energy consumption in China over the last few years (see Figure 2.1). During 1990–2000 energy use in buildings increased only marginally, mostly due to replacement of coal with natural gas in urban areas. However a significant increase in energy demand was seen after 2000. A major reason for this increase is the rise of energy service demands accompanying higher incomes and standards of living. For example, the prevalence of air conditioning and electric appliances has increased markedly. Demand for these services is becoming a key factor contributing to power shortages in China.

Figure 2.1 Energy use in buildings in China (Mtoe)



Note: Mtoe = million tons of oil equivalent.

Source: China Energy Statistical Yearbook, 2006. National Bureau of Statistics, Beijing.

Energy efficiency in buildings is therefore a major issue of concern for policymaking and energy supply. This paper seeks to explore the future path of energy use in buildings presenting alternative feasible scenarios and the impact of different policy options to reduce energy demand. This study is part of an energy demand and emission scenario analysis for China, conducted by the Integrated Policy Assessment Model for China (IPAC) modelling team at the China Energy Research Institute.

National policies

The 16th National Congress of the Communist Party of China (CPCNC) proposed that China will achieve the objectives of building an all-round, well-off society by 2020. Along with an increased population and the acceleration of industrialisation and urbanisation, the demand for energy will increase significantly. The imbalance between energy constraints and economic development and the environmental pollution brought about by energy utilisation will become even more evident.

In November 2004, the China Medium and Long-Term Energy Conservation Plan (MLTECP) was announced. This plan aims to push the whole society towards energy conservation and lower energy intensity, to remove energy bottlenecks, to build an energy saving society, and to promote sustainable social and economic development, thus realising the grand objective of building a society that is well-off in every aspect.

The plan foreshadows incentive policies to intensify energy conservation and to implement the guideline of prioritising energy conservation. It also includes efforts to:

- implement unified and harmonised energy and environmental policies to promote energy conservation;
- implement industrial policies to facilitate structural adjustment;
- strengthen energy conservation management according to laws;
- accelerate the development, demonstration and promotion of energy conservation technology;
- promote new market-based energy conservation mechanisms;
- reinforce energy conservation regulation on key energy consuming units;
- intensify promotion, education and training on energy conservation;
- enhance organisation and leadership; and
- promote program implementation.

If the government targets for energy conservation contained in the MLTECP are achieved, we estimate that energy demand growth in China will drop significantly—from 11.9 per cent annually during the 10th FYP period (2001–05) to just 3.8 per cent annually during the 11th FYP period (2006–10), assuming GDP growth of 8.5 per cent. The impact of this energy conservation strategy on Chinese enterprises could be significant, given the energy-intensive nature of China's economy. While machinery and equipment sectors may benefit from increased investment in energy conservation, environmental protection and renewable energy, and upstream oil companies may suffer.

The Chinese political system is currently in the process of devising more detailed sectoral implementation plans under the 11th FYP, including an Energy Plan, which is expected to draw heavily on the MLTECP. One specific initiative currently under preparation is the '1000 Enterprise Program', which would require the largest energy end-use enterprises (many of which are state-controlled enterprises) to report on their energy use and to enter into voluntary agreements with the government. These companies are responsible for approximately 30 per cent of China's total energy demand and the program is expected to result in fuel savings equivalent to 500 million tons of coal equivalent (tce) (14.7 EJ) by 2010. As provincial and local plans for implementation of the 11th FYP are devised over the next months, more concrete carrots and sticks for enterprises to engage in energy efficiency improvements will emerge.

China's 11th FYP for National Economic and Social Development puts energy at the top of the agenda and represents a major shift in government strategy towards a 'scientific approach to development'. For the first time, the Chinese Communist Party formally recognised that economic growth (measured in GDP terms) is not an adequate measure of economic development. This policy shift is reflected explicitly in the 11th FYP, which contains two quantitative targets:

- doubling of per capita GDP between 2000 and 2010; and
- a 20 per cent reduction in energy intensity (energy consumption per unit of GDP) over the period 2006–10.

Clean coal technology future

Global progress

In 2000, the United States initiated Vision 21, a program that focuses on the development of various advanced integrated technologies to promote the highly efficient and clean utilisation of coal. The final target of the program is to develop clean coal technologies with near zero emissions. The basic idea is to begin with the gasification of coal, and then further refine the gasified coal to hydrogen (H_2). H_2 could be used for power generation with an efficiency of nearly 60 per cent through fuel cell and gas turbine combined cycles. H_2 could also be used as transportation fuel. Carbon dioxide (CO_2) produced during the process can be collected and stored.

Early entrance co-production plants (EECPs) were planned to be in commercial use by 2007 with financial support from the Department of Energy (DOE) to verify technology feasibility and risk control. This program initiated three pilot phase feasibility projects.

In the United States, the Air Product & Chemicals Co. and Eastman Chemical Products Co. started to construct pilot phase plants utilising the liquid phase methanol (LPMEOH) and liquid phase dimethyl ether (LPDME) processes. These plants were constructed in 1997. Some well-known international companies, including BP, GE, Air Products and Chemicals, and Shell, conducted studies on coal integrated generation systems. More than 10 sets of integrated gasification combined cycle (IGCC) systems are operating in petrochemical companies in the world.

However, as coal use is reducing in many European countries, the investment funds for clean coal technology R&D are decreasing. Even in the United States, the investment for energy technology R&D is decreasing. This presents a challenge for future clean coal technology development. More initiatives and international collaboration will be required in the near future.

Clean coal technology development in China

The following section contains a brief status report of the current state of clean coal technology in China.

- *Coal washing*. In 2003, the coal washing rate was only 24 per cent, a very low washing rate.
- *Coal water mixture*. There are huge developments in coal water mixture in China. In 1999 the production capacity was less than 900,000 tons. The production capacity increased to nearly 7 million tons in 2003.
- *Industry briquettes*. Because of high prices, progress on industrial briquettes is slow. Recently air pollution issues increased the likelihood of greater use of industrial briquettes.
- *Ultra super critical unit*. A 1-gigawatt (GW) unit is under construction in Yuantian Power Plant; construction started in 2004 and the unit will be in operation in 2007. This is one component of the National 863 Project.
- *IGCC*. A project feasibility study was done for the Beijing IGCC project and the Yantai IGCC project during 1995–2000. Now the Yantai IGCC project is under construction. Yanzhou Coal Mine Group also made plans for IGCC, together with a methanol generation system. This project started construction in 2003.
- *Underground coal gasification*. Shandong Lineng Group made plans for a pilot phase project on underground coal gasification. This project includes four gasification furnaces with a total capacity of 3 million m^3 per day.
- *Poly-generation*. A preliminary analysis was conducted in the 973 Program; and several companies, research institutes and universities are planning to construct gasification power generation, fuel and feedstock poly-generation systems.
- *Direct coal liquefaction*. In 2002, the Shenhua direct coal liquefaction project was approved by the State Council and entered construction. This project is expected to start production in 2007. Research institutes such as the China Coal Research Academy undertake research for direct coal liquefaction.
- *Desulphurisation*. With the recent rapid increase of coal-fired power plants, newly constructed coal-fired power plants with a sulphur content higher than 1 per cent must be equipped with desulphurisation technology. Additionally, due to air pollution in cities, some existing coal-fired power plants near cities have begun to be equipped with desulphurisation equipment.
- *Low NO_x combustion technology*. This is still in the research stage. One pilot project is under construction as a research project. More than 10 units are equipped with a low nitrous oxide (NO_x) combustor.

National programs and planning

The National High Technology Research and Development Program (known as the '863 Program') was launched in March 1986 with the aim of enhancing China's international competitiveness and improving China's overall R&D capability in high technology. The program covers 20 subject topics selected from eight priority areas: biotechnology, information, automation, energy, advanced materials, marine, space and laser. The first six areas are managed by the Ministry of Science and Technology. In the program, there are several key energy technologies for development, including clean coal technology. In this program under the 10th FYP, advanced coal-fired power generation, advanced coal conversion and fluid gas purification of coal combustion were set as key research topics.

The Coal-Fired Magneto-hydrodynamic (MHD) Power Generating Technology Project has completed the design and manufacture of a helical electrical MHD propeller used for conducting performance tests of the high-field superconducting electrical MHD propeller. Through international cooperation, the performance test of a 15-tesla high-field helical closed loop electrical MHD propeller was conducted successfully. The actual field intensity was 14 teslas. Additionally, a 700-ampere electrode current and 9.3-14 per cent propeller efficiency were achieved under the high-field condition.

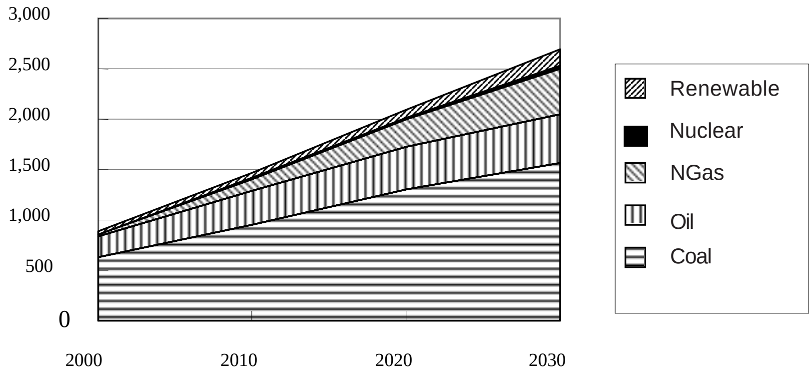
In recognition of the importance of coal in China, clean-coal focused policies have been adopted. In 1995, the China Clean Coal 9th FYP and Development Framework up to 2010 was announced by the government. This plan mainly covers four areas, including coal processing, high efficiency clean combustion, coal conversion, emission control and disposal processing. Fourteen technologies were specified in the plan: coal washing and dressing, briquette use, coal liquefaction, FBDC, pressurised fluidised bed combustion (PFBC), integrated coal gasification combined cycle (IGCC), fuel cells, fluid gas control, utilisation of waste from power plants, utilisation of coal bed methane, coal stone washing water use, industrial boilers and kilns.

Energy scenarios with a focus on clean coal

Our future projections are made using a baseline scenario. This scenario uses a basic trend to describe future economic activities. It is expected that there will be better international trading and that China's economy will increasingly be integrated with the global economy. Therefore China could rely on international markets and energy resource imports to meet part of its energy supply needs.

With rapid economic growth in China, primary energy demand in the baseline scenario could reach 2.1 billion tons of oil equivalent (toe) in 2020 and 2.7 billion toe in 2030 (see Figure 2.1). The annual growth rate from 2000 to 2030 is forecast at 3.6 per cent, while the energy elasticity of GDP is 0.58. Coal will remain the major energy source in China for the next several decades. In the baseline scenario, coal use will be 1.4 billion toe in 2020 and 1.7 billion toe in 2030, accounting for 58 per cent of energy use, compared to 720 million toe in 2000. A rapid increase in natural gas demand is expected in China, with its share in total primary energy use increasing from 4 per cent in 2000 to 17.3 per cent in 2030 (annual growth rate: 10 per cent).

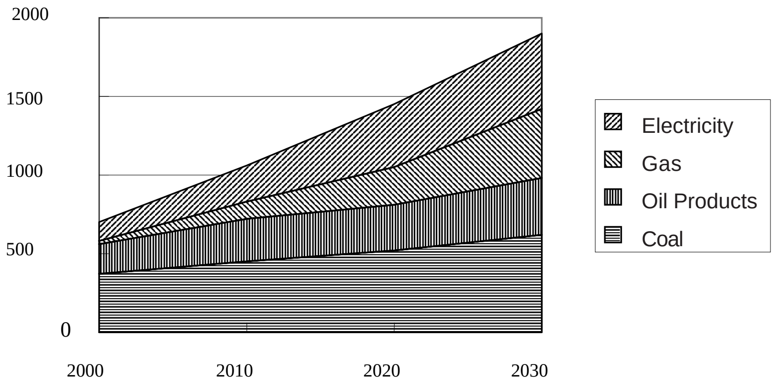
Figure 2.2 Primary energy demand in China (baseline scenario) (Mtoe)



Note: Mtoe = million tons of oil equivalent.
Source: Authors' calculations.

With respect to final energy use, electricity and natural gas increase rapidly. Electricity demand increases from 112 million toe in 2000 to 478 million toe in 2030. Natural gas demand increases from 21 million toe in 2000 to 437 million toe in 2030. Coal and oil demand increase more slowly. Coal use in the residential sector will generally decrease and be replaced by gas and electricity; coal will be mainly used in large equipment such as boilers and in steel making and building material production. Demand for oil products used for transport will grow quickly with the rapid increase of vehicles in China. Oil use in transport will increase from 105 million tce in 2000 to 457 million tce in 2030 (see Figure 2.2).

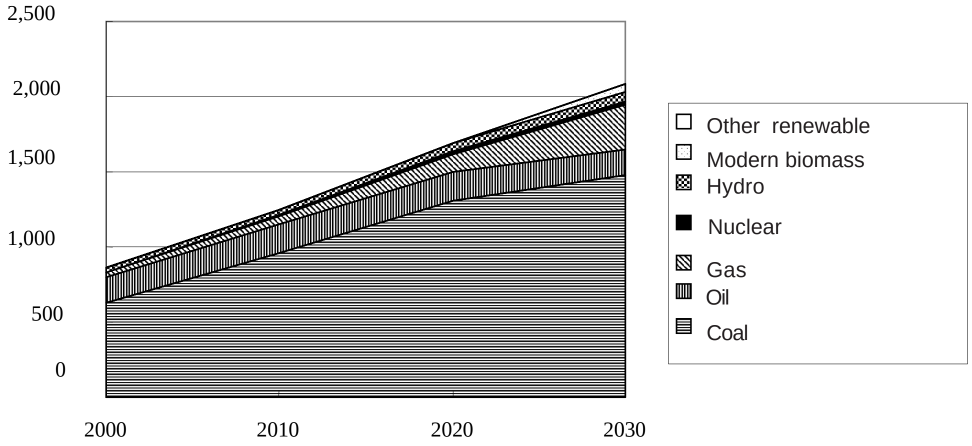
Figure 2.3 Final energy demand in China (baseline scenario) (Mtoe)



Note: Mtoe = million tons of oil equivalent.
Source: Authors' calculations.

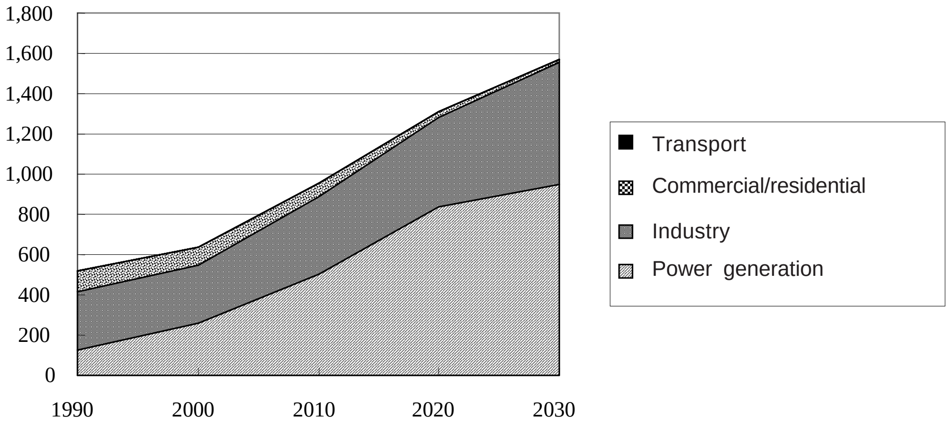
From these results we can see that coal will play a very important role in both primary and final energy supplies. Coal production could reach 1.31 billion tce by 2020 and 1.48 billion tce by 2030. Chinese coal industry experts estimate an upper limit of coal production of 1.2 billion tce by 2020. Coal demand, therefore, could exceed domestic coal production in China (Figures 2.3 and 2.4).

Figure 2.4 Energy production (baseline scenario) (Mtoe)



Note: Mtoe = million tons of oil equivalent.
Source: Authors' calculations.

Figure 2.5 Coal use by sector (Mtoe)



Note: Mtoe = million tons of oil equivalent.
Source: Authors' calculations

In the baseline scenario, development of these technologies was assumed to diffuse naturally throughout the market. Table 2.1 outlines the principal technologies in the baseline scenario.

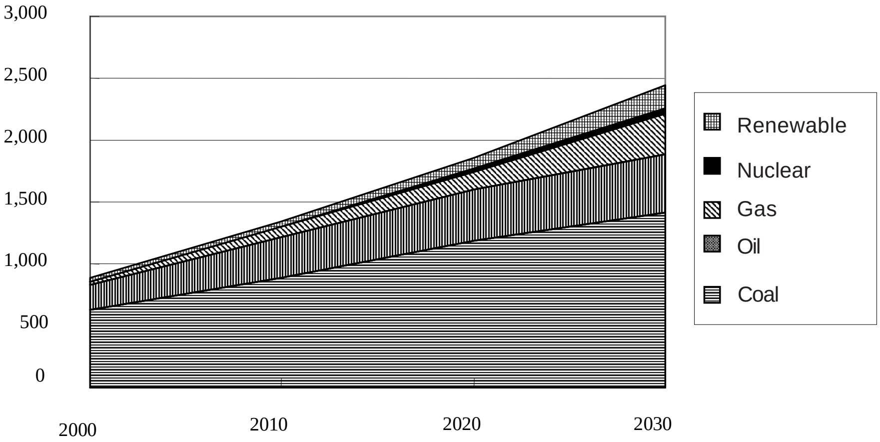
Table 2.1 Clean coal technologies (baseline scenario)

Sector	Technology	Share in 2030 of total coal use
Power generation	Super critical	25%
	IGCC	4%
Industry/boiler	Advanced boiler	45%
Industry/kiln	Advanced kiln	38%
Coal processing	Coal liquefaction	2%
Desulphurisation in power plants		58% of total coal fired power plants

Note: IGCC = integrated gasification combined cycle.

By assuming the adoption of energy and environmental policy measures, the policy scenario results are described in Figures 2.5 and 2.6. Compared with the baseline scenario, energy demand is nearly 245 million tce lower in 2020 and 280 million tce lower in 2030. There is 160 million toe coal saved due to the alternative policies. By exploring the policy options, we found significant pressure to apply these policy options in order to reach the lower energy demand scenario. Furthermore, there is considerable urgency regarding their introduction due to the long life span of energy technologies. Among these policy options, clean coal technology development and diffusion is a key component. The major assumptions regarding clean coal technology development in this scenario are given in Table 2.2.

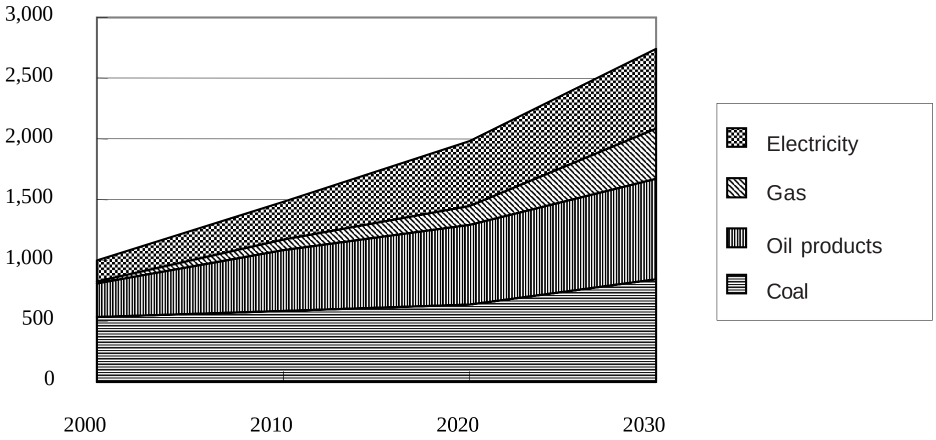
Figure 2.6 Primary energy demand (policy scenario) (Mtoe)



Note: Mtoe = million tons of oil equivalent.

Source: Authors' calculations.

Figure 2.7 Final energy demand (policy scenario) (Mtoe)



Note: Mtoe = million tons of oil equivalent.

Source: Authors' calculations.

Table 2.2 presents the clean coal technology diffusion in the policy scenario.

Table 2.2 Clean coal technology (policy scenario)

Sector/process	Technology	Share in 2030
Power generation	Super critical	25%
	IGCC	30%
Industry/boiler	Advanced boiler	75%
Industry/kiln	Advanced kiln	70%
Coal processing	Coal liquefaction	10% of total coal
Desulphurisation in power plants		80% of total coal fired power plants

Note: IGCC = integrated gasification combined cycle.

Energy demand in buildings

Scenario assumptions

Beside GDP growth and population, several important factors need to be considered in the scenario study for buildings. These additional factors are presented in Table 2.3.

Table 2.3 Factors influenced by key driving forces

Driving forces	Factors	Policies to promote the change
Social efficiency change	Energy activity change within the sector (such as change of use of heating and cooling, use of more efficient electrical appliances, etc.)	Public education, price policies
Technology progress	Efficiency progress for technology (unit energy use improvement)	Technology R&D promotion, market oriented policies, and international collaboration
	Technology mix change (more advanced technologies)	Market-oriented policies and environmental regulation
	Fuel mix change (more renewable energy and nuclear) policies, tax system	National energy industry policies, import and export

Our study covers three sectors: urban residential, rural residential and the service sector (tertiary sector not including transport). The number of households, size of the living area in the residential sector, and total building area in the service sector are major factors determining energy demand. Assumptions relating to the residential sector are given in Table 2.4.

Table 2.4 Assumptions regarding the residential sector

	2000	2010	2020	2030
Number of urban households (million)	139	205	273	326
Number of people per urban household	3.30	3.20	3.10	3.05
Living area per person in urban (m^2)	19.70	30.00	34.84	36.72
Number of rural households (million)	227	196	175	158
Number of people per rural household	3.84	3.70	3.5	3.4
Living area per person in rural (m^2)	24.7	31.1	36.0	38.8

This model considers technology used in these sectors by providing desired energy services. Energy services are activities such as lighting, space heating and washing machines in buildings, and steel and copper output in the industrial sector. These energy services can be measured in different ways, such as heating demand per square meter in buildings. But here we use service demand by household area as the major driving force. This was decided based on assumptions for service ownership, intensity change and utilisation time change. For ease of comparison, we take the energy services in 2000 as a benchmark. Service assumptions and factors for service change for the urban and rural sectors are given in Tables 2.5–2.10.

Table 2.5 Service assumptions for urban residents

Energy service	2000	2010	2020	2030
Cooking	139	205	273	326
Electric cooking	115	225	462	639
Hot water	85	197	516	815
Space heating	51	133	234	329
Air conditioner	51	247	681	1096
Fan	209	297	546	685
Lighting: C	100	148	280	632
Lighting: F	40	148	315	843
Refrigerator	94	154	363	489
Colour TV	109	207	455	665
Black & white TV	56	71	31	0
Washing machine	167	286	721	1552
Other appliances	76	141	254	310

Table 2.6 Change index in intensity of services for urban residents, 1990=1

Energy service		2000	2010	2020	2030
Cooking	Cooking time	1.05	1.05	1.05	1
Electric cooking	Use times per week (2 hours in 1990)	1.1	1.2	1.3	1.4
Hot water	Heating time	1.5	1.8	2.1	2.5
Space heating	Heating time	1.25	1.3	1.33	1.36
Air conditioner	Cooling time	1.2	1.36	1.5	1.5
Fan	Lighting time (3.5 hours in 1990)	1.10	1.22	1.22	1.22
Incandescent lighting	Lighting time	1.14	1.29	1.29	2.50
Fluorescent lighting	Capacity change	1.14	1.29	1.29	2.50
Refrigerator	Capacity change	1.05	1.2	1.4	1.5
Colour TV	Capacity change	1.1	1.3	1.4	1.5
Washing machine	Capacity change	1.05	1.1	1.2	1.7
Other appliances	Capacity change	1.5	2.5	3.5	4.5

Table 2.7 Ownership of services for urban residents, per 100 household

Energy use	2000	2010	2020	2030
Cooking	100	100	100	100
Electric cooking	90	120	130	140
Hot water	49	70	90	100
Space heating	37	40	43	45
Air conditioner	30.8	60	100	130
Fan	180	190	200	210
Incandescent lighting	75	50	48	45
Fluorescent lighting	30	50	54	60
Refrigerator	77	82	95	100
Colour TV	80	90	105	120
Washing machine	91	98	100	100
Other appliance	65	90	93	95

Table 2.8 Service assumptions for rural residents

	2000	2010	2020	2030
Cooking	272.40	254.55	245.28	236.25
Electric cooking	27.24	58.74	96.36	110.25
Hot water	13.62	48.95	87.60	126.00
Space heating	80.02	142.22	204.95	279.02
Air conditioner	2.95	44.33	418.27	1066.86
Fan	159.35	180.15	227.76	236.25
Incandescent lighting	147.10	136.29	135.94	131.31
Fluorescent lighting	74.91	142.22	188.22	227.60
Refrigerator	22.70	39.16	70.08	141.75
Colour TV	79.45	97.91	147.17	209.48
Black and white TV	158.90	137.07	134.90	86.63
Washing machine	62.43	70.49	122.64	240.98
Other appliance	204.30	274.14	350.40	401.63

Table 2.9 Change index in service intensity for rural residents, 1990=1

	2000	2010	2020	2030
Cooking	1.2	1.3	1.4	1.5
Electric cooking	1.2	1.3	1.4	1.5
Hot water	1.2	1.3	1.4	1.5
Space heating	1	1.5	2.1	2.55
Air conditioner	1	1.87	3	3.9
Fan	1.08	1.15	1.3	1.5

Incandescent lighting	1.08	1.15	1.3	1.5
Fluorescent lighting	1.1	1.2	1.35	1.6
Refrigerator	1	1	1	1
Colour TV	1	1	1.2	1.4
Black & white TV	1	1	1.1	1.1
Washing machine	1.1	1.2	1.4	1.8
Other Appliances	1.5	2	2.5	3

Table 2.10 Ownership of services for rural residents (per 100 households)

	2000	2010	2020	2030
Cooking	100	100	100	100
Electric cooking	10	30	55	70
Hot water	5	20	50	80
Space heating	38	40	42	50
Air conditioner	1.4	1	4	125
Fan	65	80	100	100
Incandescent lighting	60	50	45	40
Fluorescent lighting	30	50	60	65
Refrigerator	10	20	40	90
Colour TV	35	50	70	95
Black & white TV	70	70	70	50
Washing machine	25	30	50	85
Other appliances	60	70	80	85

Energy service demand and key factors in the service sector are given in Tables 2.11–13. Table 2.11 gives the building area in the services sector. Different building areas are reflected in the ownership of energy services.

Table 2.11 Energy service demand in the service sector

Energy use	2000	2010	2020	2030
	Building area (million m^2)			
	9,000	16,000	23,000	28,000
Cooling	44.9	38.0	88.9	157.2
Space heating	71.5	110.3	153.3	210.6
Lighting	209.0	312.0	429.0	560.0
Duplicating machine	13.2	24.2	42.8	63.0
Computer	22.6	61.8	123.6	211.7
Elevator	21.5	36.0	52.3	71.3
Other electric appliance	76.6	114.3	157.1	205.1
Hot water	48.9	89.9	139.0	194.4
Cooking	13.6	23.5	26.8	49.6

Table 2.12 Service ownership changes in the service sector (per cent)

Energy use	2000	2010	2020	2030
Cooling	21.0	24.0	26.0	28.0
Space heating	38.0	41.0	43.0	45.0
Lighting	100.0	100.0	100.0	100.0
Duplicating machine	7.0	9.0	12.0	14.0
Computer	12.0	22.0	32.0	42.0
Elevator	12.0	14.0	16.0	18.0
Other electric appliance	40.7	40.7	40.7	40.7
Hot water	26.0	32.0	36.0	40.0
Cooking	100.0	100.0	100.0	100.0

Table 2.13 Change index in service intensity change, 1990=1

Energy use	2000	2010	2020	2030
Cooling	1.25	1.28	1.34	1.38
Space heating	1.1	1.15	1.2	1.3
Lighting	1.1	1.2	1.3	1.4
Duplicating machine	1.1	1.15	1.2	1.25
Computer	1.1	1.2	1.3	1.4
Elevator	1.05	1.1	1.1	1.1
Other electric appliance	1.1	1.2	1.3	1.4
Hot water	1.1	1.2	1.3	1.35
Cooking	1.1	1.2	1.3	1.35

The model calculates energy demand based on technology use for each energy service. More than 100 energy technologies are listed in the model. Table 2.14 summarises the technology used in different sectors.

Table 2.14 Technologies used in the sectors

Energy service	Technology	Sectors
Energy saving buildings	Normal building	Urban residential, rural
residential,	50% energy saving building	Rural residential
service sector	60% energy saving building	Service sector
	75% energy saving building	
Space heating	Co-generation heat supply	
	Central heat supply	
	Small coal stove	
	Electric heater	
	Space heating by gas	
	Gas boiler	
	Air conditioner for space heating	

	Air conditioner for cooling	
Cooking	Gas stove (for cooking)	
	Coal stove (for cooking)	
	Briquette stove	
	LPG stove	
	Work gas stove	
	Biomass stove	Rural residential
	Efficient biomass stove	
	Biogas stove	
Electric cooking	Electric pot	Urban residential, rural residential, service sector
	New Electric pot	
Incandescent light	Incandescent light	
	Incandescent light (8 energy efficiency or higher)	
	Incandescent light (20 energy efficiency or higher)	
Fluorescent light	Fluorescent light (normal)	
	Fluorescent light (20 energy saving)	
	Compact fluorescent light (75 energy saving)	
	Ring fluorescent light (20 energy saving)	
Space cooling	Electric air conditioner	
	Advanced Electric air conditioner	
	Super air conditioner	
	Central air cooling	Service sector
Fan	Fan	Urban residential, rural residential
Washing machine	Washing machine	
	New washing machine	
Refrigerator	Electric refrigerator	
	New electric refrigerator	
Colour TV	Colour TV	
Black & white TV	Black & white TV	
Other electric appliances	Other electric	
	Other electric (advanced)	
Hot water	Solar heater	
	Gas heater	
	LPG heater	
	Electric heater	
Computer	Computer	Service sector
	Energy-efficient computer	
Duplicator	Duplicator	
	Energy saving duplicator	
Elevator	Elevator	
	Energy saving elevator	
Other office appliance	Office appliance	
	Energy saving office appliance	

Energy demand scenarios

In order to analyse future energy demand in buildings in China, we consider two scenarios. The Baseline uses a basic trend to describe future energy use assuming moderate energy efficiency improvements. The policy scenario assumes that energy efficiency in buildings and equipment is greater than that suggested by current trends. Policy options to be considered in the policy scenario are given in Table 2.15.

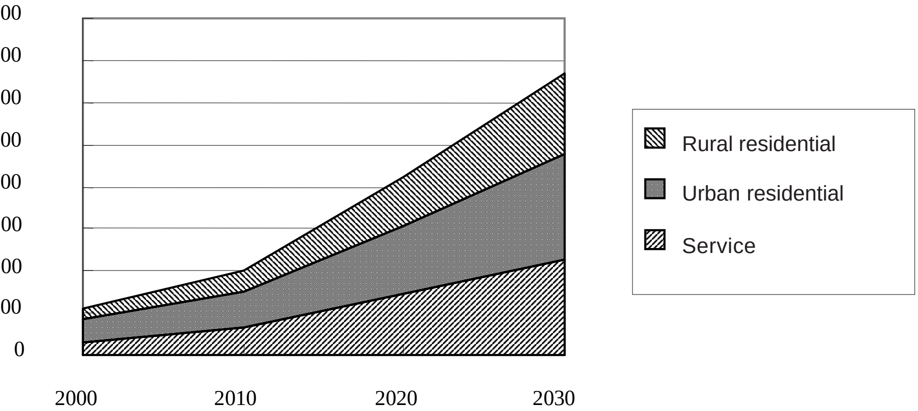
Table 2.15 Policy options used in the modelling study

Area	Options (in 2030)
Cooking households	Natural gas cooking in urban households, LPG and biogas in rural
Space heating	70% of urban buildings and 65 per cent of rural buildings using energy saving central heating. Rural buildings also using heat pumps.
Space cooling	60% adoption of ultra high efficiency air conditioners 80% adoption of energy efficient cooling
Electric appliances	100% utilisation of high efficiency refrigerators 45% utilisation of higher efficiency washing machines
Lighting	100% utilisation of compact lighting 80% higher efficiency
Hot water	Solar heater
Office electric equipment	30% utilisation of higher efficiency computers and photocopiers

Results

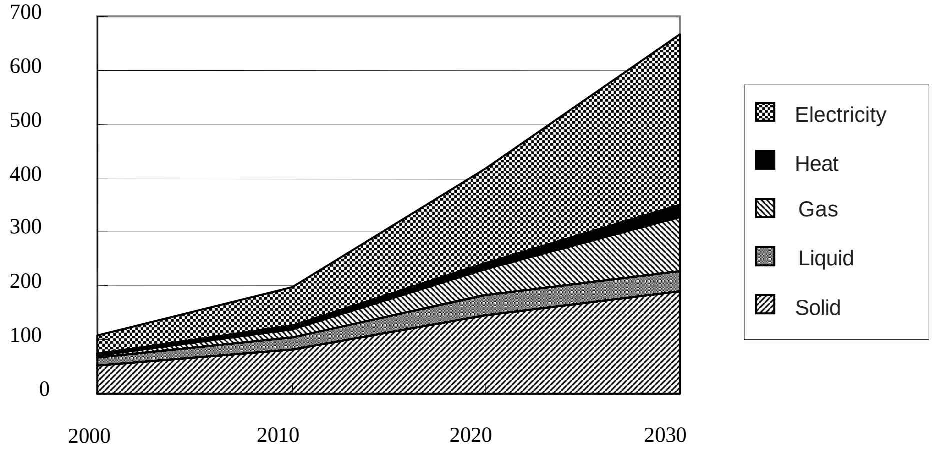
Energy demand is calculated using the IPAC-AIM/technology model. Baseline scenario results are given in Figures 2.5 and 2.6. Final energy use in buildings in the baseline scenario could reach 417 million toe in 2020 and 666 million toe in 2030. The annual growth rate from 2000 to 2030 is 6.2 per cent. By 2020 urban residential buildings will consume 39 per cent of energy consumed in buildings while rural residential buildings will consume 27 per cent and buildings in the service sector will consume 34 per cent (see Figure 2.8). Electricity will be the main form of energy used in buildings, accounting for 42 per cent in 2020 and 48 per cent in 2030; however coal use will also increase due to cooking and space heating demand (see Figures 2.3 and 2.4).

Figure 2.8 Final energy use in buildings by sectors (baseline scenario) (Mtoe)



Note: Mtoe = million tons of oil equivalent.
Source: Authors' calculations.

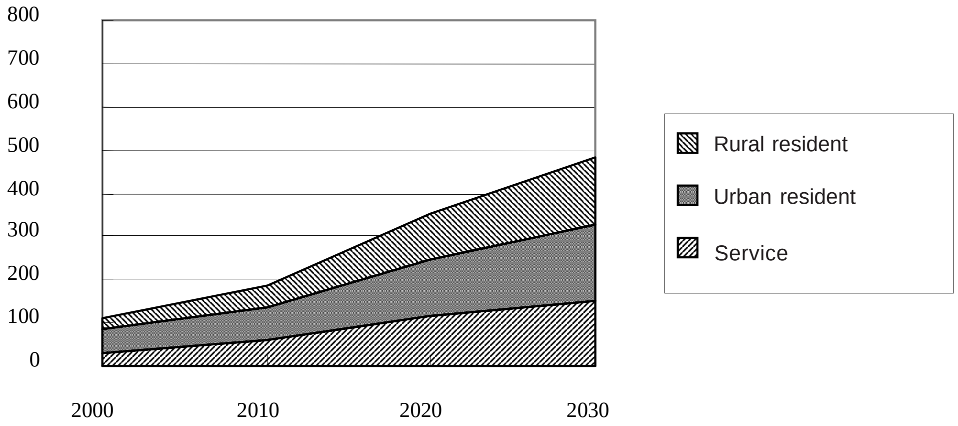
Figure 2.9 Final energy use in buildings by energy type (baseline scenario) (Mtoe)



Note: Mtoe = million tons of oil equivalent.
Source: Authors' calculations.

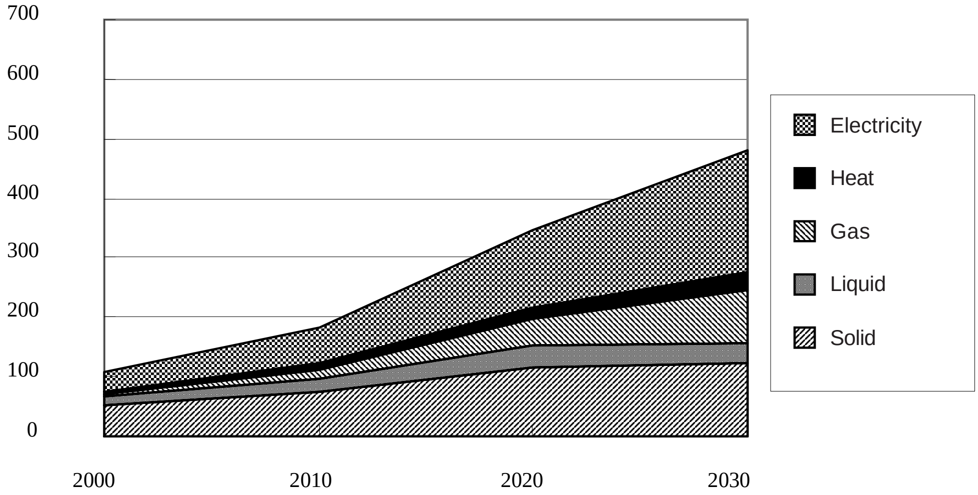
In the policy scenario, final energy demand in buildings is forecast to reach 347 million toe by 2020 and 479 million toe by 2030, an annual growth rate of 6.2 per cent from 2000 to 2030. By 2020 urban residential buildings will consume 37 per cent of all energy consumed in buildings, while rural residential buildings will consume 30 per cent and buildings in the services sector 33 per cent. By 2030 these figures will be 36 per cent, 32 per cent and 32 per cent respectively, a slight shift away from urban residential buildings (see Figure 2.10). Electricity will be the major energy form used in buildings, taking a share of 38 per cent by 2020 and 42 per cent by 2030 (see Figure 2.11).

Figure 2.10 Final energy use in buildings by sectors (policy scenario) (Mtoe)



Note: Mtoe = million tons of oil equivalent.
Source: Authors' calculations.

Figure 2.11 Final energy use in buildings by energy type (policy scenario) (Mtoe)



Note: Mtoe = million tons of oil equivalent.
Source: Authors' calculations.

Energy resources

Coal

Among confirmed fossil fuel energy resources, 96 per cent is coal. The remaining 4 per cent of confirmed fossil fuel energy resources includes 2.36 billion tons of oil (by the end of 2003), and 572.3 trillion m^3 of natural gas (by the end of 2000). Economic reserves of gas are only 1 trillion m^3. This relative abundance of known coal assures a future in which the price of coal is relatively low. Coal will therefore continue to play a key role in the energy security concerns of China.

There is an urgent demand to reduce coal use in China because of the very large amount of coal used currently and expectations that this will keep increasing in the future. Such a large amount of coal use has brought major pressure on coal mine production to deal with safety issues, transport issues and environmental issues, including land damage, water pollution and air pollution. The role of clean coal technology development in China and elsewhere is well identified. In order to further promote a clean energy future, the following recommendations are given:

- Firstly, clean coal technology should be emphasised. This can mitigate emissions from coal combustion. Because only a few countries in the world are using coal on a large scale, development of clean coal technologies relies on these countries. China is the world's largest coal consumer. In future China's use of coal is only likely to increase, with China potentially taking more than 40 per cent of world coal consumption by 2020. Therefore China should be a leading partner in the development and adaptation of clean coal technology, working closely with several other countries.

- Secondly, various national laws, regulations and standards for the energy industry should be prepared to enable China to reach the target of a clean energy system. So far the legal system is very weak for the promotion of a clean energy system.
- Third, R&D must be emphasised. Technology is the key issue for clean energy and lower energy demand in the future. International collaboration for technology transfer and diffusion must be encouraged. China and a few other major coal consuming countries should further develop clean coal technologies.
- Finally, international activities for clean coal technology R&D, such as clean coal partnership and the Clean Development Mechanism, should be promoted. These provide opportunities for China and for a clean coal future.

Gas

Historically China has paid less attention to natural gas than to other energy sources, with much less investment in exploration for gas resources. However, the emphasis on environmental protection in recent years has led both the Chinese government and private firms to direct much more investment to natural gas resource exploration. In the last two years three very large natural gas resources have been found in mainland China.

Hydropower

China has significant hydropower resources, but they are very unevenly distributed. Seventy per cent of hydropower resources are located in southwest China, far from the main consumption centres. Water resources appropriate to smaller-scale hydropower are plentiful in China. According to the results of China's latest hydropower resource survey, the potential total capacity of small-scale hydropower that could be feasibly developed in the country is 125 GW. The hydropower resource base is widely distributed, including sites in over 1,600 counties (or cities) spread over 30 of China's provinces (or provincial level municipalities). Of 1,600 counties, 65 are located in southwest China; the small-scale hydropower resources of this region account for over 50 per cent of total national potential capacity.

The Chinese government has implemented policies that strongly support small-scale hydropower, including in its rural electrification plans. Small-scale hydropower has already played a very important role in the electrification of China, particularly in rural areas. About one-third of China's counties rely on small-scale hydropower as their main source of electricity. China has further made the building of small-scale hydropower stations a critical component of rural energy development in its Western China Cropland Conversion Program and its Western China Energy Development Program. Within the context of these programs, the government has provided special funds derived from government bonds for small-scale hydropower development. At present, existing small-scale hydropower stations, with an installed capacity of 30 GW, represent about 20 per cent of the total projected potential capacity. It is expected that between 2020 and 2030 China's small-scale hydropower resources will be almost fully developed, with a capacity of 100 GW and accounting for about 10 per cent of China's total installed power capacity.

This development has had to overcome several problems, such as bad transportation infrastructure, difficulties in construction, economic problems in long-distance transmission, ecosystem problems, long payback periods and difficulties in raising capital. China will need to continue to overcome these problems to further develop its small hydro capacity.

Nuclear power

China has good conditions for the development of nuclear power. Domestic uranium resources are 650 kilotons (Kt), and international uranium resources are also quite large. There are around 3–4 million tons of uranium resources with extraction costs below $80 per kilogram of uranium—enough for more than 50 years of power generation. If uranium is used in fast-breeder reactors, the uranium reserves would be enough for more then 3,000 years. Chinese companies already produce 300 MW using light-water reactor technologies, and nuclear power plants could be constructed with domestic technologies. Chinese companies already have the ability to produce 3–4 sets of nuclear power generators. The existing capacity of nuclear power plants in China is already more than 40–50 GW. China also has the ability to produce and supply nuclear fuel, and to process used fuels.

Biomass energy

China's main biomass resources are agricultural wastes, scraps from the forestry and forest product industries, and municipal waste. Agricultural wastes are widely distributed. Among them, the annual production of crop stalks alone surpasses 600 million tons. Crop stalks suitable for energy production are estimated to represent a potential of 12,000 petajoules (PJ) annually. Wastes from the processing of agricultural products and manure from livestock farms could theoretically yield nearly 80 billion cubic metres of biogas. Scraps from forestry and forest product industries represent a resource equivalent to 8,000 PJ per annum.

Furthermore, with the implementation of China's Natural Forest Protection Program (which includes logging bans and logging reductions over much of the nation's natural forests) and its Sloping Cropland Conversion Program (which calls for the conversion of much of the nation's sloping cropland to trees and grasses), it is expected that the amount of scraps from forestry and forest product industries used in energy applications will increase substantially, potentially reaching 12,000 PJ per annum by 2020.

Municipal waste in China is expected to reach 210 million tons per annum in 2020. If 60 per cent of this is used in landfill methane applications, 2–10 billion cubic metres of methane could be produced.

Finally, 'energy crops' are a biomass energy resource with the potential for commercialisation. Many types of energy crops are suited for growing in China. Chief among these are rapeseed and other edible oil plants and some plants that grow in the wild, such as sumac, Chinese goldthread, and sweet broomcorn. By 2020, such crops could potentially yield over 50 million tons of liquid fuel annually, including over 28 million tons of ethanol and 24 million tons of biodiesel. In sum, whether burned directly, used to produce electricity or used as a substitute liquid fuel, biomass energy resources have the potential to play a decisive role in China's energy supply.

Wind power

With its large land mass and long coastline, China has relatively abundant wind resources. According to estimates by the China Meteorology Research Institute, land-based exploitable wind resources represent a potential power generation capacity of 253 GW (based on wind resources at a height of 10 metres above the ground). The institute has further estimated ocean-based wind resources to represent an exploitable potential of about 750 GW, so the total estimated wind power potential of China is about 1,000 GW. Areas rich in wind resources are located mainly along the southeast coast and nearby islands and in Inner Mongolia, Xinjiang, Gansu Province's Hexi corridor, and some parts of northeast China, northwest China, north China, and the Qinghai–Tibetan Plateau. Aside from this, certain areas in China's interior are rich in wind resources. China also has large marine areas with plentiful ocean-based wind resources. With current technology, wind turbines can be installed in the ocean up to 10 kilometres away from the coast and at ocean depths of up to 20 metres.

By the end of 2003, the total capacity of installed and grid-connected wind power in China was 560 MW, ranking China 10th in the world in terms of total installed wind power capacity. Aside from grid-connected installations, China has about 200,000 stand-alone small-scale wind turbines (with installed capacity of 25 MW) that provide electricity to rural households located in remote areas. China can manufacture large-scale wind turbines with a capacity of 750 KW or less efficiently and economically; at the time of writing, it was in the process of developing megawatt-scale turbines. China has also established 40 wind farms with efficient operation and management. There are now qualified technical personnel in the areas of wind power design and construction, creating a sound base for developing large-scale wind power in China.

Conclusion

The national government has established a portfolio of policies for energy conservation and the development of renewable energy. The centre of this policy portfolio is the target for 2010, established in the 11th FYP, of reducing energy intensity by 20 per cent from 2000 levels. Energy issues have become a top concern of the government in China. The recently developed policies are expected to be fully backed by action, with the government fully committed to reach the targets.

There are several international collaboration programs currently under way, including under the Kyoto Protocol. Now, however, post-Kyoto discussion is required. Other programs include the Asia Pacific Partnership on Clean Development and Climate and numerous bilateral collaborations. These programs will support the Chinese government's national program by establishing various opportunities for collaboration and cooperation with other countries.

Our study shows that the energy demand of buildings in China will increase significantly. The energy demand in buildings could range from 347 to 417 million toe in 2020, and 479 to 666 million toe in 2030. This depends critically on technological progress and government polices.

A combination of the right policies and the widespread adoption of new technologies could significantly reduce energy demand in buildings in China. Even with falling costs for existing technologies (energy-efficient buildings, solar heaters, high-efficiency refrigerators and air conditioners), energy demand could be much lower.

China's buildings provide considerable potential for major energy savings at potentially low costs. For these savings to be achieved, strong policies are urgently needed to encourage the adoption of new energy saving technologies and to change energy consumption behaviour in buildings.

Policies regulating energy efficiency in buildings (with strong government enforcement), fiscal policies to reduce the cost of space heating for users of energy-efficient buildings, much higher energy efficiency standards for electric appliances, and the promotion of solar and geothermal heaters for space heating and heat pumps should be implemented as soon as possible to avoid long technology lock-in effects. There are precedents for successful energy saving in buildings in other countries. China should make efforts now to reduce rapid increases in energy use in buildings in China. This is necessary for the sake of energy security as well as local and global environmental issues; the IPAC modelling team has demonstrated that it is also beneficial for local economic activities (Jiang et al. 2005).

Our study shows that the use of appropriate technologies and policy options can contribute to at least a 28 per cent energy saving in buildings compared with the baseline scenario. However, we did not consider some advanced technologies that are available now – for example, distributed heating, cooling and power generation systems, super high energy saving buildings, and countermeasures such as energy-saving campaigns. If those technologies are also implemented, the potential energy savings will be even greater.

It is clear that coal demand in China will keep growing. We can conclude that emissions from coal use will also keep increasing if we do not make further efforts. Development of clean coal technology in China is therefore both urgent and critical. In 2004, the coal industry employed 7.6 million people; it is projected to employ 7.8 million by 2030. The sustainable development of coal can therefore provide many opportunities for low-income people to find employment.

Furthermore, taking a global lead in the development of clean coal technology will bring major economic benefits. However the environmental impacts of developing clean coal technologies are more important for long-term sustainability. CO_2, SO_2, NO_x and particulate matter (PM) emissions, as well as water pollution, will be significantly reduced by the use of clean coal technologies. This will have major beneficial impacts on China's local environment and on climate change. Finally, the development of clean coal technologies will be crucial for successfully meeting the government's environmental target in the 11th FYP.

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3 STRATEGIES FOR THE MANAGEMENT OF THE ENVIRONMENTAL IMPACT OF ENERGY CONSUMPTION IN CHINA

XIULIAN HU AND KEJUN JIANG

Introduction

This chapter assesses the environmental impact of energy use in China. The first section provides an overview of energy use throughout the Chinese economy. The overall growth of energy production and consumption is considered, along with the structure of different fuel types. Energy use in each of three key consuming sectors - industry, buildings, and transport - is considered in additional detail. The first section should provide context for understanding the scale and nature of China's energy consumption.

The second section quantifies pollution levels resulting from energy use in China. The specific forms of environmental degradation resulting from each fuel type - coal, oil and natural gas - are discussed, along with environmental damage caused in the generation of electricity. Pollution and environmental damage associated with different final uses is also discussed, paying particular attention to industry and vehicle consumption.

The third section is the most extensive part of the chapter, providing a detailed picture of strategies available in China for mitigating the environmental impact of energy. These strategies are broken into four broad categories: legal strategies (at both national and local levels); fuel substitution strategies (to promote alternative energy); technological strategies (clean coal technologies, improving energy efficiency at the consumption end, and a discussion of potential gains across several key industries and in transport and construction); and market strategies (development of international markets and the use of taxes and special funds).

The final section presents forecasts of emissions of the major pollutants, NO_x, SO_2, CO_2 and TSP based on scenarios of various levels of adoption of the pollution control measures discussed in the previous section. A baseline scenario, in which only a limited set of environmental policy options are utilised, is contrasted with a policy scenario, in which a

Energy and Environmental Development in China

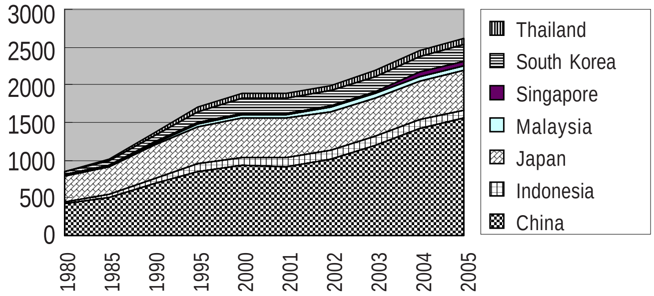
Coal dominant energy production and consumption in China

China is facing an unprecedented challenge in energy use. Dealing with this challenge is a key requirement for sustained economic growth. From 1978 (the beginning of economic reform in China) to 2000, primary energy consumption in China rose from 400 Mtoe (million tons of oil equivalent) to 970 Mtoe, an annual increase of 4.11 per cent. GDP in this period grew by 9.66 per cent resulting in an average energy consumption elasticity over the 22 years of 0.43. Since 2000, energy consumption in China has grown at an unusually rapid rate, outstripping GDP growth for the first time since the reform period. From 2000 to 2005, primary energy consumption increased from 970 Mtoe to 1557 Mtoe, an annual increase of 9.93 per cent. In the same period, the average annual growth of GDP was 9.49 per cent, indicating an energy consumption elasticity of production greater than 1 (equal to 1.05).

Putting this growth in context, the global average annual increase of primary energy over the 2000 to 2005 period was 3.08 per cent, while in East Asia1 energy consumption grew by 6.86 per cent. In both output (GDP) and energy consumption, China's growth far outstripped both the region and the globe over the last five years. This rapid growth has led to a situation in which primary energy consumption in China in 2005 accounted for 59.4 per cent of total consumption in East Asia and 14.8 per cent of the world total, making China the second largest energy consuming nation, after the United States.

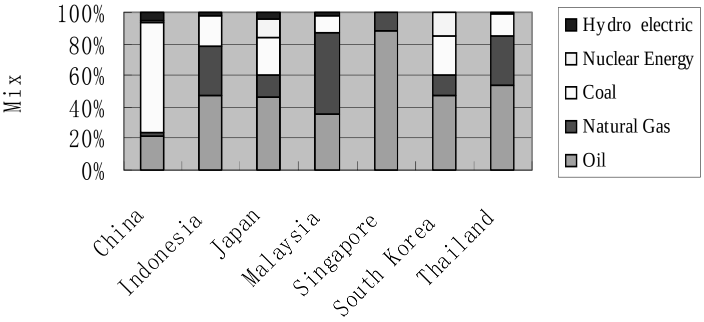
In 2005 total energy consumption in East Asia was 2,614 Mtoe, accounting for 76.4 per cent of energy consumption in the Asia Pacific region and 24.8 per cent in the world. Energy related carbon emissions were 1,790 Mt, accounting for 26.1 per cent of total carbon emissions in the world. Excluding China (which mainly relies on coal), the countries of East Asia mainly rely on oil. As a whole, the consumption of oil, natural gas, nuclear power and hydropower in East Asia in 2005 accounted for 22 per cent, 9.9 per cent, 18 per cent and 17.5 per cent respectively of the total world consumption, while coal consumption accounted for 44.4 per cent. Of this, China, consumes about 36.9 percent. From 1990 to 2005, global coal consumption increased by 696 Mtoe, while that in East Asia increased by 812 Mtoe, of which 551 Mtoe is from China alone. Figure 3.1 and Figure 3.2 show the primary energy consumption in East Asia from 1980 to 2005 and the energy consumption mix in 2005.

Figure 3.1: Primary energy consumption in East Asia from 1980 to 2005



Source: Authors' calculations

Figure 3.2: Energy consumption mix in East Asia by 2005



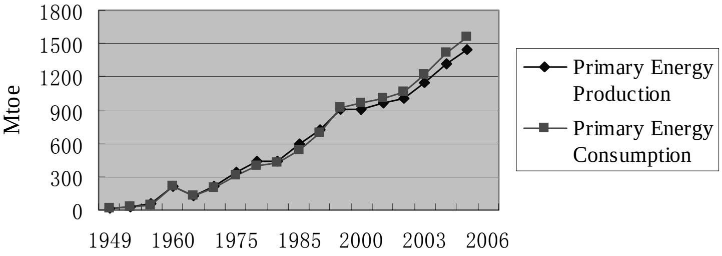
Source: Authors' calculations

China has a relatively high population but insufficient energy resources. It is now in a process of rapid industrialisation and urbanisation. It is faced with a situation of very rapid and energy intensive economic growth. Continual expansion of the scale of consumption and the growing conflict between energy supply and demand have become serious problems in the economic development of China.

Energy Development

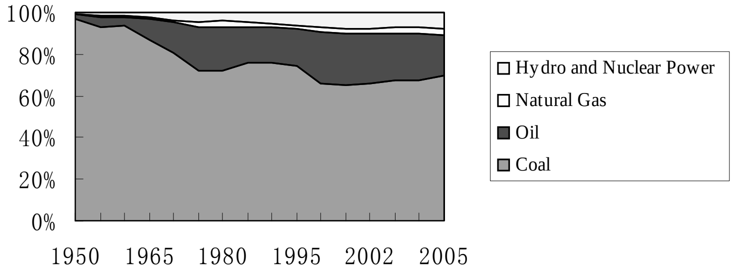
Because of rapid economic growth, total primary energy consumption increased from 400 Mtoe in 1978 to nearly 1557 Mtoe in 2005, with an annual average rate of increase of 5.16 per cent (see Figure 3.3) (China Energy Year Book 2002-5, China Year Book 2004-5). Coal is the major energy source, providing 70.7 per cent of total primary energy use in 1978 and 69.9 per cent in 2005 (see Figure 3.4). Recent years have witnessed a dramatic surge in the rate of increase of energy use in China and widespread energy shortages.

Figure 3.3: Primary energy production and consumption in China



Source: China Energy Statistical Year Book 2000-6, National Bureau of Statistics, Beijing.

Figure 3.4: Primary energy use in China by energy type



Source: China Energy Statistical Year Book 2000-6, National Bureau of Statistics, Beijing.

China is the largest coal producing and consuming country in the world. Between 1978 and 2005, total raw coal output increased from 618 Mt to more than 2,187 Mt, with an average annual growth rate of 4.8 per cent per year. Prior to 2000, the share of coal use in total energy use decreased, but it then increased again, from 66.6 per cent in 2000 to 75.8 per cent in 2005. The heavy dependence on coal has led to serious environmental problems and represents a burden for the transportation system.

Between 1978 and 2005, total crude oil output increased from 104 Mt to 181 Mt (an average annual growth rate of 2.1 per cent). Of the total oil output in 2002, 154 Mt is produced on land and 27 Mt is produced offshore. Crude oil output in China accounts for 4.7 per cent of the world total. Between 1978 and 2005, total natural gas output increased from 13.7 billion cubic metres to 50 billion cubic metres (an average annual growth rate of 4.91 per cent). Natural gas output in China accounts for 1.8 per cent of the world total.

Thermal power generation (including coal- and oil-fired power generation and natural gas-fired power generation) is the main pattern of power generation in the world at present. According to UN statistics, thermal power accounted for 65 per cent of total power generation in the world in 2005. In developed countries, the coal used for electricity generation generally accounts for more than 80 per cent of total coal consumption (and more than 92 per cent in the United States). Coal is the main energy resource in China and is also presently the cheapest energy resource. In 2005, coal used for electricity generation in China amounted to 1,100 million tons (Mt), just 50.5 per cent of total coal consumption.

During the 22-year period between 1978 and 2000, the economic reforms implemented by the Chinese government drove the rapid development of China's economy. The installed capacity for power generation during this period increased at an annual rate of 8.13 per cent, from 57.1 gigawatts (GW) to 319 GW; power generation increased at an annual rate of 7.9 per cent from 256 terawatt hours (TWh) to 1,369 TWh. The power industry experienced the fastest growth from 2000 to 2005: during this period, installed capacity increased at 9.9 per cent per annum, from 319 GW to 512 GW, and power generation increased at 12.6 per cent per annum, from 1,369 TWh to 2,475 TWh. At the time of writing, China ranked second in the world for total installed capacity and total power generation, lower only than the United States.

With continual economic growth, the demand for power has been very strong in recent years. From 2000 to 2005, the total newly installed capacity was 191 GW, representing a growth in capacity of more than 30 GW each year and more than 60 GW in 2005 alone. By comparison, the average annual newly installed capacity from 1990 to 2000 was only 18 GW.

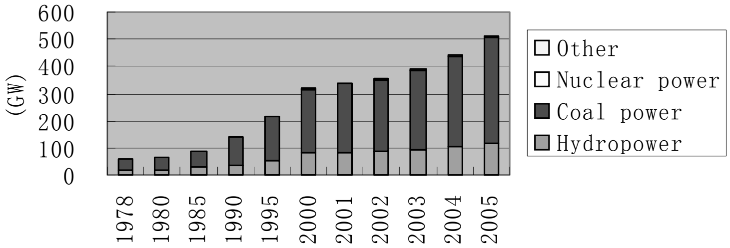
In total, installed capacity in 2005 was 512 GW. Hydropower accounted for 115 GW (22.5 per cent), while thermal power accounted for 389 GW (76 per cent), nuclear power 6.84 GW (1.3 per cent), and renewable energy such as wind power 1.2 GW (just 0.2 per cent of total installed electric generation capacity).

In contrast to the installed capacity, the actual electric power generation from hydro plants was 402.6 TWh, 16.3 per cent of the total power generation in 2005 (2,475 TWh). Generation from thermal power was 2,018 TWh (81.55 per cent of total generation) while generation from nuclear power was 50.5 TWh (2.04 per cent) and generation from renewable energy was 3.6 TWh (0.11 per cent). Coal accounted for 95 per cent of the total thermal power generation.

The development of hydropower in China is relatively slow and the exploitation ratio is presently only about 25 per cent. The development of nuclear and renewable energy is also slow; after 10 years of effort, the share of nuclear power in total installed capacity is only 1.3 per cent, much lower than the global level of 10 per cent. Additionally, the share of renewable energy such as wind power and solar power is only 0.2 per cent, also much lower than the global level of 1 per cent.

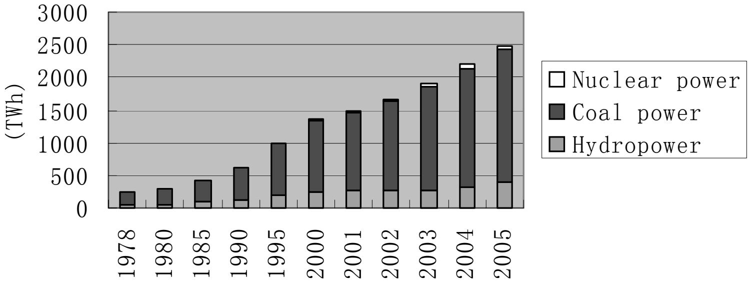
The power shortages of recent years have led to a resurgence in the construction of low parameter thermal power units, with a rising trend similar to that of total installed capacity. In 2004 the total installed capacity of thermal power units with unit capacity lower than 100 MW was 91.5 GW, accounting for as much as 29.5 per cent of total installed thermal power capacity. Steam power units with unit capacity lower than 50 MW accounted for more than 50 per cent of all power units with capacity between 6 MW and 100 MW, resulting in a high coal consumption rate, low energy efficiency and high environmental pollution. The mix of installed capacity and power generation from 1978 to 2005 in China can be seen in Figure 3.5 and Figure 3.6.

Figure 3.5: Installed capacity of electricity power generation in China



Source: *China Power Yearbook 1990-2005*, China Power Press, Beijing.

Figure 3.6: Power Generation in China

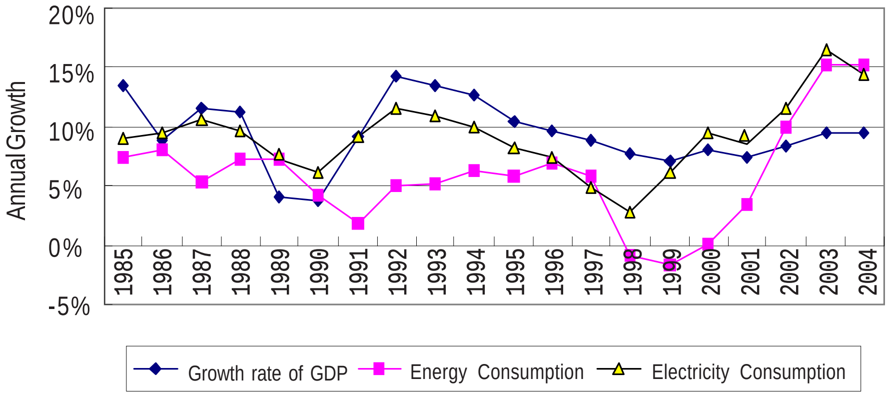


Source: *China Power Yearbook 1990-2005*, China Power Press, Beijing.

Energy consumption

Energy consumption in China has seven main characteristics. First, rapid economic growth leads to a high increase in energy consumption. Second, coal continuously takes a leading role in total energy consumption. Third, the pace of industrialisation has increased and heavy industry has become more and more dominant in relation to energy consumption. Fourth, the building and transportation sectors have become new driving forces for energy consumption. Fifth, the potential for energy efficiency improvements and energy saving is high. Sixth, as a result of energy consumption, the emission of pollutants and greenhouse gases (GHGs) has increased rapidly. Finally, energy consumption has grown faster than GDP since 2001see Figure 3.7.

Figure 3.7 Growth rate of GDP, Energy and Electricity use

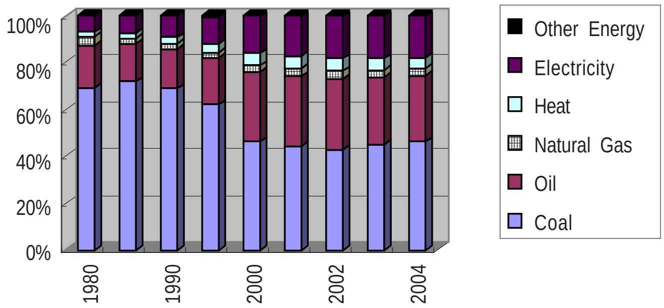


Source: China Statistical Yearbook 1990-2005, National Bureau of Statistics, Beijing.

The industry sector has been the main energy consumer in China. In 1995, energy consumption in industry accounted for 73.3 per cent of total energy consumption (Figure 3.8 and Figure 3.9). In the process of accelerated industrialisation, heavy and chemical industries have tended to have an increasing share of in the economic structure of China. The rapid growth of heavy industries and chemical industries has led to a tremendous increase in energy consumption, particularly in recent years. This industrial growth has contributed significantly to the growth of energy consumption, exceeding the growth of GDP, reflected in the fact that the energy elasticity factors for these three years are all higher than 1. By comparison, in developed countries, the manufacturing, transportation and construction industries each account for one-third of total energy consumption.

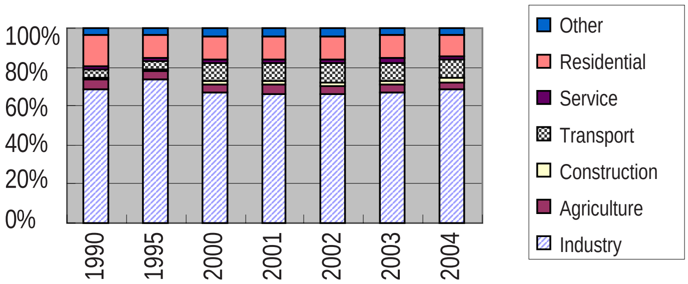
As for the internal structure of industry, the output of energy intensive products such as black metal, non-ferrous metal and building materials has increased rapidly. From 2000 to 2005, the output of steel materials increased by 24.7 per cent annually, that of crude steel by 22.36 per cent annually, and that of machine-made paper and paperboard by 16.79 per cent annually. Currently, the energy intensity of output in the industrial sector is 70-90 per cent higher than the energy intensity per unit of GDP.

Figure 3.8 Final energy consumption mix in China



Source: Authors' calculations

Figure 3.9 Final energy consumption mix in China



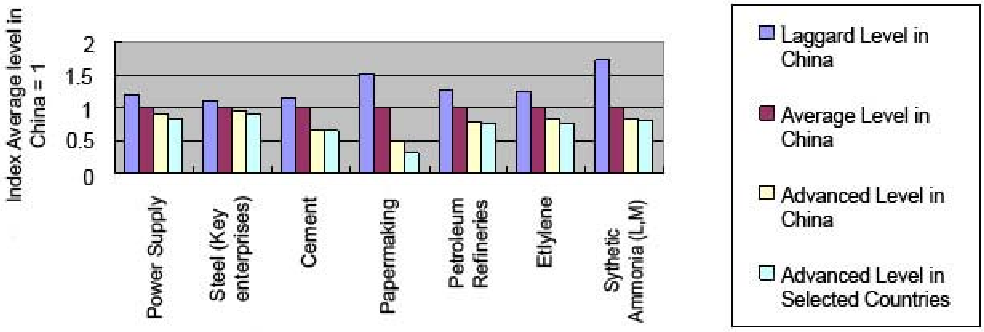
Source: Authors' calculations

Coal dominates in energy production and consumption in China. The energy structure is not optimised sufficiently and technological innovation is not encouraged. China's industrial system is still backward as a whole and its energy efficiency is obviously lower than that of developed countries. Figure 3.10 shows the average unit energy consumption for six main energy intensive products (electricity, steel, petroleum refining, cement, synthetic ammonia and ethylene) as an index comparing China to a 'global frontier' (the average value of selected, advanced countries). For China, the coal consumption for power supply is 15 per cent higher than the average value for the selected advanced countries; the comparable unit steel consumption of large scale steel plants is 10 per cent higher; the integrated energy consumption of cement production is 35 per cent higher, the energy consumption of large scale gas-based synthetic ammonia is 18 per cent higher; the integrated energy consumption of oil refining is 25 per cent higher; and the integrated energy consumption of ethylene production is 22 per cent higher.

The structure of the energy mix is not optimal in part due to the use of outdated technologies. For example, clean coal technologies such as Integrated Gasification Combined

Cycle (IGCC) are not well developed and their running costs are high, so there is only limited clean use of coal. Coal consumption in China is more than 40 per cent of final energy consumption, much higher than in developed countries.

Figure 3.10 Energy consumption for main energy intensive products by comparing China with selected countries (2004)



Source: Authors' calculations

In recent years, the building and transportation sectors have grown rapidly, becoming new engines of energy consumption in China.

Energy use in buildings

Floor space per capita, measured in square metres, provides an indicator of the development of national economies. International experience indicates that, as per capita GDP reaches $800, demand for accommodation begins to increase dramatically. The accompanying high growth period for the construction sector lasts until the dwelling area per capita reaches around 30-35 m^2. China's construction and building sector entered just such a period in 2004, with GDP per capita exceeding $1,000. The World Bank estimates that in 2015, half of China's building area for civil use will have been constructed after 2000.

By the end of 2004, China had constructed 42 billion m^2 of building area, 29 per cent higher than in 1990 (32.6 billion m^2). Since 2000, the annual newly completed building area has been more than 1 billion m^2, higher than the annual total newly completed building area in all developed countries in the same period.

China is yet to establish reliable statistical regulations for energy consumption in buildings, so the energy consumption of buildings can only be estimated. The Ministry of Construction of China estimates that energy consumption in buildings was around 320 Mtoe in 2003, accounting for about 26.1 per cent of total energy consumption. Energy for heating and cooling accounted for 65 per cent of all energy used in buildings in that year.

The energy consumption for heating per unit of building area in China is about 2-3 times higher than that in developed countries with similar climates. The heat loss through external walls is about 3-5 times higher in China than in Canada or other countries in the Northern Hemisphere and the heat loss through windows is about two times higher. It is feasible and practical to fully implement a 50 per cent energy saving standard in public and residential buildings in China. Even after meeting this target, there would still be an energy saving potential of 50 per cent in China's buildings.

Energy use in transport

The demand for transportation also closely tracks the development of the national economy. China's increasing use of transportation is consistent with its growth in GDP. The rapid development of the national economy, the acceleration of industrialisation and urbanisation, rising incomes and changing living styles are the main driving forces for the development of the transportation sector.

The transportation sector in China is composed of five transportation forms: railway, road, water, civil aviation and the pipe system. Since the 1990s, along with economic development and income growth, the total volume and structure of transportation has changed remarkably. From 1990 to 2004, traffic volume increased by 8 per cent annually for passenger transportation and by 7.2 per cent annually for freight transportation; the number of vehicles for civil use increased by 12 per cent annually, including a 23 per cent annual increase in the number of private cars in China. Vehicle ownership per 1,000 people also increased, from 7.9 in 1994 to 21.1 in 2004.

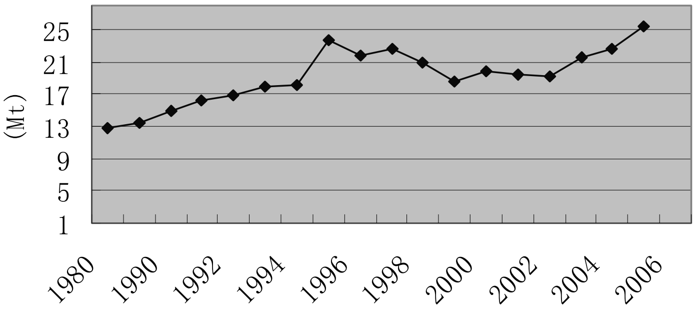
Energy consumption in the sector also increased. In 2004, energy consumption for transport was 113 Mtoe, about 2.86 times the level in 1990. The share of transport in final energy use increased from 7 per cent in 1990 to 16 per cent in 2004. Most energy consumed for transport is in the form of oil. In 2004, China consumed 82 Mt of oil for transport, accounting for 40 per cent of total oil consumption in China.

Energy environmental issues in China

The rapidly growing energy consumption in China, especially in buildings and the transport sector, creates considerable environmental strains. These are exacerbated by the dominance of coal as China's primary source of energy.

Driven by excess investments and domestic demand, some energy intensive industries grew over-heatedly in recent years, driving consumption of energy and raw materials, and thus rapidly increasing the quantity of pollutants such as SO_2 and carbon. In 2005 China emitted about 2,550 Mt of SO_2 (see Figure 3.11), ranking first in the world. More than 80 per cent of these emissions were from coal combustion. China's CO_2 emissions from fossil fuel combustion are the second highest in the world, after the United States. In 2005, NO_x emissions in China were estimated to have exceeded 18 Mt, leading to over one-third of China's land area being affected by acid rain.

Figure 3.11 SO_2 emissions in China



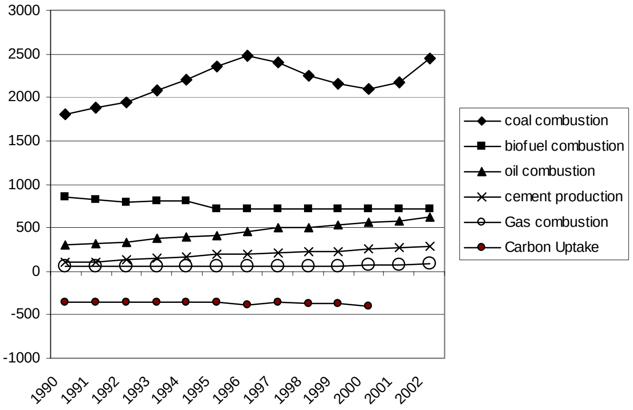
Source: *China Environmental Yearbook 1990-2005*, China Environmental Sciences Press, Beijing.

China's greenhouse gas emissions are also the second highest in the world, mainly as a result of fossil fuel combustion. This is largely due to China's large population—more than four times that of the United States, the world's largest emitter. However, China's decisions on greenhouse gas emissions profoundly affect global emissions growth; as elsewhere, these decisions are driven by trends in economic development, local environmental protection, and technological change. China's development policy has reduced its emissions growth well below expected levels, however, and a convergence of environmental issues with development imperatives offers an ongoing, if uncertain, opportunity to continue to slow emissions growth.

China has begun to make environmental protection a policy priority. Sustainability has become a key concept for the Chinese government, which has formulated policies and measures toward goals for sustainable development. China is also paying increasing attention to matters directly related to climate change. The government established the inter-ministerial National Climate Change Policy Coordinating Committee in 1990, making it responsible for policies and measures to address climate change. China signed and ratified the United Nations Framework Convention on Climate Change in 1992, and ratified the Kyoto Protocol. The government has cooperated with other governments and multilateral organisations in a number of international programs in the broad field of climate change. For example, it has conducted five joint implementation projects conducted in cooperation with Japan, Norway, and the United States.

Figure 3.12 [Davids et al, 2001] shows CO2 emissions in China, calculated using IPCC emission factors [IPCC 1997] and some revised emission factors for the country.

Figure 3.12 CO_2 emissions in China, by source



Source: Streets et al, 2001 IPCC 1997

To date, policy priorities have focused on economic growth rather than environmental issues. The concept of sustainable development is gaining traction, driven by the obvious costs of local environmental problems; however, due to resource constraints, climate change is still far from the top priority in China. The international negotiation process has made climate change increasingly political; however, this has both positive and negative impacts on the government's ability to act on the issue. It draws attention to the issues, but it can also place pressure on the government to take political rather than scientific positions. There is a need to find a way to combine combating climate change with local development policies.

Pollution from energy activities in China

Pollution from coal development

As noted in Hu and Jiang (2007), coal has developed as China's main source of energy, with coal combustion having severe environmental impactis, especially in coal mining areas. Air pollution in urban and rural areas has become more and more serious.

Coal production in 2005 was over 2.2 billion tons, nearly 70 times the level of production when the People's Republic of China was first established. The government has been aware of the importance of environmental protection since the 1970s; however, its capacity to act has been constrained by economic and technological factors. As described in Hu and Jiang (2007), coal has five main detrimental impacts. Below we update the figures provided in Hu and Jiang (2007).

Damaged land resources due to coal exploration. Up to 2004, about 480,000 hectares (ha) lands had collapsed. On average, 0.2 ha will collapse for every 10,000 tons of coal mined. The annual collapse of land has increased by more than 20,000 ha; however, the rate of recovery is now only about 20 percent.

Damaged water resources due to coal exploration. Nineteen per cent of water resources in bedrock have been polluted to some extent in North China. Some 2.2 billion tons of waste water has been discharged from various coal mine and coal washing process.

Occupation of land and damaged river beds due to coal production. Accumulated coal stone from coal production has reached 3 billion tons. The burning of waste coal stones occupies land and causes damage to river beds.

Emission of methane during the coal mining process. The emission of methane during the coal mining process accounts for around 10 per cent of total from anthropogenic methane emissions. Chinese methane emissions from the coal industry account for one-third or one-fourth of global coal mining methane emissions.

Coal combustion as a major source of air pollution. In 2005, SO_2 emissions were 25.5 million tons, and around 85 per cent of which were due to coal combustion. Acid rain covered more than one-third of China's area.

Pollution from oil and natural gas industry

As with coal, activities in the oil and natural gas industries have environmental impacts. These activities include exploration, extraction, processing, transport and use. Potential sources of impact include oil leakage, waste water and the discharge of polluted water. Evaporation and leakage from oil stock and transport also cause environmental problems. Evaporation mainly occurs during the loading and unloading processes of oil tanks, allowing hydrocarbons and sulphurated hydrogen to escape as vapourised substances. Leakages and other accidents, such as breaks in pipelines and capsising oil tankers also have considerable local impacts.

Waste water, exhausted gas and waste residue are major pollutants from oil refineries. Waste water has malfeasance compound transformed from the sulphur, oxygen and nitrogen content in crude oil. Approximately 3 to 4 tons of waste water was discharged per ton of oil processed in 1980s in China. Major pollutants in exhaust gases include SO_2H_2S, NO_x, CO_2, hydrocarbon components, and dust. Much of exhausted gas is fetor which has negative health impacts on humans. Waste residue is mainly chemical waste which has a high toxicity and could damage soil, water and air.

There is waste water from natural gas exploration. There areSince sulphur, lithium, kalium, bromine, and caesium are contained in waste water, it could damage soil.

Pollution from power generation industry

China is the world's second largest producer of electricity, after the United States, with 2475 TWh generated in 2005 (82 per cent of which comes from coal fired power plants). Electricity generation resulted in the consumption of 1040 million tons coal in 2005.

Most of the coal used in electricity generation in China does not go through washing and selection processes, leading to high ash rates. Therefore coal used in electricity generation is a major source of SO_2, NO_x and dust, which lead to acid rain (a major problem in China). And coal is of course a major emitter of CO_2.

According to data from the China Environmental Year Book, in 2004 9.29 million tons of SO_2 were emitted from electricity generation, accounting for 41.21 per cent of the national total and 3.2 million tons of dust emissions, accounting 29.24 per cent of the national total. An estimated 7.2 million tons of NO_x were emitted from power generation. In 2004 2.3 billion tons waste water and 210 million tons waste residue were discharged in this sector. Table 3.1 and Table 3.2 show energy consumption and emissions of SO_2, dust and NO_x in the electricity sector in China. in which the figures for year 2005 are the estimated values.

Table 3.1: The energy consumption of thermal power generation units with capacity equal or higher than 600 MW in China from 2000 to 2005

Year	Coal (Mt)	Oil(Mt)	Gas(Mm^3)	Energy Consumption used for power generation in total coal production (per cent)	Share of Coal used for power generation in total primary energy consumption (per cent)	Share of energy in total final energy consumption (per cent)	Share of power
2000	528	10.41	15382	60.85		41.72	16.65
2001	576	10.23	18112	58.2		42.9	17.69
2002	656	10.89	21147	51.47		43.56	18.19
2003	765	13.22	31657	50.96		43.8	18.39
2004	994	14.88	44320	51.00		46.3	18.40
2005	1048			50.00			

Source: *Chinese Electricity Yearbook, 2000-2005*, Chinese Electricity Press, Beijing.

Table 3.2: SO_2 and dust emissions from thermal power plants in China from 2000 to 2005

	SO_2 Emissions (10,000 ton)			Dust Emissions (10,000 ton)		
	National total	Thermal power	Share in national total (per cent)	National total	Thermal power	Share in national total (per cent)
2000	1995	720	36.09	1165	301	25.85
2001	1948	654*	33.58	1070	290	27.08
2002	1927	667	34.61	1013	292	28.87
2003	2159	803	37.18	1049	313	29.83
2004	2255	929	41.21	1095	320	29.24
2005	2550	1110	43.55	1182	345	29.19
2000-2005(per cent)		5.02	9.04		0.29	2.77

Note: The SO_2 emission volumes in 2001 is the statisticare compiled from data of 1033 power plants, which consume 500M tons of raw coal, accounting for 86 per cent of total coal used in power plants (576M tons).

Sources: *China Environmental Yearbook, 1990-2005*, China Environmental Sciences Press; *China Statistics Yearbook, 2000-2004,* National Bureau of Statistics, Beijing.

In 2005 the Energy Research Institute (ERI) undertook a project to compile China's inventory of greenhouse gas emissions from energy combustion. CO_2 emissions from the power sector were around 600 Mt of carbon; CO_2 emissions per unit of power generation were around 0.29 7 kg of carbon per kilowatt hour. The fuel structure and power generation technology level are two major factors influencing CO_2 emissions per unit of power generation. Since coal will continue to be a dominant fuel for heat and electricity production in China in the future, the power sector will continue to be China's main emitter of CO_2 in the future.

Pollution from final energy consumption sectors

In China, most coal combustion occurs in industry boilers and kilns. Boiler capacity has grown almost as much as industry and coal use. Industry boilers, industry kilns and utility boilers are major consumers of coal (accounting for about 900 Mt in 2004, or 46 per cent of total coal consumption). They are also major sources of pollutants: SO_2 emissions are about 7.6 Mt (accounting for about 34 per cent of the total in China) and 34 per cent of NO_x emissions. Some 5.29 Mt of SO_2 emissions come from the oil refining and coke-making industry, the chemical industry, the construction material industry, the steel industry and the non-ferrous industry, accounting for about 70 per cent of total emissions from industrial boilers and kilns. Industrial boilers are more numerous, more widely used and less efficient than utility boilers, leading to SO_2 emissions that are about 30 per cent higher per unit of coal consumption.

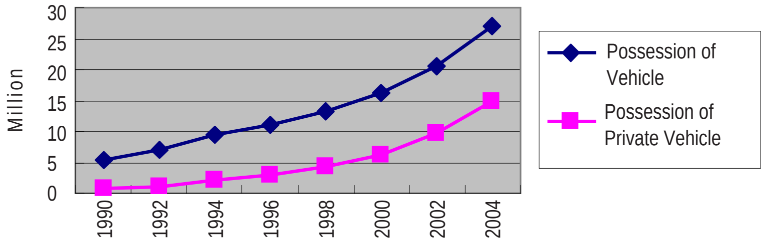
In 2004, about 149 Mtoe of energy (accounting for 11 per cent of total energy use, of which 30 per cent is from coal) was used for civil purposes. This accounted for 3.64 Mt of SO_2 emissions (16 per cent of the total in China); NO_x emissions accounted for about 3 per cent of the total. In other words, industrial boilers, kilns and cooking ranges are and will continue to be non-negligible, dispersed sources of SO_2 and NO_x emissions that will be hard to control.

In 2004, China became the fourth largest vehicle producer in the world (5.07 million vehicles, 17 million motorcycles and 2 million vehicles for agricultural use) and the third largest vehicle consumer. There are now 26.94 million vehicles, 79 million motorcycles and 25 million agricultural vehicles in the country. From 1990 to 2004, the total number of vehicles increased by 12 per cent annually, including a 23 per cent annual increase in private vehicles.

In 2004, China consumed 310 Mt of oil, one-third of which is used for vehicles. Emissions of hydrocarbons, CO_2 and NO_x from vehicles amounted to 36.4 Mt, 8.36 Mt and 5.49 Mt respectively. Figure 3.13 shows the vehicle volume in China from 1990 to 2004. Table 3.3 shows the vehicles‘ contributions of hydrocarbon, CO_2 and NO_x to air pollution in big cities.

In 2004, the fuel economy of motor vehicles in China was 25 per cent less than in Europe, 20 per cent less than in Japan, and 10 per cent less than the overall level in the United States. Oil consumption per 100 t-km of freight vehicle was 7.6 L in China, more than double the amount used in foreign advanced levels. Practical Actual oil consumption of motor vehicles was 30 per cent higher than that of demarcated level. The oil consumption of vessels used for inland river transportation in China was 10-20 per cent higher than that of foreign advanced level vessels.

Figure 3.13 Number of civilian motor vehicles in China



Source: *China Transportation Yearbook 1990-2005*, China Transportation Publishing House, Beijing.

Table 3.3 Share rate of vehicle contamination (per cent)

City	CO_2	HC	NO_x
Beijing	63.4	73.5	46.0
Shanghai	87.0	97.0	74.0
Chongqing	85.8	36.6	86.3
Xian	98.6	-	69.7
Qingao	70.0	20.0	10.0
Urumchi	88.7	-	48.5
Tianjin	83.0	81.0	55.0
Chengdu	62.0	70.0	45.0
Guangzhou	84.1	-	25.7

Source: Huang Yonghe, 2005. Leveraging the Chinese Tax System to Promote Clean, Fuel Efficient Vehicle Development, Presentation to Clean Air Initiative for Asian Cities conference, 22 October 2005, Beijing.

Strategies for the management of the environmental impact of energy use in China

Energy policy has become integrated with China's sustainable development objectives. Energy saving and environmental protection have become priority areas for China's goal of sustainable development and they are important driving forces in ensuring national energy security, promoting technology improvement and innovation, protecting and improving environmental quality, improving international competition, establishing a resource saving society and improving the sustainable development of China's society and economy.

In March 2006, the Chinese government issued the Outline of the Eleventh Five Year Plan for National Economic and Social Development ('the Outline'). In order to address the acute problem of mounting pressure on resources and the environment, the Outline set a target for reducing energy consumption per unit of GDP by 20 per cent over 5 years, with a target for cutting the total discharge of major pollutants by 10 percent. This equates to an annual reduction of 4.4 per cent from 2005 to 2010.

In order to achieve the above targets, China is pursuing four types of strategies:

- First, legal strategies will be used to establish and improve laws, regulations, policies and standards in the field of energy and the environment; to clarify the responsibilities of different entities such as governments, enterprises, producers and consumers; to build a new mechanism to promote energy saving and environmental protection in market economy conditions and a comprehensive policy system for energy and environment; and to carry out plans and action plans for energy saving and environmental protection.

- Second, fuel substitution strategies will be used. The principle of 'multi energy development' will be adopted; efforts will be made to exploit and utilise clean energy, alternative energy and renewable energy; a reasonable consumption pattern will be encouraged; the international energy market will be expanded; and the energy supply and consumption structure will be optimised.
- Third, technological strategies will be used. People will be encouraged to rely on scientific and technological advances and innovations to promote the economical, clean and effective use of coal. The efficiency and benefit of final energy use will be promoted. People will be provided with information on the technologies of pollution control and management. Pollution from urban transportation will be strictly controlled, and the challenge of global warming will be responded to actively.
- Fourth, market strategies will be used. Foreign experience will be used in measures to promote energy saving and environmental protection on the basis of an economic incentive mechanism. Further, the government will establish price and tax policies to promote energy saving and environmental protection. In the short term, it will do this by introducing a fuel tax levy, improving the pollution fee system, cancelling the production subsidy for energy intensive products, and promoting the internalisation of environmental costs. In the long term, a carbon tax and energy tax will be introduced.

Legal strategies

In order to effectively mitigate the impact of energy activities on the environment, China has established a series of laws, regulations, policies and standards at all levels of government to improve the management of energy activity and standardise all kinds of activities associated with energy production and consumption that have impacts on the environment. Below we outline the current environmental policy system as it affects energy use. There are three main areas: laws, regulations and standards.

Laws: national and local

The central government uses national laws in an attempt to regulate environmental damage and pollution. The key laws at the national level include the Environmental Protection Law of the People's Republic of China, the Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution, the Law of the People's Republic of China on the Prevention and Control of Water Pollution, the Law of the People's Republic of China on Prevention and Control of Pollution from Environmental Noise, the Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste, the Marine Environment Protection Law of the People's Republic of China, the Law of the People's Republic of China on the Promotion of Clean Production, the Law of the People's Republic of China on Conserving Energy, and the Renewable Energy Law of the People's Republic of China.

In addition to these national laws, some local governments establish their own laws and regulations on energy activities in order to achieve their targets for environmental quality. For example, in many cities the local government has issued regulations limiting the use of small scale coal fired boilers in urban areas, playing an active role in reducing pollutions from coal combustion and improving local air quality.

Regulations: national and local

The State Environmental Protection Administration (SEPA) of China formulates the relevant regulations on the control of SO_2 emission in 'Two Controlled Zones', prescribing strict limits on coal exploitation activities and the sulphur content of coal and desulphurisation facilities in power plants in the two zones. SEPA also established policies to close and stop 'fifteen kinds of small scale enterprises' with high energy consumption and high pollution within a prescribed limit of time, which plays an active role in limiting the environmental impact of energy activities. Since 2000, SEPA has implemented a system to limit the total quantity of pollutant discharge in different enterprises. This system was strengthened and deepened in the tenth five year planning period and played an active role in controlling the total quantity of pollutants, including those from the energy sector, and improving environmental quality.

In 2005, the National Development and Reform Commission (NDRC) formulated the Advices for Promoting the Development of Flue Gas Desulphurization in Thermal Power Plants and issued 'the first set of small scale thermal power units needed to be close down or stopped and the timeline for action'. This was done essentially to solve the problems of SO_2 pollution from thermal power plants and promote the health benefits of developing flue gas desulphurisation measures in thermal power plants. In order to promote the orderly development of projects under the Clean Development Mechanism (CDM) addressing climate change in China, four ministries and commissions jointly issued the Operation and Administration Rules for CDM Project. In 2005, the NDRC established and issued the Medium- and Long-term Special Plans for Energy Conservation.

Standards: mandatory and non-mandatory

The SEPA has issued a series of standards to strictly control pollutant discharge from energy production enterprises. Some local environmental departments have established their own environmental standards to meet local requirements for environmental quality. For example, Shanxi Province is now planning to establish an SO_2 emission performance standard for local power industries and Beijing has established standards for vehicle pollution which are stricter than the national standard.

Besides issuing mandatory standards, the environmental departments issued a lot of non-mandatory standards, such as the national standards for clean production. The objective of these non-mandatory standards is to enhance environmental management and the supervision of energy activities. In addition, a series of national, local and industrial standards have been established and issued to promote energy saving in buildings, household electric instruments and the transportation sector, The strict implementation and enforcement of these standards would bring the control of emissions and environmental degradation within the realm of the possible. However, this will be an arduous task, with strong resistance from adversely affected sectors and firms. The use of non-mandatory standards is itself an acknowledgement of this reality.

Fuel substitution strategies

Developing international energy markets and establishing stable channels for energy imports

Establishing global energy markets is essential for optimising the use of high quality and clean fuels. China will continue efforts to develop an international energy market, broaden import channels for crude oil, further diversify import sources of crude oil, and encourage private enterprises to develop oversea oil markets through policy stimulus.

In recent years, there has been rapid development of liquefied natural gas (LNG) production projects based on purchased overseas resources. The Guangdong LNG project in cooperation with ALNG Corporation of Australia was the first LNG project in China. The first phase began in mid-2006, with the second phase beginning in 2008.

Utilising clean and alternative energy

Coal dominates China's fuel consumption. While this will continue to be the case for many years, adopting the principle of "multi energy development" is a critical component of China's sustainable development strategy. Multi energy development requires the promotion of alternative fuels, including hydro, nuclear, natural gas, coal mine methane and renewable energy. Of these alternatives, hydro is currently the most developed within China.

Hydropower

The relevant Chinese government departments are to promote the development of hydropower by strengthening macroeconomic regulation and market planning, regulating the construction of hydropower projects and establishing practical and feasible policies such as incentives and taxes.

The plans of relevant departments can be summarised as follows. The exploitation of hydro resources such as the Hongshui River, the middle and upper reaches of the Yangze (Chang Jiang) River, the upper reaches of the Yellow River, the middle and lower reaches of the Lancang River and the Wujiang River have added more than 2GW of annually installed capacity of small hydro power. The installed capacity of hydropower in China is now expected to reach 180 GW by 2010, and the exploitation rate of hydropower will be 33 per cent. From 2010 to 2020, newly installed middle and large scale hydropower will be around 110 GW. Mini hydropower and small scale hydropower will continue expanding at an annual rate of 2 GW. Total installed capacity of small scale hydropower will reach 260 GW by 2020, with an exploitation rate of more than 56 per cent. By 2030, the exploitation of hydropower will approach its upper limit (70 per cent) and total installed capacity will be around 300 GW. Newly installed hydropower between 2004 and 2030 is expected to be approximately equivalent to 82 Mtoe.

Natural gas

The total verified geological reserves of natural gas in China are expected to reach around 10^{12} m^3 by 2020. The domestic production of natural gas will rise to 80-100 Gm^3 by 2010 and to 120-150 Gm^3 by 2020. The consumption of natural gas in China in 2004 is 39 Gm^3, accounting for 2.6 per cent of total primary energy consumption. As the world average percentage is 24.2 per cent, the Chinese value is less than 10 per cent of the world average and 25 per cent of the average in the Asia Pacific region. In recent years, natural gas has been the fastest growing energy form, with annual growth as high as 14 per cent.

Industry currently accounts for the largest share of natural gas consumption in China (78 per cent). The main industrial use of natural gas is for chemical materials. The second largest consumer is the transport sector, accounting for about 20 per cent of China's gas consumption. On the basis of the availability of natural reserves, natural gas consumption is expected to increase significantly. The main uses are expected to diversify, with electricity generation, the building sector and the chemical materials sector being the major sources of demand.

Nuclear power

China started the construction of nuclear power plants in 1985. By 2004, the total installed capacity of nuclear power was 6.84 GW. This accounted for just 1.6 per cent of China's total installed capacity in 2004, with 2.36 per cent of total electricity generation coming from nuclear plants. By comparison, in 2000 the share of nuclear power in total power generation in the world was 16 per cent; while in developed countries nuclear power represents 20 per cent of total electricity generation. There is a still considerable potential for the development of nuclear power in China. The Chinese government has included the development of nuclear power in its national plan. The installed capacity of nuclear power is projected to be 40 GW by 2020.

Coal mine methane

Coal mine methane (CMM) is an abundant resource in China and the exploitable portion is estimated around 10^{12} m^3. By the end of 2000, the annual drainage of CMM in China was 820 Mm^3. Most of the CMM was used in electricity generation, chemical production (carbon black and fertiliser) and household fuel. Production of CMM in China is projected to reach 10 Gm^3 by 2010, 22 Gm^3 by 2020, and 35 Gm^3 by 2030. Between 2004 and 2030, CMM production is expected to expand by 35 Mtoe.

Technological strategies

Production technologies: clean and high efficiency coal

Regardless of efforts to increase the use of alternative fuels, coal will be a major part of China's energy future for many years. The total amount of coal consumption will continue to rise, from about 2.1 billion tons per year in 2005 to 2.5 billion tons per year by 2020. Making coal cheaper, cleaner and more efficient is essential for China's long-term sustainable development.

It is cheaper to produce energy using coal than using oil. The cost of producing a given amount of energy from oil is 2-3 times that of coal on the international market; the difference is even greater in the domestic market, where the price of oil is 4-6 times higher than that of thermal coal in China, and that of natural gas 3-4 higher than that of thermal coal.

A variety of methods exist for making coal use cleaner and more efficient. Examples are advanced coal processing technologies such as coal washing, coal shaping, coal blending and coal water slurry; advanced coal conversion technologies such as circulating fluid bed (CFB), pressured fluid bed combustion (PFBC) power generation, IGCC, coal gasification co- generation of energy, supercritical and ultra supercritical power generation; technologies for converting coal to substitute oil and gas, such as coal liquefaction and coal gasification technologies; and advanced high efficiency industry boilers and kilns and household cooking ranges.

Developing and promoting clean and efficient coal technologies and increasing their share in relevant industries will improve the energy and economic efficiency of coal use; increase the share of coal being directly converted to electricity and the conversion efficiency; reduce the direct consumption of coal in end use sectors; optimise the final energy consumption structure; and reduce pollutant and GHGs discharged from relevant equipment.

Below we discuss some of these issues as they apply to final energy use.

Final energy use technologies: advanced and high efficiency

Key industries

Iron and Steel Industry

China should speed up the replacement of out-of-date processing equipment and enhance energy consumption standards for new buildings and for retrofitting and expansion projects. It should employ large advanced technical equipment, and production processing characterised by being systematic, continuous, integrated and highly efficient, so as to maximise the utilisation of various energies and resources. Large iron and steel enterprises equipped with coke ovens should install coke dry quenching facilities; large blast furnaces should be equipped with furnace top pressure differential power generating equipment (TRT); and steel producers should apply technologies such as continuous casting and methods to preventing slag splashing in furnaces. Steel rolling systems should continue to increase the use of continuous casting; they should also increase the use of single heating processes to final production of continuous casting billets; increase the use of hot charge and hot conveyance technology; and apply heat storage combustion technology. Producers should use combustible gases such as blast furnace gas, coke oven gas and basic oxygen furnace gas, and various steams, and should use self- sustained power stations to save energy and reduce consumption.

Nonferrous Metals Industry

The use of large, efficient, energy saving equipment will increase the efficiency of mining and ore dressing.

Copper smelting should be done using advanced oxygen enriched flash and oxygen enriched bath smelting processes rather than traditional technologies such as reverberatory furnaces, blast furnaces and electric furnaces; this will improve smelting intensity.

Alumina smelting should be done through technologies such as the ore dressing Bayer process, with direct heating and melting technology gradually replaced.

The electrolytic aluminum smelting process should be done using large pre baking electrolytic cells; within a specified period, self baking electrolytic cells should be discarded and the small pre baking electrolytic cells should be gradually phased out.

Lead smelting should be done using the new lead smelting process of oxygen bottom blowing and other technologies that involve direct lead smelting by oxygen; plants should renew the sintering blast furnace process and eliminate the traditional primitive lead smelting process.

Zinc smelting should be done using the new wet process rather than traditional primitive zinc smelting processes.

Oil and Petrochemical Industry

In the exploitation of oil and natural gas, optimisation technology should be used for the oil exploitation system; energy saving supplementary technology should be used for thick oil hot exploitation; optimised operation technology should be used for the water filling system; comprehensive energy saving technology should be used for oil and gas enclosed collection and transmission; and recovery and reutilisation technology should be used for discharged natural gas.

In the process of oil refining, China should improve equipment operation loading and heat exchange efficiency, optimise operation and decrease processing loss. In the process of ethylene production, China should optimise the raw material structure, retrofit ethylene cracking furnaces with advanced technology, optimise quenching system operation, strengthen facilities management and decrease energy consumption in the process of non production. It should also replace fuel oil (light oil) with clean coal, natural gas and high sulphur petroleum coke; promote circulating fluidised bed boiler technology and petroleum coke gasifying combustion technology; and recover and reuse residual heat and geothermal energy through the use of energy optimisation technologies, heavy oil emulsification, high efficiency burners and absorption heat pumps.

Chemical Industry

Large-scale synthetic ammonia plants should use advanced energy saving technical processes, new catalysts and high-efficiency energy saving equipment, so as to enhance conversion efficiency and the recovery and reuse of residual heat. China should promote the use of technology to recover residual heat from flue gas in one-section furnaces for gas-based synthetic ammonia, and renovate its steam system. It should accelerate the retrofitting of measures to replace fuel oil with clean coal or natural gas for oil based synthetic ammonia. It should apply energy saving equipment and variable pressure adsorption recovery technology to medium- and small-scale synthetic ammonia production processes, so as to reduce energy consumption. Coal gas production should increasingly involve the use of coal water slurry or advanced pulverised coal gasification technology to replace traditional fixed bed coal gasification technology.

In the production of caustic soda, China should gradually eliminate the graphite anode diaphragm process and should increase the use of the ion membrane method.

In the production of soda ash, China should discontinue the use of energy intensive equipment and replace it with large scale and automatic equipment.

Building Materials Industry

The cement industry should use the new dry-process kiln with precalcinator technology; increase the percentage of the new dry-process cement clinker; promote energy efficient grinding equipment and power generating technology by using residual heat recovered from cement kiln; improve the performance of existing large and medium sized rotary kilns, mills and drying machines for the purpose of energy conservation; gradually phase out mechanised vertical kilns, wet process kilns, long dry process kilns and other outdated cement production technologies.

In the glass industry, China should develop advanced float processes; eliminate outdated Fourcault and Colburn processes; promote technologies of overall heat insulation for furnace and kiln and enriched oxygen and full oxygen combustion.

The architectural ceramics industry should discard outdated kilns such as downdraft kilns, pushed slab kilns and multi-hole kilns; promote roller kiln technology; and improve combustion systems. The sanitary ceramics industry should move to clean gas fuel so as to apply sagger free burning technology. China should encourage the use of new wall materials, thermal insulation material, sound insulation material, waterproof material and sealing material that are of high quality, offer environmental protection and are energy efficient. It should also increase the use of high performance concrete.

Transportation

Road transport

China should speed up its push to eliminate old energy intensive automobiles and it should develop diesel automobiles, large tonnage automobiles and special vehicles. It should promote the use of vans and special transport vehicles such as container vehicles, and should improve road quality. It should accelerate progress in the development of transport enterprises and improve the organisational structure of China's transport systems People should be discouraged from operating single vehicles without loads and encouraged to improve transport efficiency.

Newly Added Motor Vehicles

Experience in the United States, Japan and European countries suggests that the most economic and effective measure to reduce the oil consumption of motor driven vehicles is to formulate and implement fuel oil economy standards for motor vehicles and related measures such as vehicle fuel oil taxes. In this way, automotive manufacturers can be encouraged to improve technology, reduce oil consumption, increase fuel oil economy and encourage consumers to purchase cars with relatively low oil requirements.

Urban Transportation

China should accelerate the development of public transport such as rail and improve the efficiency of integrated traffic and transport systems. In China's large cities, improving public road transport (such as busses) should be a priority, with rail transit as an auxiliary method, private motor vehicle transport a supplementary method and bicycle transport encouraged. In China's medium and small cities, public road transport and private vehicle transport shoud be the main development direction.

Construction, commercial and residential building

Buildings

During the period of the Eleventh Five year Plan, new buildings should be strictly required to meet the design standard of 50 per cent energy conservation. Major cities such as Beijing and Tianjin should take a lead in implementing the 65 per cent energy saving standard. There should be full-scale reform of the heat supply system. In large and medium sized cities, a charge system based on thermal meter will be widely spread in district heating of residential and public buildings; small cities will be used as a pilot program. As urban reconstruction is carried out, residential and public buildings should be retrofitted to make them more energy efficient. The target is for a 25 per cent improvement in the energy efficiency of large cities, 15 per cent in medium cities and 10 per cent in small cities. The government will promote the use of cold storage air conditioners, heat storage air conditioners and cold heat electricity cogeneration technology. People will be encouraged to use centralised air conditioning systems with variable frequency speed adjustable technology for fans and pumps; and to use energy saving doors and windows and new wall materials. In addition, we should speed up application of renewable energy such as solar and geothermal energies in buildings.

Household and Office Electric Appliances

China should promote the use of energy efficient household and office electric appliances such as refrigerators, air conditioners, televisions and washing machines; reduce energy consumption through standby; implement energy efficiency standards and labelling; and standardise the market for energy saving products.

Lighting Appliances

China should promote the use of high efficiency fluorescent lamp products such as phosphorus energy saving lamps and high intensity gas discharge lamps. It should encourage people to decrease the use of incandescent lamps, gradually eliminate high pressure mercury vapor lamps, introduce and enforce a standard for energy efficient lighting products and increase the use of energy efficient saving fluorescent lamps.

Advanced and efficient pollution control and treatment technologies

Pollution reduction technologies are a critical part of any comprehensive strategy to mitigate the environmental impact of energy consumption. Pollution can be captured either pre or post combustion, however a comprehensive approach to developing mitigation technologies should include both.

Pre-combustion pollution control technologies

Coal blending technologies is a key pre combustion pollution control technology. The basic principle of coal blending is to manufacture environmentally friendly, high quality and homogenous coal that is most required by markets from low cost coal. The blended coal will obviously improve the combustion efficiency of boilers, improve the economy benefit of end users such as power plants and steel plants and help them meet environmental standards.

The first phase of the biggest coal blending center (CBF project) has been fully initiated in China. Gaining support from enterprises, the CBF project will help complete the coal supply chain in China and improve the coal utilisation efficiency, reduce loss and reduce environmental pollution. In the first phase of this project four coal blending centers will be established in June 2006. The expected construction period is 10 months. After completion, the center will be capable of processing 40 Mton of coal each year. By 2010 China expects to have completed 16 such centers.

Post-combustion pollution control technologies

The main combustion or post combustion pollution control technologies include: CFB boiler combustion, limestone plaster methods, simple wet method, rotate spraying method, LIFAC (Limestone Injection into the Furnace and Activation of Calcium Oxide), electronic beam method and new ammonia desulphurisation. The relevant departments of Chinese government have formulated incentive policies directed at the consumers of desulphurisation technologies and sectors for studying and manufacturing desulphurisation equipments to actively support the demonstration projects of localisation of flue gas desulphurisation technologies (including mature ones and new ones) to promote the localisation process of desulphurisation technologies in China. They also provide support for the manufacture and supply of desulphurisation equipments and establish the quality standards and technology criterions for the processing and installation of desulphurisation equipments and components; train and give support to the competitive desulphurisation companies to improve their abilities to undertake all the activities to deliver a complete project, including system design, complete set of equipments, construction, installation, adjustment and management; strengthen the regulation of bidding and introduce the market incentive mechanisms; and establish supportive policies for promoting the localisation of flue gas desulphurisation in power plants including loans, tax deductions, electricity deployment, and electricity price subsidies.

Market strategies

Implementing economic incentive policies in favor of energy saving and environmental protection, including the energy tax and carbon tax, subsidies to consumers, establishment of technological, environmental and emission standards, etc.

Key sectors such as thermal power, steel, electrolytic aluminum and cement producers should be required to obtain permission to emit pollutants. In particular, the allowable total discharge amount and reduction amount of main pollutants should be clarified for key enterprises. This can be done in four main ways. First, companies can be required to install in-site monitoring equipment and this can be enforced through strict supervision and management. Second, enterprises that violate pollution standards can be asked to treat the pollution in a given time frame, during which production and pollution will be limited. Third, if enterprises still cannot meet requirements, local governments can fine them and stop their production.

Governments should make full use of special funds for environmental protection. They can do this in seven main ways. First, they should promote air pollution control projects, particularly those focused on the control of coal fired pollution. Second, they can prohibit the combustion of high pollution fuels in certain areas. Third, they can prohibit the the use of equipment that burns high pollution fuels. Fourth, they can encourage people to use clean energy rather than coal. Fifth, they can encourage urbanisation and reduce coal combustion in cities. Sixth, they can limit the use of high sulphur coal, accelerating improvements in urban air quality.

In addition, they can require or encourage existing thermal power plants to internalise desulphurisation costs by including them in the grid electricity price., They can provide price deductions for environmental protection measures in power generation. To reduce SO_2 pollution, they can introduce fees for those producing emissions, encourage those who carry out desulphurisation; and use funds from national debt and pollution fees to subside key desulphurisation projects.

The Administration Rules for Collection and Utilisation of Pollution Fees introduce a system for charging for the total discharge of pollutants and new charging criteria. In the future, the range of charges for pollutant discharge will be expanded and the criteria for charging for SO_2 pollution will be gradually increased until the charges equal or surpass the pollution treatment costs. This will encourage enterprises to take initiatives to mitigate pollution. The pollution fee will be listed in the fiscal budget and included in special funds for environmental protection.

The vehicle fuel tax is a kind of energy tax system adopted in many countries. With China's oil demand and transport energy use growing rapidly, the adoption of a vehicle fuel tax will have a positive impact in guiding the behaviour of people using transport, encouraging the development of advanced traffic technologies and limiting the fast growth of energy demand for vehicles.

International experience suggests that a carbon levy will promote the development of new industries—for example, clean coal technology using carbon removal and carbon storage methods; renewable energy industries; nuclear power generation; and energy saving technology.

The fiscal and tax policies to promote energy saving should be introduced as soon as possible. A vehicle fuel tax and environmental tax could be considered for the short term and a carbon tax and energy tax for the long term. Economic incentives and fiscal and tax policies will be very important saving energy in end use sectors such as industry, building and transportation.

Results of policy options for pollutants and CO_2 emission mitigation simulation

The impact of energy use on the environment could be the continuous of existing policy options, with much more efforts. Table 3.4 lists policy options could be used in both short term and long-term. Technologies are also identified in IPAC modeling study for energy conservation, new and renewable energy, for clean energy future. Table 3.5 presents the technologies available for near future on energy conservation.

Table 3.4 Policy options for pollutants and carbon emission mitigation

Policy	Related measures
Incentive policy for investment on energy efficiency improvement	preferential duty/subsidies low or no interest loan information publication registered trademark/standard investment on public transport system voluntary compliance agreement
Energy tax	gasoline/kerosene tax as one component of “green tax” system
Market share policy on energy end use	preferential duty/subsidies on natural gas or biofuel emission standard establishment
Incentives for application of high performance gas turbine combined cycle (CC) technologies and advanced clean coal (ACC) technologies in power generation	engineering standard and emission standard institutional reform R&D grants additional investment
Enhancing the share of nuclear power and renewable energy (such as solar energy and wind power) in power generation	engineering standard and emission standard implementation of renewable energy quota system energy institutional reform R&D grants additional investment and constitution of financing mechanism
Accelerating the application of biofuel	R&D grant duty free/subsidies on end users low or no interest loan implementation of renewable energy quota system
Charge of carbon tax	imposing carbon tax on fuel use by every industrial sector

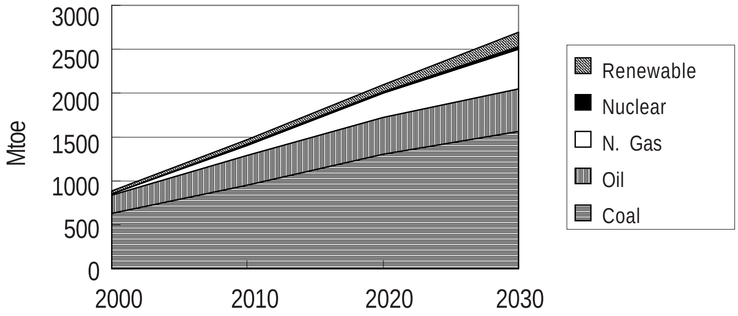
Incentives for power generation from new energy sources or renewable energy sources (such as solar energy, wind energy, small hydropower, biomass, etc.)	R&D grant low or no interest loan high return rate guarantee for electricity feeded in national power grid institutional reform
Initiating international cooperation on natual gas development and utilisation	bilateral and multilateral cooperation strengthening the development and utilisation of natural gas

Table 3.5 Technologies contributing to pollutant and GHG emission reduction in short and medium term

Sector	Technologies
Steel Industry	Large size equipment (Coke Oven, Blast furnace, Basic oxygen furnace ,etc.), Equipment of coke dry quenching, Continuous casting machine, TRT,Continuous rolling machine, Equipment of coke oven gas, OH gas and BOF gas recovery , DC electric arc furnace
Chemical Industry	Large size equipment for Chemical Production, Waste Heat Recover System, Ion membrane technology, Existing Technology Improving
Paper Making	Co generation System, facilities of residue heat utilisation, Black liquor recovery system, Continuous distillation system
Textile	Co generation System, Shuttleless loom, High Speed Printing and Dyeing
Non ferrous metal	Reverberator furnace, Waste Heat Recover System, QSL for lead and zinc production
Building Materials	dry process rotary kiln with pre calciner, Electric power generator with residue heat, Colburn process, Hoffman kiln, Tunnel kiln
Machinery	High speed cutting, Electric hydraulic hammer, Heat Preservation Furnace
Residential	Cooking by gas, Centralised Space Heating System, Energy Saving Electric Appliance, High Efficient Lighting
Service	Centralised Space Heating System, Centralised Cooling Heating System, Co generation System, Energy Saving Electric Appliance, High Efficient Lighting
Transport	Diesel truck, Low Energy Use Car, Electric Car, Natural Gas Car, Electric Railway Locomotives
Common Use Technology	High Efficiency Boiler, FCB Technology, High Efficiency Electric MotorSpeed Adjustable Motor, Centrifugal Electric Fun, Energy Saving Lighting
Power generation	Supercritical coal fired generating units, natural gas integrated combined cycle generating units, nuclear power generating units, hydroelectric power generating, new energy power generating, •integrated coal gasification combined cycle (IGCC) power generating
General purpose technology	high efficiency boiler•fluidised bed boiler•high efficiency electromotor•frequency adjustment electromotor•centrifugal fan•high efficiency lighting

Energy demand is calculated using the IPAC Emission model. Baseline scenario results are given in Figures 3.14 and 3.15. Primary energy demand in the baseline scenario could reach 2.1 billion toe in 2020 and 2.7 billion toe in 2030. The annual growth rate from 2000 to 2030 is projected at 3.6 per cent, while energy elasticity of GDP is 0.58. Coal will continue to be the major component energy in China with 1.57 billion toe in 2030, a 58 per cent share in total energy demand. There is a rapid increase for natural gas demand in China, with its share in total primary energy use increasing from 4 per cent in 2000 to 17.3 per cent in 2030 (annual growth rate: 10 per cent).

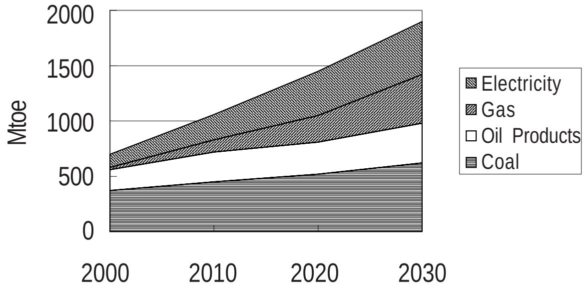
Figure 3.14 Primary energy demand in China for baseline scenario



Source: Authors' calculations

With respect to final energy use, the results show electricity and natural gas increasing rapidly. Electricity demand increases from 112 million toe in 2000 to 478 million toe in 2030. Natural gas demand increases from 21 million toe in 2000 to 437 million toe in 2030. Coal and oil demand increase slowly. Coal use in the residential sector will generally decrease and be replaced by gas and electricity; coal will be mainly used for large equipment such as boilers. Demand for oil products used for transport will increase quickly, with the rapid growth of vehicles in China. Oil use in transport will increase from 73.5 million toe in 2000 to 320 million toe in 2030.

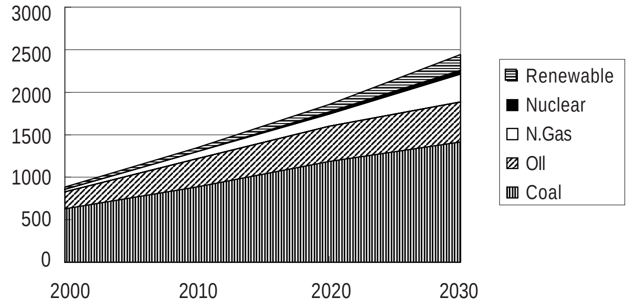
Figure 3.15 Final energy demand in China for baseline scenario



Source: Authors' calculations

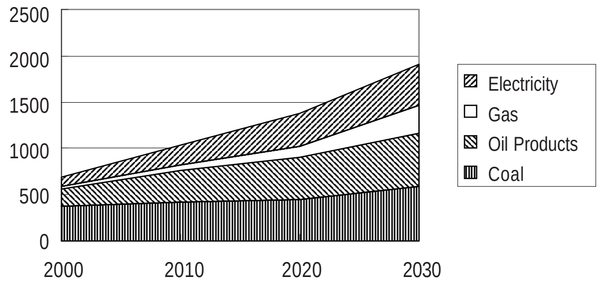
By assuming the adoption of energy and environmental policy measures, the policy scenario results are described in Figures 3.16 and 3.17. Compared to the baseline scenario, there is nearly 172 million toe energy demand lower in 2020, 200 million toe in 2030. By exploring the policy options, we found there is significant pressure to apply these policy options in order to reach the lower energy demand scenario. The policy options are also time sensitive, needing to be introduced early due to the long life span of energy technologies.

Figure 3.16 Primary energy demand in policy scenario



Source: Authors' calculations

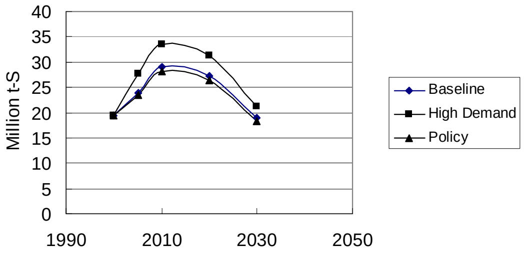
Figure 3.17 Final energy demand in policy scenario



Source: Authors' calculations

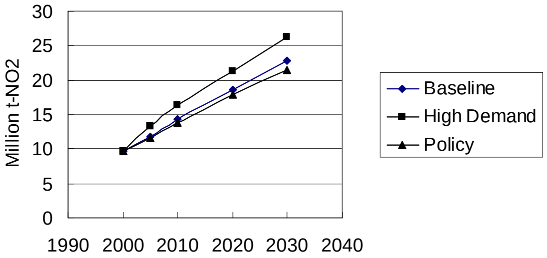
With the calculation of energy demand, several pollutant emissions were calculated. Figure 3.18 to 3.21 give SO_2, NO_x, TSP and CO_2 emissions from energy activities. SO_2 emissions will keep increasing before 2010 with the rapid increase of coal use in China. After 2010, more and more desulphurisation technologies will be used and therefore SO_2 emissions will depart from fossil fuel use. Compared with the high demand scenario, SO_2 emissions for the baseline scenario in 2010 will be 4.5 million tons lower, but still increase by 9.45 million ton from 2000. Because of lack of policy to controls emissions of NO_x, and TSP continue to rise. This will provide a considerable challenge for the government targets.

Figure 3.18 SO_2 emissions in China



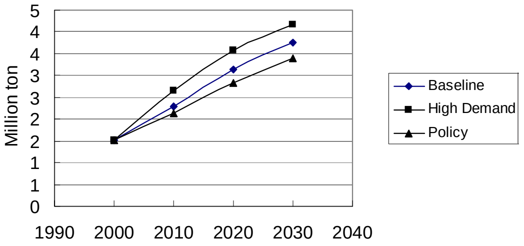
Source: Authors' calculations

Figure 3.19 NO_x emissions in China



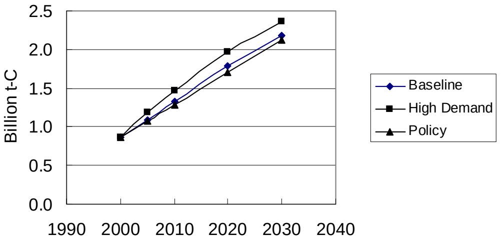
Source: Authors' calculations

Figure 3.20 TSP emissions in China



Source: Authors' calculations

Figure 3.21 CO_2 Emissions in China



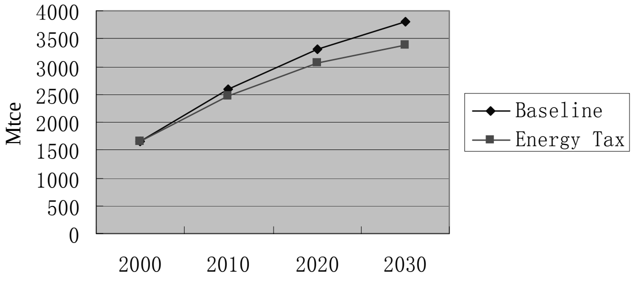
Source: Authors' calculations

In this study, the IPAC model also was used to analyse the effects of energy fiscal policies. The results are described in Figures 3.22 and 3.23. This analysis shows the use of an energy tax would have a significant impact on energy use. By 2010 with a tax rate of 50 yuan/tce, energy demand will decrease 6.3 per cent, around 123 million tce, compared with baseline scenario. By 2030 with tax rate 120 yuan/tce, energy demand will decrease 16.2 per cent, around 400 million tce.

Levy of vehicle fuel tax could have strong impact on fuel demand in road transport. By 2010 with tax rate 2.7 yuan/litre gasoline, energy demand for vehicles will decrease 10.3 per cent, around 16 million ton oil, compared with baseline scenario. By 2030 with tax rate 4.6 yuan/litre gasoline, energy demand will decrease 20 per cent, around 90 million ton oil. Vehicle fuel tax is commonly used in developed countries with valuable experience. Seeing rapid increase of oil demand and vehicle fuel demand in China, use of vehicle fuel tax could have very active effects. Properly use of fiscal policies on energy could guide public consumption preference, promote clean and new vehicle technology development. Vehicle fuel tax is such kind of policy option and could have good effects.

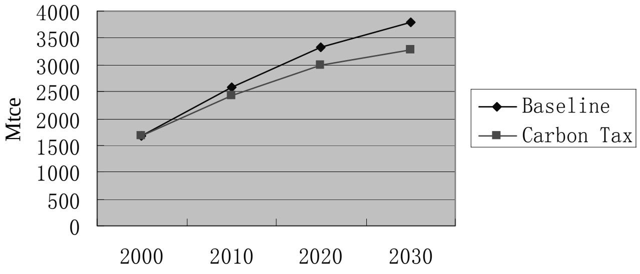
Such policies would have some negative impact on GDP, but the impact is limited. In 2010, loss would be 0.4 per cent and 0.36 per cent in 2030. The main reason is the reduction of output from energy industries due to energy saving, and impact on other sectors due to energy price increase. But this modeling study did not fully reflect the impact of reduced energy import, and new economic activities due to more investment on other new sectors. If these factors could be considered, the negative impact on GDP development could be abated. In the meantime, such a GDP loss could not be reflected in change of GDP growth rate. And more importantly, the green GDP concept could further abate the negative impact.

Figure 3.22 Impact of carbon tax on energy demand



Source: Authors calculations

Figure 3.23 Impact of vehicle fuel tax on energy demand



Source: Authors' calculations

Conclusion

It is clear that energy development in China already has considerable impact on local environmental issues such as air pollution, water pollution, land damage and toxic material emissions. Energy policies are partially driven by environmental pressures, as experienced in developed countries. This trend will continue and is expected to intensify as issues such as climate change become more concerning. In order to reach sustainable development targets, there is a need for well-developed policies for China's clean energy future. These will require the integration of energy development and environmental policies design with economic policies on issues such as industry development and international trade.

Thermal power generation, energy intensive industries, buildings and transport are major sources of pollutants and greenhouse emissions; this situation is likely to continue for the next 20 years. However, they can be reduced or abated through measures such as the use of energy supplies from a variety of sources, a better energy mix, increased energy efficiency and wider diffusion of clean coal and pollution control technologies.

China's energy development strategy places a high priority on greater energy efficiency and energy conservation and the efficient and clean use of coal and other fossil energy sources. The development of clean coal technology will improve the efficiency of coal use, reduce environmental pollution and promote economic development. If China is to achieve a low emission development path, its energy policies must encourage the development of technology to promote efficient energy use and clean technology.

NO_x emissions will continue to grow with increasing economic activity. China should follow the example of developed countries in controlling NO_x emissions by including them as a package for a national mitigation strategy in response to climate change and to support local sustainable development.

These energy related fiscal policy options are very important for China. Recently, there have been wide discussions on the use of vehicle fuel taxes. These discussions provide a solid basis for expanding energy tax policies. Carbon taxes have a strong effect on carbon emissions and the optimisation of the energy system in China. Further, the impact of such a policy on GDP is expected to be limited. Any negative impacts a carbon tax does have are likely to be offset by the stimulation of new technologies and industries based on clean coal technologies, new and renewable energy, energy services, and the upgrading of technology in China, therefore promoting economic development.

The multi-source energy supply, improving energy mix, raising energy efficiency, wide diffusion of clean coal technologies and pollution control technologies, making more policies especially fiscal policies will contribute to reduce or abate pollutant and GHG emissions.

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Notes

1 In this article, East Asia is defined to include China, Indonesia, Japan, Malaysia, Singapore, South Korea and Thailand.

4 MANAGING THE ENVIRONMENTAL IMPACT OF EAST ASIAN ENERGY USE

TONY BECK

Introduction

Unprecedented growth in energy demand in East Asia, especially China, presents unprecedented challenges of environmental management. The capacity to manage greenhouse gas emissions from China probably holds the key to effective global greenhouse gas emission management.

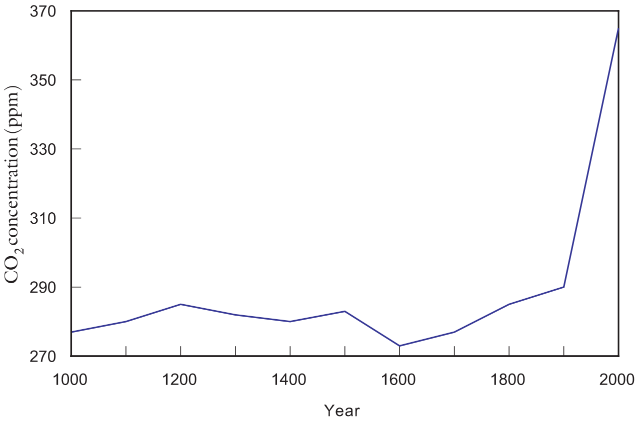
In this chapter two broad approaches are outlined. The first is a market-based approach, represented by the Kyoto Protocol and its Clean Development Mechanism (CDM). The second is a technology-focused plurilateral approach, represented by the Asia-Pacific Partnership for Clean Development and Climate (AP6). Both are currently being trialled and, to some extent, are competing to become the prime vehicle for ongoing global emission abatement beyond Kyoto—that is, post-2012.

Early results from the market approach are positive, but questions remain about if and how this approach can develop to provide the basis for an effective longer-term response. The technology-focused approach is still in the early stages of implementation and it remains to be seen if questions of incentives for technical innovation and deployment can be addressed.

Previous analysis (Beck and Gray 2005) indicates that, in meeting China's growing demand for energy, the future availability and price of coal are not likely to be serious issues for China and it is likely to be possible to increase the imports of other fossil fuels. However, the environmental impact of fossil fuel use is going to be an increasing concern. Local environmental impacts will continue to be significant but can be addressed over time with regulatory and technological advances, but the carbon dioxide (CO_2) emissions from the combustion of fossil fuel, especially coal, will remain an issue. China is the second largest contributor to global energy related CO_2 emissions after the United States. The annual growth rate of Chinese emissions is projected to be 2.8 per cent, leading to China's share of global emissions increasing from 14 per cent to 19 per cent over the period to 2030.

Management of China's emissions from fossil fuel use will therefore be critical to any effective global emissions management regime. Atmospheric concentrations of greenhouse gases are already 30 per cent above 18th century levels and projections by the International Panel on Climate Change (IPCC) suggest that it will take a concerted global effort to contain the increase in atmospheric concentrations to less than double 18th century levels (see Figure 4.1).[1]

Figure 4.1 Atmospheric carbon dioxide concentrations



Note: CO_2 = carbon dioxide.
Source: IPPC data, 2005: see <www.ipcc.ch>.

Consequently, the unprecedented growth in energy demand in East Asia, especially China, presents unprecedented challenges for environmental management. The capacity to manage greenhouse gas emissions from China probably holds the key to effective global emission management. However, whether this will ultimately prove possible is an open question.

Market-based approach: Kyoto protocol and the clean development mechanism

The Kyoto Protocol came into force in February 2005 after more than 10 years of multilateral negotiations. To date 175 countries have ratified the protocol, making it one of the best-supported international treaties in history.

The protocol is essentially the framework for a cap-and-trade emissions trading scheme for developed countries supported by a baseline-and-credit scheme for developing party members. Developed country parties have accepted a legally binding target that they can meet by domestic abatement, by trading amongst themselves, or by using emission credits generated from emission abatement projects in developing country parties, through the CDM or, in other developed country parties, through joint implementation (JI).[2]

The CDM uses a 'baseline-and-credit' approach whereby project proponents must demonstrate that their projects reduce emissions below the level that would otherwise have occurred. Approved projects earn tradable certified emission reduction (CER) units that can then be used to meet domestic targets. The CDM itself was conceived to help industrialised countries to meet their Kyoto emission targets through investment in emission abating projects in developing countries. It is also seen as a prime instrument for technology transfer and capacity building. The effectiveness of the CDM is therefore a test of one of the fundamental elements of the multilateral market approach.

Progress with the CDM. After a slow start the CDM has grown rapidly in terms of projects approved and expected abatement achieved As of September 2007, around 800 projects have been registered representing a total expected abatement of over 1000 megatons (Mt) of CO_2 emissions by 2012. This represents a rapid growth in project approvals: at the end of 2005, only around 140 activities were registered or being considered for registration.

Around 83 Mt of certified emission reductions have already been issued. The CDM Executive Board recently announced that it expects to generate at least two billion tons of emission reductions by the end of 2012 from around 2000 projects.[3] This equates to 2 billion tradable certified emission reduction units with a possible market value of more than $20 billion.

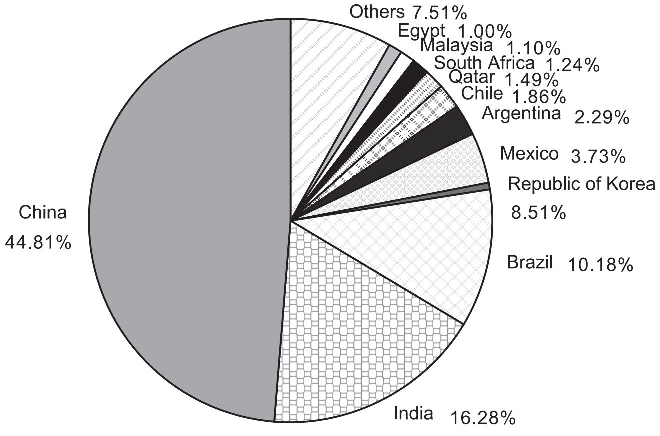
CDM in Asia

The significance of this scheme in Asia is demonstrated by the fact that over 50 per cent of projects and over 60 per cent of projected certified emission reductions are in Asia. Host countries are diverse but four countries have so far proven the most prospective in terms of expected certified emission reduction generation. These are China, India, South Korea and Brazil. Together they account for around 80 per cent of the expected certified emission reductions from currently registered projects, with China alone accounting for over 40 per cent (see Figure 4.4).

The wide range of project sizes means that the incidence of projects across host countries (Figure 4.5) can differ markedly from the distribution of expected certified emission reductions. This is particularly the case for China, which accounts for only 15 per cent of projects (but over 40 per cent of certified emission reductions), and India, which accounts for over 35 per cent of projects (but only 16 per cent of expected certified emission reductions). China's portfolio of registered projects includes several large industrial emission reduction projects which generate large volumes of certified emission reduction s; the Indian portfolio of projects includes more small-scale projects.

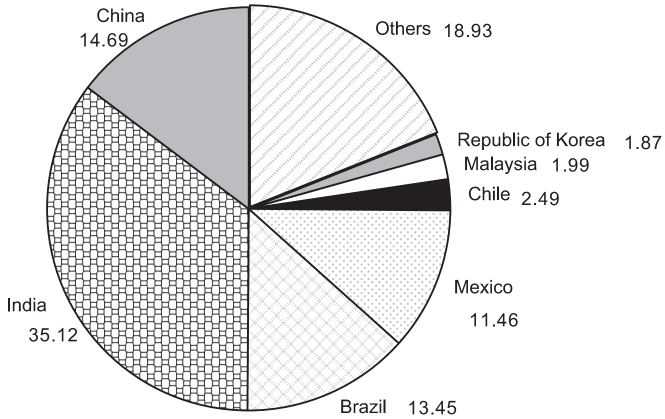
Energy sector focus. The CDM is particularly relevant to the energy sector, with energy-related projects dominating the registered project list. However, significant numbers of projects have also been approved in waste handling, agriculture, and manufacturing industries.

Figure 4.2 Expected average annual CERs from registered projects by host parties.



Source: CDM Executive Board, 2007; see <http://cdm.unfccc.int>.

Figure 4.3 Registered project activities by host parties



Source: CDM Executive Board, 2007; see <http://cdm.unfccc.int>.

Buyers. European and Japanese private entities dominated the buy-side of the market, accounting for nearly 90 per cent of all transacted project emission reductions in the last three years.

Developing country participation in CDM. The take-off in CDM activity has been facilitated by the establishment of designated national authorities (DNAs) in each participating country to provide a one-stop shop for project proponents seeking information about CDM potential, local regulatory requirements, government facilitation, and so on. To date 126 countries, including most in Asia, have established designated national authorities. These include designated national authorities that have also been established in most (25) developed country parties to provide support for their national companies in seeking and implementing CDM project development and investment opportunities.

The recent World Bank survey of the global carbon market (World Bank 2006a) found that developing countries have become engaged and active in promoting the CDM as they have recognised the large potential of the market. Many CDM host countries have eased their administrative processes for approval by the designated national authorities.

In China, the designated national authority is the Office of the National Coordination Committee on Climate Change within the National Development and Reform Commission. China has established and refined the guidelines to facilitate the smooth implementation of CDM projects, and an effective official website has been established for access and information.[4] China has also demonstrated its commitment to support sustainable development by announcing that it intends to reinvest significant proceeds from the sale of carbon credits from hydrofluorocarbons and other gases to support renewable energy development through the China Clean Development Mechanism Fund.[5]

Project management and technology transfer. With certified emission reduction sellers increasingly bearing project registration risk, the primary concern of buyers has moved downstream to project performance, issuance of certified emission reductions and delivery into the buyer's account. The World Bank (2006a:36) reports that in an effort to reduce potential operational and performance risks, many buyers are becoming more actively involved in the development of the project as a means to deal with technology risks, especially the risks associated with the operational and commercial aspects of the technology used in the project activity. For instance, they may offer extended assistance during the early stages of the project or once it has started, participate in the operation and maintenance of the project, or participate in the monitoring of the certified emission reduction data.

Some buyers invest in the underlying project itself, especially when the buyer is familiar with the technology to be implemented (for instance, a multi-service energy company developing renewable energy projects or a company selling catalyst incinerators for nitrous oxide projects). These actions to hedge against technology risk can also create a closer tie between buyers and sellers; this was a key element in recent successful negotiations.

Technology-focused plurilateral cooperation

The Kyoto Protocol approach has been strongly criticised by some developed country governments, principally the United States and Australia, mainly on the grounds that it does not include binding emission targets for the major developing countries such as China and India. This, they say, fails to address the growing proportion of global emissions being generated by these developing countries while giving developing countries an unfair trade advantage. Consequently, the United States and Australia have not ratified the protocol. In April 2006 Australia's Prime Minister, John Howard, stated the government's position in these terms:

> Signing up to Kyoto is not going to help because China and America aren't part of Kyoto in the way that we would be. China is, but China doesn't have any obligations and if we sign Kyoto in its present form it would be more attractive for investment to leave Australia and go to China or Indonesia. Now I'm not going to do that because that would export Australian jobs.[6]

Asia-Pacific partnership for clean development and climate. The Australian and US concerns about the Kyoto Protocol have led to the launch of the AP6, an alternative plurilateral approach to global emissions management involving six major emitting countries (Australia, China, India, Japan, South Korea and the United States). Together these countries account for around half of global emissions, population and income. The Australian Prime Minister spelt out the rationale for the AP6 in April 2006:

> You can't do more on greenhouse gas until you get the biggest polluters in the world inside the tent and the biggest polluters in the world are America and China. And one of the advantages of this Asia Pacific Partnership which we put together is that it brings America and China into contact with the process.[7]

The emphasis of the AP6 is on voluntary cooperation to develop and deploy low-emission technology in order to make the achievement of significant abatement cuts less costly in the long term. As set out in the AP6 Charter,[8] its purposes are to:

- Create a voluntary, non-legally binding framework for international cooperation to facilitate the development, diffusion, deployment, and transfer of existing, emerging and longer term cost-effective, cleaner, more efficient technologies and practices among the Partners through concrete and substantial cooperation so as to achieve practical results;
- Promote and create enabling environments to assist in such efforts;

- Facilitate attainment of our respective national pollution reduction, energy security and climate change objectives; and
- Provide a forum for exploring the Partners' respective policy approaches relevant to addressing interlinked development, energy, environment, and climate change issues within the context of clean development goals, and for sharing experiences in developing and implementing respective national development and energy strategies.

The AP6 is organised through a Policy and Implementation Committee and an Administrative Support Group.[9] The Policy and Implementation Committee comprises representatives from the partner countries and governs the overall framework, policies and procedures of the partnership, will periodically review progress of collaboration, and will provide direction to the Administrative Support Group. It will be responsible for managing the implementation of the cooperative activities of the partnership, and for engaging representatives of the private sector, as well as representatives of development banks, research institutions, and other relevant governmental, intergovernmental and non-governmental organisations, as appropriate. It will undertake activities in the promotion and creation of enabling environments within partner economies and in support of partners' efforts to meet relevant national-level clean development objectives.

The Policy and Implementation Committee may form appropriate task forces and other subgroups to assist it in its work. The Policy and Implementation Committee will meet as often as is determined necessary by its members to accomplish its work, and may focus its agenda on policy issues or technical issues, or both, as appropriate. Policy and Implementation Committee decisions are to be made by consensus of the partners on the committee.

Taskforces and action plans. The inaugural meeting of the AP6 was held in January 2006 in Sydney. It established some task forces and received initial pledges of funding (A$100 million over five years from Australia, and a proposed US$52 million from the United States).

The eight public private sector task forces cover cleaner fossil energy; renewable energy and distributed generation; power generation and transmission; steel; aluminium; cement; coal mining; and buildings and appliances. Each task force has formulated action plans outlining both immediate and medium-term specific actions, including possible 'flagship' projects and relevant indicators of progress. The task forces were asked to:

- review the current status of their sector with regard to clean development and climate;
- share knowledge, experience and good practice examples of how industrial efficiency, energy efficiency and environmental outcomes can be improved, including through valuable and practical short-term actions;

- identify specific opportunities for cooperation, including with relevant international financial organisations such as the Asian Development Bank and the World Bank;
- define the current state of the technology in terms of cost, performance, market share and barriers;
- identify cost and performance objectives and the actions needed to achieve these objectives; and
- identify, wherever possible, ambitious and realistic goals.[10]

Discussion

Both the market-based and technology-based approaches to emission management are in the early stages of implementation and have only just started to deal with the enormity of the emissions management task ahead. The initial responses of governments and markets to the CDM have been encouraging and this suggests that a market-based approach has good potential as a basis for emission management in China and globally. Perhaps most telling in this regard has been the response of capital markets.

Capital market response to CDM. The capacity of policies to generate a positive capital market response will be critical to the success of effective emission management in China and globally. Reducing climate change risk and promoting investment in clean energy systems is a long-term venture requiring billions of dollars of annual investment. The World Bank and International Monetary Fund estimate that about $40 billion annually of incremental capital will be required for climate change mitigation in developing countries over the next two decades.[11] Only private capital markets have the capacity to generate enough long-term resources to undertake the necessary scale of investment.

The World Bank (2006a), in its survey of the carbon market, found that the capital markets had started to respond to CDM opportunities:

> A growing number of companies successfully raised capital for those [CDM abatement project] efforts through IPOs on the London Alternative Investment Market (AIM) or attracted hedge fund capital to arbitrage between markets. Financial innovation thrived as a plethora of clever carbon-based securities and hedge instruments became available to hedge carbon price risk against price volatility in other commodity markets. Brokers, consultants, carbon procurement funds, hedge fund managers and other buyers scoured the globe for opportunities to buy credits associated with projects that reduce emissions in developing countries. Innovative structures that managed both down-side and up-side carbon price risk and reduced delivery

> risk began to emerge, which aligned purchases of carbon with an interest in the underlying project, through equity, debt, mezzanine finance, technology or operating agreements. The City of London developed as a sort of hub for many of these activities and a vibrant new climate services industry developed.

Carbon funds have augmented this private market fund-raising activity. They are usually established with contributions from both government and public sources, and invest in abatement projects that can generate tradable credits through CDM and JI. Over 10 such funds have been established, assembling over $5 billion for investment through the Kyoto mechanisms.

AP6 potential. It is too early yet to judge how the AP6 will develop or how effective it will be in abating emissions. Initial reaction has been mixed. Generally, it is seen as positive that the development and transfer of new low-emission technologies is being encouraged, but the level of funding and the lack of a commercial incentive for private sector involvement have raised questions about its potential effectiveness. A number of commentators have pointed out that an emissions trading scheme would probably provide a better incentive for necessary R&D investment.

For example, a leading Australian economist and Reserve Bank of Australia director, Professor Warwick McKibbin, warned that the AP6 was making a mistake by delaying a carbon trading system. He indicated that ‘there is very little evidence that government subsidies ever directly lead to breakthrough technology, with companies more likely to be inspired by high prices for commodities’.[12] The head of Global Renewables and chair of the Australia Uranium Industry Taskforce, Dr John White, indicated that, while the AP6 meeting should improve accountability and boost R&D, ‘proper pricing’ was the missing factor. Using market instruments would lead to existing technologies being widely adopted while emerging ones are ‘proved up’, he said.[13]

More recently Zhang (2006) compared the AP6 approach and that of the CDM. He questioned the effectiveness of a voluntary scheme to deliver abatement on the scale required. In particular, he questioned ‘the extent to which the Asia Pacific Partnership is going to facilitate the transfers of low emission technologies, once they become available, to developing partners like China and India, beyond what is already being achieved through the Kyoto flexibility mechanisms like the clean development mechanism (CDM)’.

Zhang (2006) points out that such transfers require ‘some kind of market incentives, given that most advanced technologies are commercially valuable and held by private companies’. He says:

> 'It is true that the Asia Pacific Partnership views the private sector as critical to its efforts. But for now at least, I do not see such market incentives there. Without such incentives, governments can do little to ensure the transfers of these technologies to the scale we need in order to have a real impact on the emissions of these two countries. This will undermine the effectiveness of the APP.'

Technology development. One could also question what incentives and funding for technology development the AP6 provide beyond that already being provided by the market schemes currently in place, in particular the European Union Emission Trading Scheme (EU ETS) and the CDM. As with Zhang's technology transfer question, it is too early to make a judgment, but some circumstantial evidence may be relevant with respect to carbon capture and storage (CCS).

A key focus of the AP6 action plans is likely to be clean coal technologies – and carbon capture and storage in particular. carbon capture and storage has rapidly emerged as a technology that could achieve substantial emission reductions from fossil fuel fired power stations and other large point sources. Potential geological sinks for CO_2 are widespread globally, including in China.

Re-injection of CO_2 is already used to enhance oil recovery, but the first substantial application of the technology in coal power generation is likely to be in conjunction with integrated gasification combined cycle (IGCC) coal fired power stations, which can deliver a relatively pure stream of CO_2 for sequestration. The last two years has seen a significant increase in the number of IGCC+ carbon capture and storage projects being proposed, and this appears to be largely a result of the market incentives being offered under the EU ETS. Of the 10 substantial (more than 200 megawatt) 'zero emission' stations that have been publicly announced, eight are in Europe, one is in the United States and one is in Canada.

The CDM is also generating interest in carbon capture and storage technology. In August 2005, Mitsubishi UFJ Securities submitted the White Tiger Oil Field carbon capture and storage proposal to the CDM Executive Board. It involves the use of carbon capture and storage to store CO_2 from combined cycle natural gas power plants in Vietnam. A second CDM proposal involving carbon capture and storage has also been received; it involves sequestering the CO_2 from a liquefied natural gas complex in Sarawak, Malaysia.

More generally, the World Bank (2006a) found:

> 'The evidence from the market, documented in our report, is that price signals in the carbon markets have stimulated innovation, especially in developing countries. A new urgency enveloped business managers in developing countries last year who had an incentive to reduce emissions.'

Beyond Kyoto

As a part of the Kyoto Protocol, the CDM has a finite time horizon of 2012. What form the international policy regime will take after 2012 is the subject of multilateral negotiation under the UN Framework Convention on Climate Change and is not likely to be resolved for several years. This medium-term uncertainty is already an issue for investors in both developed and developing countries.

To address this uncertainty for its member states and also declare its support for a market based approach beyond Kyoto, the European Union has indicated that the EU ETS will continue to 2020. It is also supportive of a continuing project-based mechanism involving developing countries, but the ultimate outcome of international negotiations is uncertain.

In these negotiations the relationship between the abatement efforts required of developed and developing countries remains a contentious issue. The conditions under which the Kyoto Protocol's differentiated commitments were adopted are clear. Developed industrialised countries are largely responsible for the elevated levels of greenhouse gases in the atmosphere today. Equity considerations dictated that those developed industrialised countries should take the lead in abating emissions while helping to build capacity in developing countries to do the same in the future. At the same time the CDM provided a market incentive structure for developed countries to invest in abatement projects in developing countries.

These conditions continue, but it is clear that if progress is to be made towards global emission control, developing countries must be brought more effectively into the emission management regime. Early experience with CDM would suggest that this would be best done utilising market mechanisms and incentives, but developing countries are understandably reluctant to accept inflexible binding targets.

Ward (2005) has looked at the role of emissions trading in future climate change policies in the light of concerns about the existing Kyoto framework—in particular, wider participation through greater flexibility of commitment forms and getting beyond the CDM project-based model for developing countries. He concluded that a policy framework does not need to be as constrained as the Kyoto Protocol in terms of how emission commitments are framed. He suggested that it could be much more flexible, with a mix of the following:

- binding fixed emission limits for industrialised countries [potentially combined with price caps]
- for industrialised countries not able to agree to the above, binding fixed or dynamic emission limits for some sectors in some regional groupings—or possibly economy-wide binding dynamic emission limits

- binding transnational sectoral emission limits (fixed or dynamic) for some key sectors represented by multinational ‘operators’ such as cement, steel and aluminium (with these sources excluded from any national or regional emission limits)
- for developing countries, individually customised voluntary ‘no lose’ sectoral crediting baselines in sectors for which these countries seek to attract major investment in clean technology consistent with national sustainable development priorities, and for which [the scope of] a project-based mechanism is inadequate
- a project-based crediting mechanism to provide coverage of emission reduction/sink enhancement activities not already covered by other market based mechanisms.

Conclusions

The management of the environmental impacts of East Asian energy use is an issue of global significance. A market-based multilateral approach is being tested through the Kyoto Protocol and the CDM and early responses appear encouraging in terms of both technical innovation and capital market response. The question remains, however, whether the CDM and other market mechanisms can evolve to provide the basis for an effective, comprehensive, long-term policy regime beyond Kyoto.

The technology-focused plurilateral approach being promoted through the AP6 is still in the early stages of development. There is no doubt that technology will play a fundamental role in future emission abatement, and an ongoing R&D effort will be important. However, we are yet to see whether the AP6 will stimulate additional technological innovation and, if so, what incentive there will be for it to be deployed.

The need for deeper emission cuts beyond Kyoto brings these policy choices into a situation where common ground must be found. New technology is needed but so is an effective incentive mechanism for research, development and deployment, especially in relation to developing countries. Few would dispute that ultimately market mechanisms need to play a key role in future emission management. It remains a question of when and how.

Notes

1 Intergovernmental Panel on Climate Change (2005): <www.ipcc.ch>.
2 For more details see <www.unfccc.int>.
3 CDM Executive Board; see <http://cdm.unfccc.int>.

4 Clean Development Mechanism in China site: <http://cdm.ccchina.gov.cn/english/>. See also <http://info.worldbank.org/etools/ChinaCDM/>, which is supported by the World Bank.

5 See World Bank (2006a: 41).

6 *Radio Interview*, Radio 3AW, Melbourne, 7 April 2007.

7 Radio Interview, 3AW Melbourne, 7 April 2006.

8 Charter of the Asia-Pacific Partnership on Clean Development and Climate, Article 2, January 2006; see <www.dfat.gov.au/environment/climate/ap6/charter.html>.

9 See Charter of the Asia-Pacific Partnership on Clean Development and Climate, Article 4.

10 See <http://www.dfat.gov.au/environment/climate/ap6/work_plan.html>.

11 See World Bank (2006b).

12 *Australian*, 14–15 January 2006.

13 Environment Business Australia Forum, 6 February 2006.

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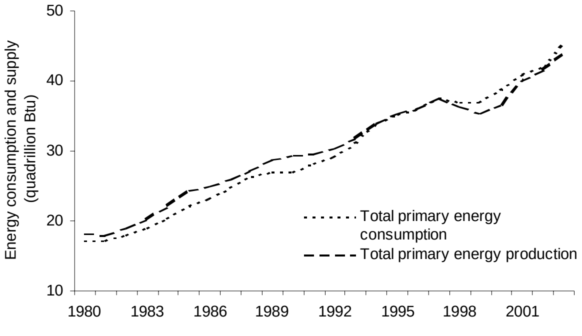
5 GROWTH, ENERGY USE AND GREENHOUSE GAS EMISSIONS IN CHINA

WARWICK J. MCKIBBIN

Energy is a key issue for the Chinese economy, now and in future decades. The need for expanding sources of energy as an input into a rapidly growing economy and the environmental implications of rising energy use are well understood within China. Chinese energy use is also becoming an increasingly important issue for the global economy because of the scale of China's energy requirements and because of the implications for global climate change of quickly rising greenhouse emissions from China.

With roughly 20 per cent of the world's population and economic growth in the range of 10 per cent per annum, China is already having a significant impact on global energy demand. By 2002, China was the world's third largest energy producer and the second largest energy consumer.[1] Although China has large reserves of energy and rising capacity it shifted from being a net energy exporter to a net energy importer in 1998 (Figure 5.1). This massive increase in the use of energy has had important implications for local environmental problems such as air quality, public health problems and local climate change. Energy generation and its related emissions of sulphur dioxide from coal use, has caused local and regional problems with acid rain.[2] The large and growing emissions of greenhouse gases (particularly carbon

Figure 5.1 China's total energy consumption and supply, 1980–2003 (quadrillion Btu)



Source: Energy Information Agency, 2006b. *International Energy Outlook 2006*, Department of Energy, Washington, DC.

dioxide emissions from burning coal) are a critical input into the global issue of climate change.[3]

In 1990 China accounted for 7.8 per cent of world energy use, which was roughly 1.5 times the energy use of Japan and seven times that of South Korea (Table 5.1). By 2002, China's share of global energy use had risen to 10.3 per cent. The United States Energy Information Administration predicts that by 2030, China will account for more than 19 per cent of global energy use, or more than five times the energy use of Japan and nine times that of South Korea. China is already the world's largest coal producer, accounting for 28 per cent of world coal production and 27 per cent of world coal consumption by 2002 (Table 5.2). China's share of world coal consumption is projected to rise to a massive 44 per cent by 2030 (Table 5.2), and at the time will be more than 2.5 times the coal consumption of the United States. China's share of world oil consumption in 1990 was 3.5 per cent, but it is projected to rise to 12.7 per cent by 2030 (Table 5.2).

Until recently, the focus of policy in China has been on sustaining economic growth and energy needs rather than the environmental consequences of rapid industrialisation. This

Table 5.1 China's share of global energy consumption and carbon dioxide emissions, 1990–2030

	1990	2002	2003	2010	2015	2020	2025	2030
Energy consumption								
China	7.8	10.3	10.8	15.1	16.3	17.4	18.3	19.3
India	2.3	3.4	3.3	3.8	4.0	4.2	4.4	4.5
Other non-OECD	33.1	29.9	30.2	30.8	31.8	32.5	33.1	33.4
South Korea	1.1	2.0	2.0	2.1	2.2	2.2	2.2	2.1
Japan	5.3	5.4	5.3	4.5	4.2	3.8	3.6	3.4
United States	24.4	23.9	23.3	21.2	20.3	19.7	19.1	18.6
Other OECD	26.1	25.2	25.0	22.5	21.3	20.2	19.4	18.7
World total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CO_2 emissions								
China	10.6	13.5	14.1	19.3	20.8	22.2	23.3	24.5
India	2.7	4.2	4.1	4.5	4.7	4.9	5.0	5.0
Other non-OECD	33.1	29.1	29.2	29.3	29.9	30.2	30.3	30.4
South Korea	1.1	1.9	1.9	2.0	2.0	2.0	2.0	1.9
Japan	4.8	4.9	4.8	4.0	3.6	3.3	3.0	2.8
United States	23.5	23.6	23.2	21.0	20.0	19.4	18.9	18.6
Other OECD	24.3	22.8	22.7	20.0	19.0	18.1	17.4	16.8
World total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Energy Information Agency, 2006b. *International Energy Outlook 2006*, Department of Energy, Washington DC.

Table 5.2 **China's shares of global consumption of fossil fuel energy components, 1990–2030** (per cent)

	1990	2002	2003	2010	2015	2020	2025	2030
Coal consumption								
China	21.3	26.9	28.1	36.4	39.1	40.8	42.3	44.0
India	4.9	8.2	7.9	8.4	8.8	9.0	8.8	8.4
Other non-OECD	25.4	18.4	18.4	16.6	16.5	16.2	15.7	15.1
South Korea	0.9	1.5	1.5	1.7	1.7	1.6	1.7	1.7
Japan	2.4	3.3	3.2	2.5	2.3	2.0	1.8	1.6
United States	17.2	20.3	20.1	17.7	16.4	16.1	16.7	16.9
Other OECD	28.0	21.4	20.7	16.5	15.2	14.2	13.1	12.4
World total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Oil consumption								
China	3.5	6.6	7.0	9.5	10.2	11.2	11.9	12.7
India	1.8	2.9	2.9	3.2	3.4	3.6	3.7	3.8
Other non-OECD	32.7	29.6	29.6	30.9	31.7	32.0	32.5	32.8
South Korea	1.5	2.7	2.7	2.8	3.0	2.9	2.9	3.0
Japan	7.8	7.0	7.0	5.9	5.6	5.2	5.0	4.6
United States	25.5	25.2	25.1	24.2	23.9	23.8	23.6	23.4
Other OECD	27.2	25.9	25.7	23.5	22.4	21.2	20.4	19.7
World total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Natural gas consumption								
China	0.7	1.2	1.3	2.6	2.9	3.4	3.7	3.8
India	0.5	1.0	1.0	1.3	1.3	1.5	1.9	2.5
Other non-OECD	48.5	44.2	45.1	48.0	49.3	50.6	51.7	52.9
South Korea	0.1	0.9	0.9	0.9	0.9	0.9	0.8	0.7
Japan	2.6	3.1	3.2	2.7	2.6	2.4	2.2	2.1
United States	26.2	24.9	23.4	20.1	19.3	17.9	16.3	14.8
Other OECD	21.3	24.8	25.0	24.5	23.8	23.3	23.3	23.2
World total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Energy Information Agency, 2006b. *International Energy Outlook 2006*, Department of Energy, Washington DC.

is beginning to change as rising income levels in China make the environment a more important issue and as environmental quality continues to deteriorate.

This chapter summarises the recent history of energy use in China and presents some estimates of future projections of energy use. Although there is a range of environmental issues associated with energy, this chapter focuses primarily on the emissions of carbon dioxide—a critical driver of global climate change.[4] Although economic growth is still a priority in China, environmental policy is emerging as an important issue.[5] Indeed, China has shown a commitment to tackle local environmental problems with encouraging outcomes.[6] For example, Jiang and McKibbin (2002) find that Chinese policy has been effective in reducing environmental problems in a number of areas, relative to what otherwise would be the case. However, many environmental problems continue to worsen despite policy intervention, due to other factors driven by strong economic growth.

The remainder of this chapter is structured as follows. The second section presents a brief overview of energy use and carbon dioxide emissions in China. It also summarises projections from the United States Energy Information Administration's *International Energy Outlook* (2006b) of energy use and carbon dioxide emissions in China until 2030. The third section summarises the current policy debate on climate change and the implications for future Chinese energy. The fourth section focuses on the sensitivity of projections of energy use and carbon dioxide emissions to assumptions about the sources of economic growth. This analysis is based on projections from the G-cubed multi-country model under different assumptions about the sources of economic growth in China. Finally, the sensitivity of projections to the price of carbon is assessed in the fifth section. A conclusion appears in the final section. Appendix Table A5.1 summarises the G-cubed multi-country model that forms the basis of some of the analysis in this paper.

Energy use and carbon dioxide emissions in China

History. The importance of China in world energy use and the projected increases in this importance are summarised in Table 5.1. In 2003, China accounted for 10.8 per cent of world energy use (compared with the United States at 23.3 per cent) and 14.1 per cent of global carbon dioxide emissions from fossil fuel use (compared with the United States at 23.3 per cent). Chinese GDP (in 2003) was estimated in PPP terms to be roughly 59 per cent of the size of that of the United States.[7] This implies that although carbon emissions per unit of energy use are higher in China than in the United States, energy use per unit of GDP (in PPP terms) is slightly lower in China than in the United States.

China has roughly 9.4 per cent of the world's installed electricity generation capacity (second only to the United States) and in the next three decades it is predicted to be responsible for up to 25 per cent of the increase in global energy generation. China's size and the composition of its energy use, with a large reliance on coal, are reflected in carbon dioxide emissions. China is estimated to have emitted 14.1 per cent of global carbon emissions from fossil fuels in 2003 (second only to the United States in terms of individual countries) and this share is projected to rise to 24.5 per cent by 2030 (Table 5.1). In an attempt to move away from reliance on fossil fuels, China has plans for another 30 nuclear power plants in the next two decades to supplement its nine existing nuclear reactors.[8] It is estimated that China has the largest hydroelectric capacity in the world (largely in the southwest of the country), currently generating 20 per cent of Chinese electricity. The Three Gorges hydroelectric dam on the Yangtze River will be the world's largest power plant when completed about 2009. The

National Development and Reform Commission (NDRC) approved the largest wind farm in Asia in March 2005, to begin construction in 2006. There is projected to be a rapidly rising share of nuclear energy and renewable energy (particularly hydro) in Chinese energy production in coming years (Table 5.3). Despite the impressive scale of this expansion, the emergence of renewable energy will dent only slightly the overall dominance of coal in the foreseeable future in China, at least under current relative energy prices. The large rise in coal as a source of primary energy implies that China will need to respond to a range of environmental problems resulting from burning fossil fuels, including air quality (including black carbon emissions), acid rain (from emissions of sulphur dioxide and nitrogen oxides) and climate change (from carbon dioxide emissions).

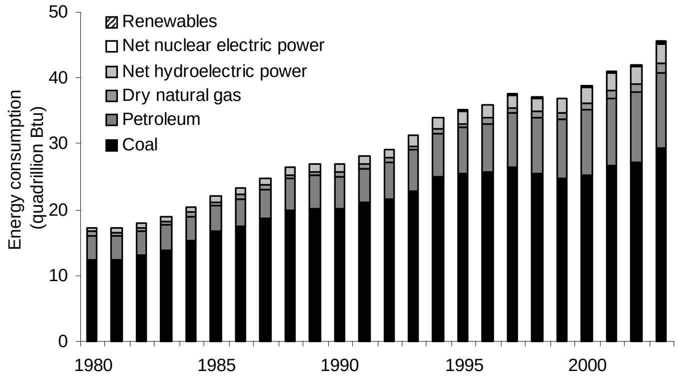
Figure 5.1 gives another perspective on the recent history of energy production and consumption in China. Energy demand and supply in China has been rising quickly—more than doubling between 1980 and 1996. In 1998, Chinese energy consumption began to outstrip production, with China becoming a net energy importer.

Table 5.3 Shares in global consumption of non-fossil fuel energy components, 1990–2030 (per cent)

	1990	2002	2003	2010	2015	2020	2025	2030
Nuclear energy consumption								
China	0.0	1.0	1.7	2.9	4.4	5.5	7.1	9.2
India	0.3	0.7	0.6	2.0	2.6	3.2	3.3	3.4
Other non-OECD	14.0	12.8	13.1	13.5	15.0	17.0	18.3	17.5
South Korea	2.6	4.4	4.9	5.2	6.0	6.4	6.7	7.2
Japan	10.1	11.0	9.4	10.0	9.8	10.2	10.8	11.2
United States	30.2	30.6	30.3	29.5	28.2	27.9	26.9	26.4
Other OECD	42.7	39.5	40.1	36.8	34.0	29.8	36.8	25.0
World total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Hydroelectricity and other renewable energy consumption								
China	4.9	8.7	8.9	13.5	13.8	13.4	12.6	12.2
India	2.7	2.2	2.1	2.9	2.6	2.8	3.1	3.5
Other non-OECD	31.6	34.5	35.5	35.8	38.1	39.5	41.5	43.1
South Korea	0.0	0.0	0.3	0.4	0.6	0.6	0.5	0.5
Japan	4.2	3.4	4.3	3.1	3.1	2.8	2.6	2.6
United States	23.2	18.3	17.4	15.9	15.3	15.3	15.1	14.6
Other OECD	33.1	32.9	31.2	28.5	26.5	25.6	24.6	23.6
World total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Energy Information Agency, 2006b. *International Energy Outlook 2006*, Department of Energy, Washington DC.

Figure 5.2 Energy consumption by source in China, 1980–2003 (quadrillion Btu)



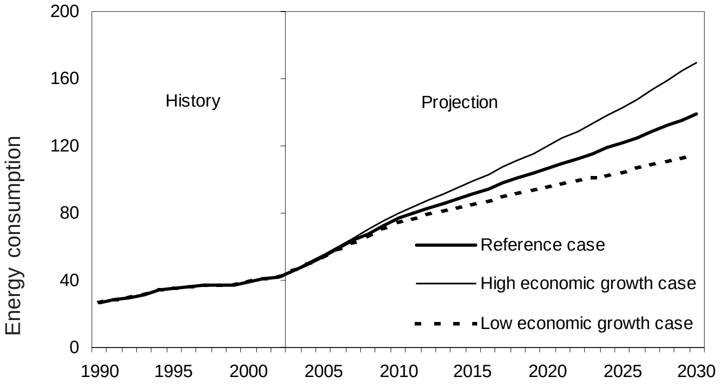
Source: Energy Information Agency, 2006b. *International Energy Outlook 2006*, Department of Energy, Washington, DC.

Figure 5.2 shows that an abundance of low-cost coal has been the predominant source of Chinese energy supply (located mainly in the northern part of the country). Crude oil (petroleum) is the next largest source of energy supply, followed by hydroelectricity, natural gas and nuclear energy. The major source of demand for energy in China[9] is industry, which accounted for 68.9 per cent of the total in 2002. This is followed by the household sector at 11.4 per cent and transportation at only 7.5 per cent.

Projections. Projecting future energy use in China, especially over horizons of more than a decade, is very difficult. It is tempting to base future projections on extrapolations of recent trends; however, as shown by Bagnoli et al. (1996) and McKibbin et al. (2004), overall economic growth need not be the key determinant of energy use. The sources of economic growth are critical. A number of projections are available publicly. The Energy Information Administration of the United States Department of Energy, in its annual *International Energy Outlook* (2006b), provides one source of projections. Projections for Chinese energy consumption in quadrillion BTU are shown in Figure 5.3 for three scenarios: high and low economic growth and a reference case.

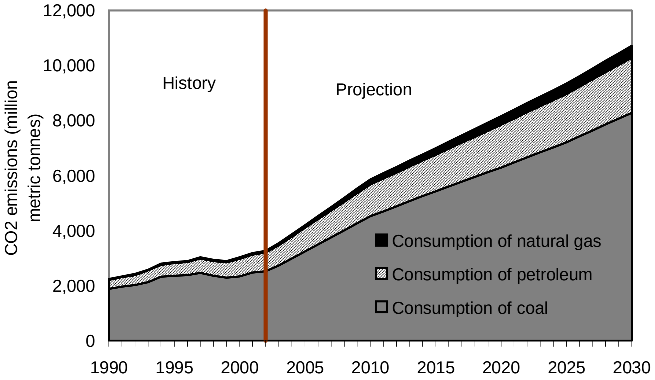
Figure 5.4 shows the Energy Information Administration's projections for carbon dioxide emissions by energy source in China for the reference case scenario. It is clear that coal burning is the overwhelming source of carbon dioxide emissions in China historically, and in these projections it is expected to be the major source of energy and therefore emissions in the foreseeable future. This is not surprising given the large quantity of low-cost coal

Figure 5.3 **Projections of energy consumption in China, 1990–2030** (quadrillion (10^{15}) Btu)



Source: Energy Information Agency, 2006b. *International Energy Outlook 2006*, Department of Energy, Washington, DC.

Figure 5.4 **Projections of carbon dioxide emissions by fuel type in China, 1990–2030** (million metric tonnes)



Source: Energy Information Agency, 2006b. *International Energy Outlook 2006*, Department of Energy, Washington, DC.

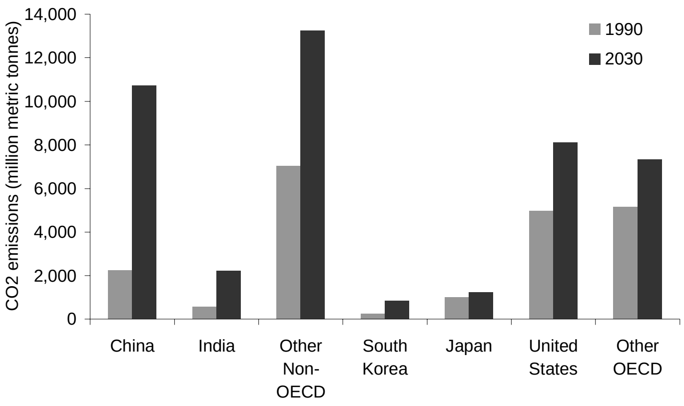
available in China and the assumptions of unchanging relative energy prices in these projections. Over time, the share of emissions from petroleum is projected to rise as greater use of motor vehicles and other non-stationary energy uses rise. It will be shown in the next section that these types of projections are contingent on assumptions about the price of energy relative to other goods and the relative price of alternative energy sources.

Figure 5.5 shows the global sources of carbon dioxide from burning fossil fuels, by region, in 1990 and those projected for 2030 in the 2006 *International Energy Outlook*. Not only is China currently an important source of carbon dioxide emissions, its share is expected to grow quickly. Its absolute size (Figure 5.5) and its share of global emissions (Table 5.1), suggest that China is a critical country in the debate over policies to deal with potential climate change. These projections assume business as usual, and therefore incorporate global Kyoto Protocol commitments.

Carbon emissions and climate change

China has begun to take action to address local environmental problems. There has been direct action to substitute non-fossil fuel energy sources such as wind, hydro and thermonuclear energy for fossil fuels in energy generation. China has also attempted to reduce the emissions of sulphur dioxide from burning fossil fuels by implementing a range of policies, from closing high-sulphur coalmines to developing markets for trading sulphur dioxide emission rights. As argued in McKibbin (2006a), a greater focus is required to address the emissions of black carbon. From a global perspective, the discussion above on future carbon emissions suggests that a critical area where China will need to take greater action is in the emissions of carbon dioxide.

Figure 5.5 Global carbon dioxide emissions from fossil fuels, 1990 and 2030 (million metric tonnes)



Source: Energy Information Agency, 2006b. 'Reference case', in *International Energy Outlook 2006*, Department of Energy, Washington, DC.

The most important cause of human-induced climate change is the accumulation of greenhouse gases in the atmosphere over many decades. The most important greenhouse gas is carbon dioxide. The global community has been struggling for several decades with how to respond effectively to the threat of climate change. The United Nations Earth Summit in Rio de Janeiro in 1992 produced a landmark treaty on climate change that undertook to stabilise greenhouse gas concentrations in the atmosphere. The agreement, signed and ratified by more than 186 countries, including the United States and China (the world's largest carbon dioxide emitters), spawned numerous subsequent rounds of climate negotiations aimed at rolling back emissions from industrialised countries to the levels that prevailed in 1990. Unfortunately, the negotiations have had little effect on greenhouse gas emissions and have not produced a detectable slowing in the rate of emissions growth.[10] The treaty's implementing protocol, the 1997 Kyoto agreement, was diluted heavily at subsequent negotiations in Bonn and Marrakesh.[11] The Kyoto Protocol entered into force on 16 February 2005 after ratification by Russia, yet there are still many problems to be faced before it will be evident that Kyoto is reducing emissions. More than a decade of negotiations has produced a policy that is likely to be ineffective in practice.

The difficulty at the international level is worse than it appears from the troubled process of Kyoto ratification. The Kyoto Protocol places restrictions only on industrial economies, excluding the world's largest greenhouse emitter, the United States. Developing countries, including China, have ratified the agreement but have not taken on any responsibilities for reducing emissions except those that emerge from mechanisms such as the Clean Development Mechanism (CDM) and joint implementation. That developing countries are not taking on targets as commitments is one of the reasons given by the United States and Australia for not ratifying the Kyoto Protocol. Because there have been no binding commitments by the key developing countries of China, India, Brazil and Indonesia (among others), effective action against possible climate change is still largely a hypothetical debate.

Developing countries have argued legitimately that while they are prepared to be part of a regime to tackle climate change, they should not be required to bear a disproportionate part of the costs of taking action. Current concentrations of greenhouse gases in the atmosphere are primarily the result of economic activities in the industrial economies since the Industrial Revolution. Because it is the stock of carbon in the atmosphere that matters for temperature changes, any climate change in the near future will be largely the result of the historical activities of industrial economies. One of the main dilemmas for developing countries is not just the reality that at some stage they will need to make some form of commitment to curbing greenhouse gas emissions, but the fact that most estimates of the damages from climate change are borne by developing countries.[12]

It is worth clarifying several important facts about the costs and benefits of climate policy and exploring whether there are approaches available to China and other developing countries that are being delayed by countries clinging to the Kyoto Protocol. Given the uncertainties of climate change and the decisions on energy systems being made in the rapidly growing regions of the developing world, this delay in providing clear incentives for moving away from fossil fuel-based systems might ultimately prove to be extremely costly.

Fossil fuel combustion is one of the largest sources of anthropogenic greenhouse gas emissions. Given the cost of changing existing energy systems substantially in the short term, one of the cheapest means of making the global energy system less reliant on fossil fuels is to remove these carbon emissions from future energy systems. As was shown in the second section, China is heavily reliant on coal for energy production and is likely to be so for many decades into the future. Technology will ultimately be the source of reductions in emissions, whether through the development of alternative sources of energy or through sequestration of carbon released from burning fossil fuels. Developing countries have a huge potential to avoid the pitfalls in terms of carbon intensities experienced by industrialised economies in their development process. The key issue is how to encourage the emergence of energy systems in developing countries that are less carbon-intensive over time. Ultimately, if climate change does emerge as a serious problem, developing countries will have to move towards a less carbon-intensive future. It is likely to be significantly cheaper to do this over time than to face a massive restructuring at some future period—the sort of problems being faced within industrialised economies today.

The current state of global climate policy is that the United States (the largest emitter of greenhouse gases) has rejected Kyoto and is arguing for policies that directly or indirectly reduce emissions through technological change; the European Union is committed to emission targets (assuming Russia provides a great deal of the reductions required through selling emission permits) and on 1 January 2005 it implemented a Europe-wide emissions trading scheme (which exempts key sectors such as aluminium, motor vehicles and chemicals), but with caps that appear to bind only by the end of 2008; Japan is considering what it can do given current emissions are 16 per cent above targets in an economy recovering from a decade of recession; and developing countries have refused to discuss taking on commitments officially.

Given this background, there are a number of ways a country such as China could begin to address carbon emissions and make a major contribution to a global response. One policy would be to move energy prices closer to world levels by removing energy subsidies. The second would be to raise the price of energy further to reflect the true economic and environmental cost of burning fossil fuels. A further approach could be direct importation of less carbon-intensive technologies provided by the CDM. This latter outcome is possible but not likely, as already outlined above.

Economic theory provides guidance about the structure of a possible climate change policy for China.[13] Since greenhouse gases are emitted by a vast number of highly heterogeneous sources, minimising the cost of abating a given amount of emissions requires that all sources clean up amounts that cause their marginal cost of abatement to be equated. To achieve this, the standard economic policy prescription would be a market-based instrument, such as a tax on emissions or a tradable permit system for emission rights. These types of market-based incentives for environmental pollution are already being undertaken in China through pollution charges and permit trading in sulphur dioxide. Cooper (2005) has advocated a carbon tax for China. Garbaccio et al. (1999) and McKibbin and Wilcoxen (2004) find that a price signal would be effective in changing China's future emission profiles. Given the advantages and disadvantages of the standard economic instruments, McKibbin and Wilcoxen (2002a, 2002b) show that it is possible to combine the attractive features of both systems into a single approach. They also show that it is possible to develop a system that is common in philosophy across industrialised and developing economies but in which developing economies do not incur the short-term costs to the economy in the form of higher energy prices until they have reached a capacity to pay. McKibbin and Wilcoxen (2002) have argued for a hybrid approach in which the short-term and long-term prices of carbon are changed in order to give incentives to move away from carbon-emitting energy sources. The implications of this hybrid approach for China are discussed in detail in McKibbin (2006a, 2006b).

Sensitivity of energy projections to growth assumptions in China

In this section, emission projections are presented from the G-cubed multi-country model[14] to show how sensitive the projections are to assumptions about the sources of economic growth in China. Two scenarios are considered: one in which all sectors have the same productivity growth and one in which sectors experience differential productivity growth similar to the experience of the United States in the past 30 years.

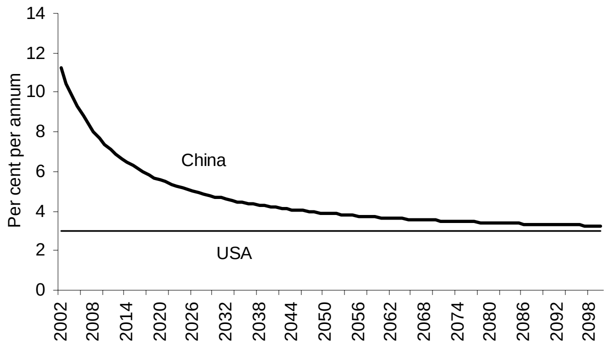
A summary of the approach is provided here but further details on the technique used in the G-cubed model can be found in McKibbin et al. (2004). In the following discussion, the source of economic growth is labour-augmenting technical change and population growth. The population growth assumptions are the same across both scenarios and are based on the 2004 United Nations population projections (Mid scenario). In order to simplify the discussion, labour-augmenting technical change is referred to as 'productivity growth' throughout the remainder of this chapter.

In the G-cubed model, productivity growth by sector and by country is assumed to be driven by a productivity catch-up model. The United States is assumed to be the technological leader in each sector. Other countries are allocated an initial productivity gap by sector and a rate at which this gap is closed. For industrial countries and China, this is assumed to be closed at the rate of 2 per cent per annum. For other developing countries, it is assumed to be closed at 1 per cent per annum, reflecting the empirical literature. In this chapter, Chinese productivity is assumed to be 20 per cent of productivity in the equivalent sector in the United States. In the first scenario, the United States is assumed to have the same productivity growth across all sectors. This is the typical assumption in models where aggregate GDP drives energy use and therefore emissions. This scenario is labelled 'uniform productivity growth'. The implications for growth are shown in Figure 5.6. Productivity growth in all Chinese sectors is the same given the same initial gaps to the United States and the same catch-up rate across sectors.

In the second scenario, it is assumed that the differential productivity growth across sectors in the United States is similar to that experienced in the past 30 years. The growth rates are adjusted so that the aggregate GDP growth rate for the United States is similar to GDP growth generated in the first scenario, and the main difference between the scenarios is the composition of growth. It is not possible to target GDP growth exactly.

Figures 5.6 and 5.7 show the productivity growth assumptions for each sector in the United States and the implications for the equivalent sector in China under the assumptions of the same initial gaps and rates of convergence. Although the initial productivity gaps are

Figure 5.6 **Labour-augmentative technical change for uniform productivity scenario, 2002–2100** (all sectors)



Source: G-cubed model version 63E.

the same, note that in Figure 5.7, different sectors in China experience different rates of productivity growth. This is important because capital accumulation is endogenous in the G-cubed model, responding to changes in real and expected rates of return to capital.

The results from the G-cubed model for Chinese carbon dioxide emissions and GDP growth under two scenarios are shown in Figures 5.8 and 5.9 for the period from 2003 to 2030. By 2020, emissions under the uniform productivity scenario are 20 per cent higher than under the differential productivity growth scenario, even though GDP growth is slightly higher under the latter. Part of the difference is due to differential sectoral demand for energy as an input as well as considerably different relative energy prices under the two scenarios. These results suggest that future projections of carbon emissions and energy use in China need to be interpreted carefully.

Despite this warning on the importance of structural change in energy projections, it is difficult to see a major shift in trends away from coal under current energy prices. Interestingly, there is also little change in the real price of oil or any fossil fuels throughout the projection period in the *International Energy Outlook* results presented earlier, yet there are significant changes in the projections from the G-cubed model, depending on assumptions about the sources of growth.

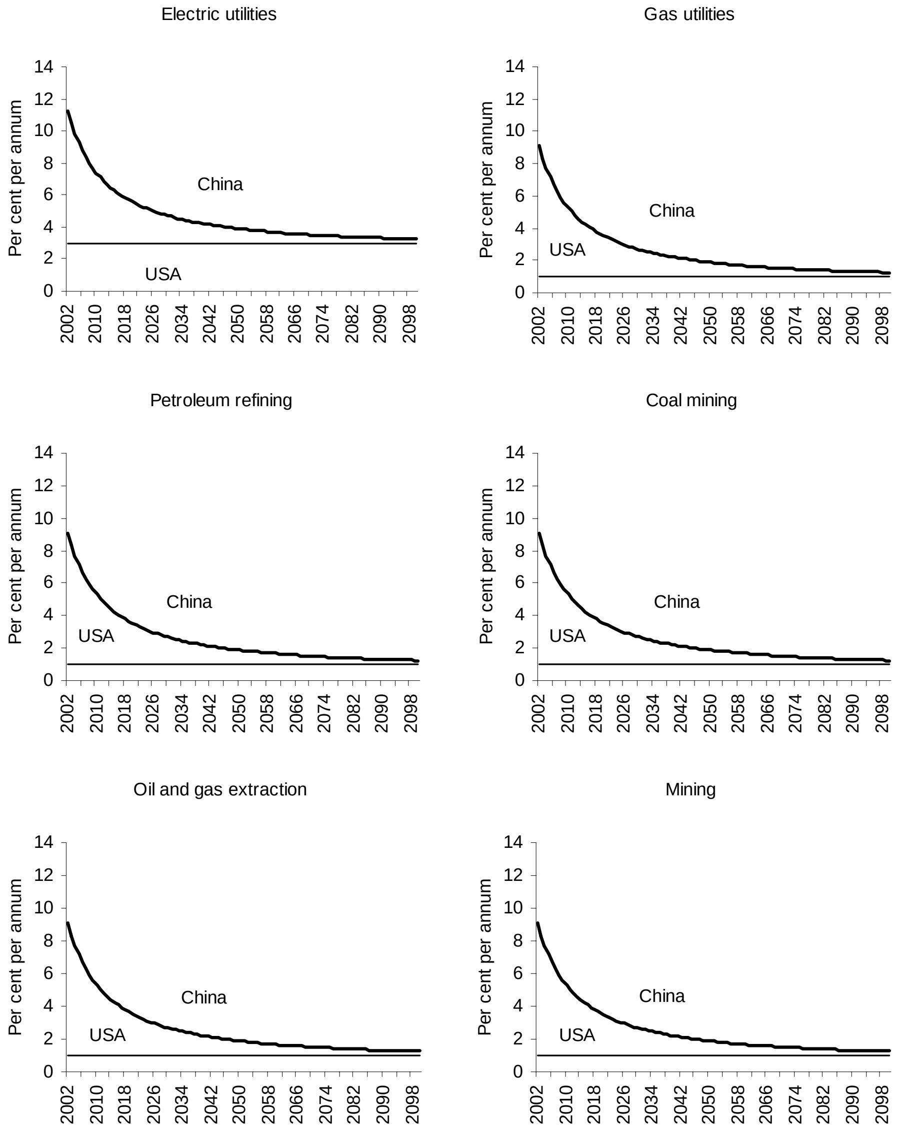
Under most scenarios, the emergence of China as a key supplier and producer of energy is one of the most important issues in the debate over global energy use for the foreseeable future. This is also critical for environmental issues in China, Asia and globally.

Sensitivity of carbon emissions to price changes

The above scenarios considered differences in emission projections due to different growth assumptions. Due to the endogeniety of relative prices in the modelling framework used, some of the differences in energy use and emissions are due to changing relative prices due to changes in demand and supply of energy and other goods in the global economy. In this section, the focus is on the sensitivity of emission projections to relative carbon prices, by considering a carbon tax in China. This result can also be translated approximately into the responsiveness of Chinese emissions to a conventional permit-trading system in China or a McKibbin and Wilcoxen hybrid system, except that there will be differential income and wealth effects of the latter system due to revenue going to the permit holders rather than to the government via a tax.

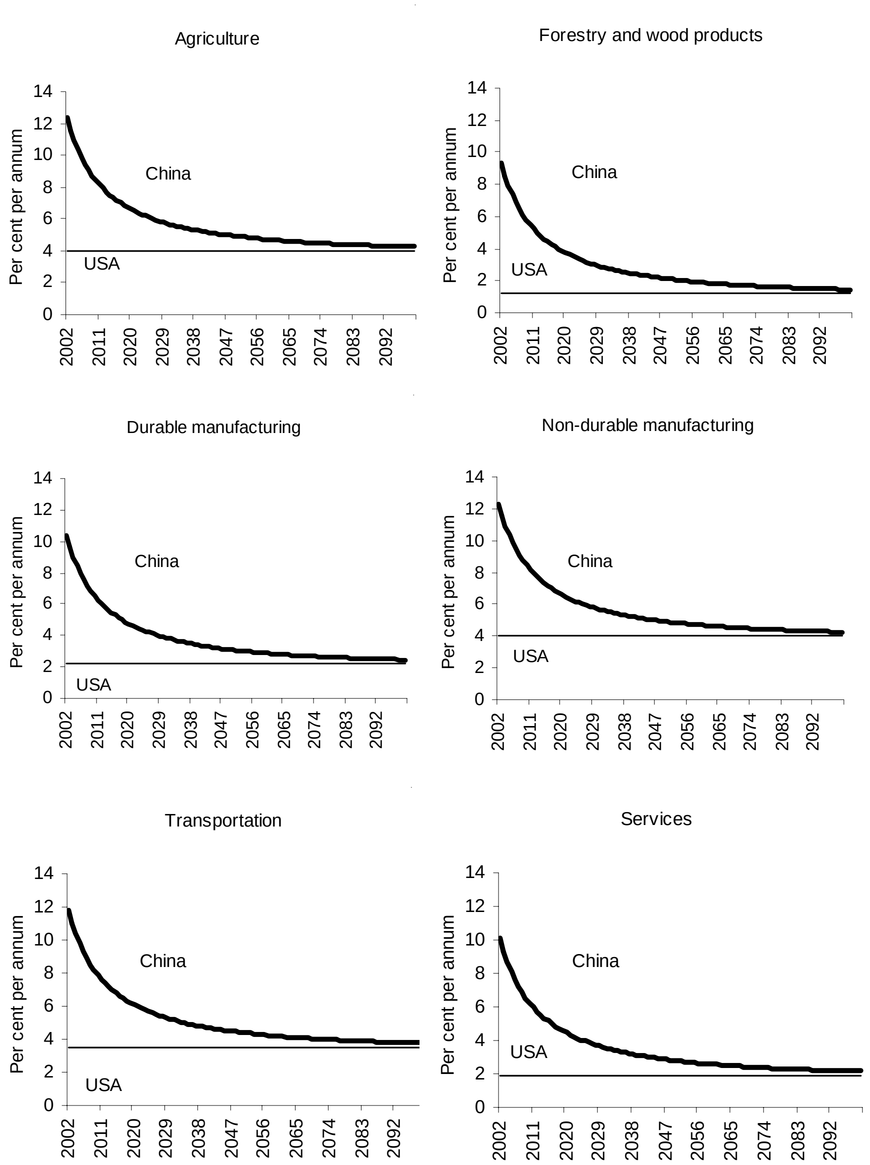
Figures 5.10 and 5.11 contain results from the G-cubed model of a tax of US$10 (in 2002 constant prices) per tonne of carbon, for the United States and China. Results are shown from 2007 to 2055. The short-term response of emissions in China is much larger than in the United States. The initial price of energy in China is much lower than in the United States

Figure 5.7 **Labour-augmentative technical change by sector in differential productivity scenario, 2002–2100**



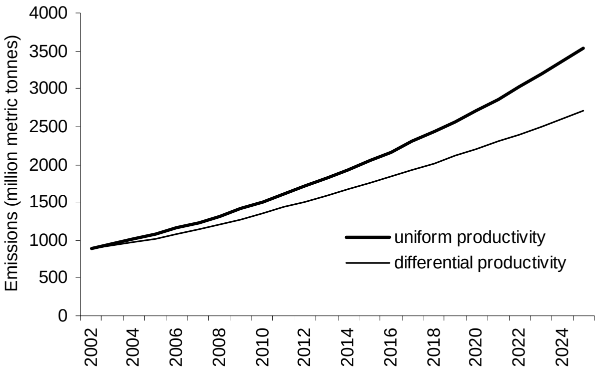
Source: G-cubed model version 63E.

Figure 5.7 **Labour-augmentative technical change by sector in differential productivity scenario, 2002–2100,** continued



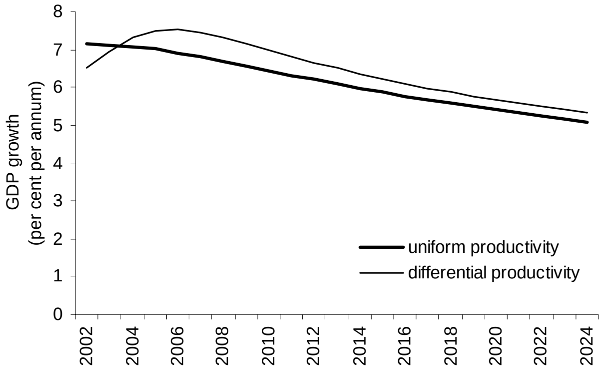
Source: G-cubed model version 63E.

Figure 5.8 Projection of Chinese carbon emissions, 2002–2026



Source: G-cubed model version 63E.

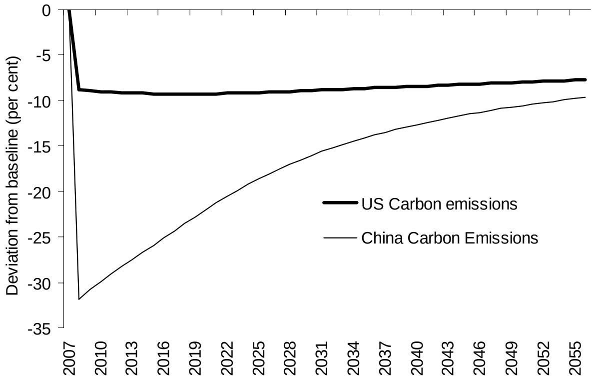
Figure 5.9 Projection of Chinese real GDP growth, 2002–2026 (per cent per annum)



Source: G-cubed model version 63E.

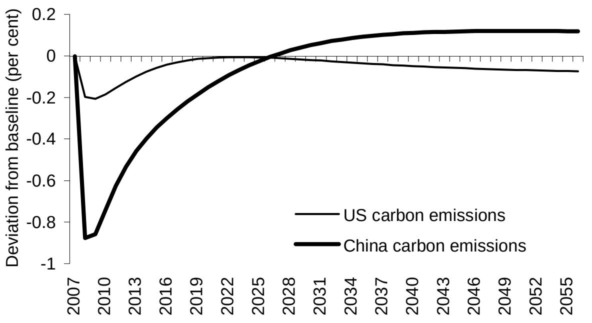
so the tax (on a per unit basis) causes a much larger proportional rise in the price of carbon-intensive energy in China than in the United States. The response in the short term reflects substitution and conservation by households and industry as well as a significant contraction in economic activity in China relative to the baseline. GDP falls by 0.9 per cent relative to the baseline in the initial year, compared with 0.2 per cent in the United States. Over time,

Figure 5.10 Response of emissions to a carbon tax in each country, 2007–2058 (US$10 per tonne of carbon)



Source: G-cubed model version 63E.

Figure 5.11 Response of GDP to a carbon tax in each country, 2007–2055 (US$10 per tonne of carbon)



Source: G-cubed model version 63E.

substitution in production and the use of energy allows a larger carbon reduction with less impact on GDP. GDP initially falls in both countries and in the longer term it is higher in China due to efficiency gains from more efficient use of energy. These results indicate that in the G-cubed model energy prices—in particular, the price of carbon—are important in changing the future emissions profile.

Conclusion

China currently faces a number of important problems related to energy use. At the forefront is the issue of how to deal with the desire for sustained economic growth at the same time as tackling serious environmental issues caused by energy generation. This issue is likely to become more important in coming years, especially as energy demand soars, environmental problems worsen and incomes rise. It is likely, under current global energy price structures, that future energy in China will be generated largely by the use of coal. Under current technologies in China, this is likely to have serious environmental consequences. Current plans to increase the use of nuclear and renewable energy such as hydroelectric and wind power are impressive but will likely have little impact in a rapidly expanding energy sector unless there is a significant change in the expected relative price of carbon. Other technologies—such as carbon sequestration, which is showing great potential—are also an option, although this technology will be more economically viable more quickly with a change in Chinese and global carbon prices.

For some time, China has been taking action on local environmental issues. This has been particularly true in dealing with air and water quality as well as sulphur dioxide emissions. Action is already under way to reduce emissions of sulphur dioxide by moving away from high-sulphur coal, by closing small, high-sulphur coalmines, with direct controls on sulphur dioxide emissions, implementation of pilot schemes for sulphur dioxide emission charges and pilot schemes for sulphur dioxide emissions trading. These are having an impact on emissions of sulphur, although the impact on acid rain in China and across Northeast Asia has been less clear.[15]

I have argued (McKibbin 2006a) that black carbon and its direct health, economic and environmental consequences are promising areas for close attention and direct policy intervention within China. This is not an issue of technological change at the power utilities as might usually be the focus of energy policy. A reduction in the emissions of black carbon will require a technology shift in the way households generate energy for heating and cooking and in the way farmers clear their land after harvest. Black carbon is a good candidate for consideration under the Asia Pacific Partnership for Clean Development and Climate (APPCDC) announced on 28 July 2005, which includes the United States, Japan, Australia, South Korea, China and India.

A critical issue facing China and the global community directly related to energy use in China is the emission of carbon dioxide. China and most other countries are yet to take effective action on reducing greenhouse gas emissions. Even if rapid action were possible, the lags between emissions and climate change are so long that benefits are unlikely for many decades. Although some researchers believe that global responses, such as through the CDM in the Kyoto Protocol, are a way to proceed,[16] it is doubtful that much can be achieved through this approach alone. A strong case can be made for responses to be developed within China, Korea, Japan and other economies in the Asia Pacific region for dealing with carbon dioxide emissions. This has already begun to emerge within the APPCDC. The current idea within this group of countries of technology transfer without a carbon price signal is unlikely to be as effective as a way forward as a system based on clear long-term price signals that give incentives for reducing carbon dioxide emissions. One estimate of the sensitivity of carbon emissions to price changes has been presented in this paper. Within the APPCDC framework, there is potential to experiment with hybrid market–government control schemes such as the McKibbin–Wilcoxen blueprint, in which important institutions are created to begin a long process of reduced carbonisation of the Chinese economy. This would allow China to continue to grow but would put in place a pricing mechanism for future carbon emissions as an incentive to shift Chinese energy systems gradually to low carbon-emitting technologies. The creation of institutions for environmental management based on market incentives together with appropriate pricing of consequences of current energy generation technologies are important for long-range energy planning in China.

China and other countries in the Asia Pacific region are at a critical juncture in determining the nature of energy use in the global economy and the potential global environmental impact of a rapidly growing China. Addressing this problem effectively is not easy, as shown by the reality that many of the potential solutions to environmental problems related to energy use are not yet implemented in other Asia Pacific economies. The form of future energy systems and the problem of reducing global carbon dioxide emissions cannot be resolved seriously without the complete participation of China in any strategies. But these strategies need to be determined domestically within a framework of multilateral cooperation rather than being imposed from the outside. The preliminary results in this chapter suggest that, given appropriate use of markets and pricing energy—in particular, carbon pricing—China can sustain high economic growth with less environmental damage from energy use and a smaller contribution to global carbon dioxide emissions than an extrapolation of recent trends would predict.

Acknowledgments

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Appendix 5.1 The G-cubed model for projecting energy use and greenhouse emissions in China

The G-Cubed model is an intertemporal general equilibrium model of the world economy. The theoretical structure is outlined in McKibbin and Wilcoxen (1998).[17] A number of studies—summarised in McKibbin and Vines (2000)—show that the G-cubed modelling approach has been useful in assessing a range of issues across a number of countries since the mid 1980s.[18] Some of the principal features of the model are as follows.

The model is based on explicit intertemporal optimisation by the agents (consumers and firms) in each economy.[19] In contrast with static CGE models, time and dynamics are of fundamental importance in the G-cubed model. The MSG-cubed model is known as a Dynamic Stochastic General Equilibrium (DSGE) model in the macroeconomics literature and as a Dynamic Intertemporal General Equilibrium (DIGE) model in the computable general equilibrium literature.

In order to track the macro time series, the behaviour of agents is modified to allow for short-term deviations from optimal behaviour due either to myopia or to restrictions on the ability of households and firms to borrow at the risk-free bond rate on government debt. For households and firms, deviations from intertemporal optimising behaviour take the form of rules of thumb, which are consistent with an optimising agent that does not update predictions based on new information about future events. These rules of thumb are chosen to generate the same steady-state behaviour as optimising agents so that in the long term there is only a single intertemporal optimising equilibrium of the model. In the short term, behaviour is assumed to be a weighted average of the optimising and the rule-of-thumb assumptions. Therefore, aggregate consumption is a weighted average of consumption based on wealth (current asset valuation and expected future after-tax labour income) and consumption based on current disposable income. Similarly, aggregate investment is a weighted average of investment based on Tobin's 'q' (a market valuation of the expected future change in the marginal product of capital relative to the cost) and investment based on a backward-looking version of 'Q'.

There is an explicit treatment of the holding of financial assets, including money. Money is introduced into the model through a restriction that households require money to purchase goods.

The model also allows for short-term nominal wage rigidity (by different degrees in different countries) and therefore allows for significant periods of unemployment depending on the labour-market institutions in each country. This assumption, when taken together with the explicit role for money, is what gives the model its macroeconomic characteristics. (Here again, the model's assumptions differ from the standard market-clearing assumption in most CGE models.)

The model distinguishes between the stickiness of physical capital within sectors and within countries and the flexibility of financial capital, which immediately flows to where expected returns are highest. This important distinction leads to a critical difference between the quantity of physical capital that is available at any time to produce goods and services, and the valuation of that capital as a result of decisions about the allocation of financial capital.

As a result of this structure, the G-cubed model contains rich dynamic behaviour, driven on the one hand by asset accumulation and, on the other, by wage adjustment to a neoclassical steady state. It embodies a wide range of assumptions about individual behaviour and empirical regularities in a general equilibrium framework. The interdependencies are solved using a computer algorithm that solves the rational expectations of equilibrium of the global economy. It is important to stress that the term 'general equilibrium' is used to signify that as many interactions as possible are captured, not that all economies are in a full market-clearing equilibrium at each point in time. Although it is assumed that market forces eventually drive the world economy to a neoclassical steady-state growth equilibrium, unemployment does emerge for long periods due to wage stickiness, to an extent that differs between countries due to differences in labour-market institutions.

Notes

1 All data, unless specifically indicated otherwise, are sourced from Energy Information Agency, 2006b. *International Energy Outlook 2006*, Department of Energy, Washington DC.

2 These issues are discussed more extensively in McKibbin 2006. See also China Council for International Cooperation on Environment and Development 2001; Panayotou and Zheng 2000; Streets 2004; and Wang and Smith 1999.

3 See Jiang 2002; and Zhang 1998.

4 There are many other environmental problems in China caused by a large population and rapid economic growth, such as water and air quality problems caused by deforestation and desertification. China's demand for resources also has a large impact on the environment of other countries. These important problems are not the subject of this paper, but for an overview see Liu and Diamond 2005.

5 China's *Environmental Protection Law* was promulgated in 1979 — a nationwide levy system on pollution began in 1982. The collection of fees for sulphur dioxide pollution from coal began in 1992. See Jiang 2003 for an overview.

6 See Jiang 2003; and Panayatou 1998 for an overview of China's environmental problems.

7 2004 UNDP Human Development Report.

8 DOE 2005.

9 See National Bureau of Statistics of China, *China Statistical Yearbooks* for 1990–2005.

10 See McKibbin and Wilcoxen 2002 for a summary of the negotiations and critique of the approach.

11 Earlier estimates of the cost of Kyoto can be found in Weyant 1999. Direct comparisons of the COP3 and COP7 versions of the protocol can be found in Bohringer 2001; Buchner et al. 2001; Kemfert 2001; Löschel and Zhang 2002; and McKibbin and Wilcoxen 2004.

12 See Intergovernmental Panel on Climate Change 2001.

13 See McKibbin and Wilcoxen 2002a for a survey; and Pezzey 2003 for a comparison of taxes and permits.

14 See McKibbin and Wilcoxen 1998, and documentation at http://www.gcubed.com

15 Nakada and Ueta 2004 point out that there are likely to be gains for other economies in the region, such as Japan and Korea, to cooperate with China in controlling sulphur emissions since these economies are also directly affected by acid rain emanating from China.

16 See Ueta et al. 2005.

17 Full details of the model, including a list of equations and parameters, can be found online at www.gcubed.com

18 These issues include: Reaganomics in the 1980s; German reunification in the early 1990s; fiscal consolidation in Europe in the mid 1990s; the formation of the North American Free Trade Agreement (NAFTA); the East Asian financial crisis; and the productivity boom in the United States.

19 See Blanchard and Fischer 1989; and Obstfeld and Rogoff 1996.