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China and East Asian Energy: Prospects and Issues

Proceedings of the Conference on 10–11 October 2005
Xindadu Hotel, Beijing

Peter Drysdale, Kejun Jiang and Dominic Meagher (eds)

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Preface

This paper is a product of a major project on *China and East Asian Energy*, 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.

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 will inform and influence the energy policy discussion in China, Australia and the region.

This first issue of the newly titled *Asia Pacific Economic Papers* is a volume that brings together papers presented at the first conference, held in Beijing in October 2005. It will be followed by a second volume, that includes papers from the 2006 conference.

We would like to thank paper writers and all participants in that conference for their contribution to this work. In particular, paper discussants, provided careful commentary on the papers in this volume. They included: Tony Beck, Liu Deshun, Christopher Findlay, Jane Golley, Yiping Huang, Kensuke Kanekiyo, Ligang Song, B. J Zhuang and Kim Zin-Oh. We are especially grateful to them for their input into the development of the research. We would also like to thank Dr Kim Zin-Oh for hosting the conference's concluding lunch.

A number of institutions' support made the conference possible. In Japan, the Institute of Energy Economics, in Korea, the Korea Energy Economics Institute, and in China, the Energy Research Institute, and the National Development and Reform Commission of the State Council, China Institute of Contemporary International Relations, Tsinghua University, Renmin University,

Petro China, the State Administration for Work and Coalmine Safety, the China Coal Information Institute, State Power, the Chinese Economic Institution Reform Committee, the National Economy Research Institute and the China Technical and Economic Research Institute all extended support in various ways. The East Asia Forum in the Crawford School and the International Centre for Excellence on Asia and the Pacific at The Australian National University have been instrumental in carrying the initiative forward.

We are grateful to Trevor Wilson for his advice and assistance in bringing these volumes to print. We also owe special thanks to Sue Matthews for her careful work in editing the papers and to Minni Reis for her excellent work in preparing them for publication.

Peter Drysdale, Kejun Jiang and Dominic Meagher
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Abbreviations

$ are US dollars unless otherwise specified
RMB renminbi
tons always refers to metric tons unless otherwise indicated

AIM	Asia–Pacific Integrated Model
ANU	Australian National University
APEC	Asia–Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Center
ASEAN	Association of Southeast Asian Nations
bbl	barrels (of oil)
bcm	billion cubic metres
Btoe	billion tons of oil equivalent
BTU	British thermal unit
CAPEX	capital expenditure
CDM	Clean Development Mechanism
CER	certified emission reduction
CFBC	circulating fluidised bed combustion
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
dwt	deadweight tonne
ERI	Energy Research Institute
GDP	gross domestic product
GW	gigawatt
GWh	gigawatt hour
GWP	gross world product
IEA	International Energy Agency
IGCC	integrated coal gasification combined cycle
IMF	International Monetary Fund
IPAC	Integrated Policy Assessment Model for China
IPCC	Intergovernmental Panel on Climate Change
JI	Joint Implementation
JODI	Joint Oil Data Initiative
KEEI	Korea Energy Economics Institute
km	kilometre
kWh	kilowatt hour

KEEI	Korea Energy Economics Institute
km	kilometre
kWh	kilowatt hour
Mtce	million tons of coal equivalent
LNG	liquified natural gas
m^2	square metre
mbd/mmbd	million barrels per day
Mt	megaton/million tons
Mtoe	megatons (million tons) of oil equivalent
NO_x	nitrous oxides
NDRC	National Development and Reform Commission
NEA	Nuclear Energy Agency
OPEC	Organization of the Petroleum Exporting Countries
OPEX	operational expenditure
PFBC–CC	pressurised fluidised bed combustion – combined cycle
PM10	respirable particulate matter under 10 microns in diameter
PNG	piped natural gas
ROE	return on equity
RTEISS	Real Time Emergency Information Sharing System
SEPA	State Environmental Protection Administration
SERC	State Electricity Regulatory Commission
SBM	single buoy mooring
SO_2	sulphur dioxide
SOM	senior officers meeting
tce	tons of coal equivalent
toe	tons of oil equivalent
TSP	total suspended particulate
TWh	terawatt hour
UK	United Kingdom
US	United States
USSR	Union of Soviet Socialist Republics
VAT	value-added tax
WTO	World Trade Organization

1 Introduction

John Garnaut

In October 2005, the Crawford School (then the Asia Pacific School of Economics and Government) within the Australian National University (ANU) initiated a major research project on China and East Asian Energy. The project is being undertaken under the school's East Asia Forum in conjunction with the China Economy and Business Program.

The first conference in the series being organised under the auspices of the China and East Asian Energy Strategies Research Program was hosted in Beijing by the Energy Research Institute and the ANU on 10–11 October 2005. It was the first of five annual conferences in the program. This book brings together the key papers presented at that conference.

In **Chapter 2**, Ross Garnaut and Ligang Song, of the ANU, discuss the effect of the rapid industrialisation of China and East Asia on markets for energy and minerals. They argue that from a historical perspective the decline of energy and mineral prices through the latter half of last century was an anomaly. From here, they say, it is likely that scarcity will lead to rising commodity prices, while the phenomenally rapid technological improvements of last century will decline to a rate more in line with that in the broader economy. They say that the fact that commodity prices have fallen over much of economic history 'should be put down to accident and not considered to be a necessarily a permanent feature of global economic development'.

Garnaut and Song say that the bullish commodity market outlook will be dramatically accentuated by China, resulting in a market that is different not only in scale but in structure. The rise of Chinese demand has been until now obscured by one-off events, including the collapse of Eastern bloc economies and the Asian economic crisis. But China has already attained per capita energy consumption levels that Japan did not reach until incomes reached $7,000 per person. And the global pattern has been for energy consumption to increase faster than income growth during periods of rapid industrialisation and income growth – meaning many years of Chinese-led demand growth for commodity markets. This has something to do with underestimation of Chinese GDP and a lot to do with China having the greatest investment share of GDP growth that the world has ever seen.

According to Garnaut and Song, 'While it is not possible for the investment share of GDP to rise without limit, it will remain extraordinarily high, and probably above the unprecedented levels reported for 2004.' Furthermore, they, say, China's comparative advantage is heading towards more capital-intensive, and therefore metals-intensive, exports. They also note that global demand growth has historically been highly sensitive to price – and that energy use actually fell from 1979 to 1983, coinciding with the largest oil price shock.

In Chapter 3, Tony Beck and Malcolm Gray of the ANU discuss the developments and prospects for international supplies of energy for China.

The US Department of Energy and the International Energy Agency (IEA) both foresee oil production shifting quickly to the Organization of the Petroleum Exporting Countries (OPEC) as non-OPEC suppliers ram up against reserve constraints. Beck and Gray note that OPEC production will need to roughly double by 2030 to meet projected demand, while non-OPEC has little room to grow. If OPEC operated more efficiently as a cartel, it would reduce production significantly from present levels. But the Jiang and Hu projections assume a declining oil price. Which do we believe?

Beck and Gray highlight pressing environmental constraints and the potential for substitution by uranium and, particularly, natural gas.

In **Chapter 4**, Kejun Jiang and Xulian Hu of the China Energy Research Institute present modelling results of China's energy market scenarios through to 2020. Crucially, their work looks at the likely industry costs of environmental control options and the subsequent effects on demand. They also present scenarios for pollution emissions.

The importance of this subject rests on the scale and pace of China's economic rise. Energy demand increased from 400 megatons of oil equivalent (Mtoe) in 1978 to 1,320 Mtoe last year (2004), an annual increase of 4.7 per cent. In contrast, between 1978 and 2004, coal's share in satisfying domestic energy demand fell only marginally, from 70.7 per cent to 69 per cent, while exports increased. This suggests that China's reliance on domestic coal reserves has not been challenged by economic reform.

Energy consumption rose significantly more slowly than GDP until the last few years – when the economy suddenly grew more energy intensive. This has crucial implications for global energy prices, climate change and the sustainability of economic growth. Is the experience since 2000 a new trend or a statistical or fundamental anomaly?

Jiang and Hu's modelling suggests a gradual reduction in China's coal reliance, replaced largely by natural gas and oil. They present three scenarios. In the baseline scenario primary energy demand grows 3.6 per cent annual to 2.1 billion tons of oil equivalent (toe) in 2020. The industry share of energy consumption is predicted to fall from 70 per cent in 2000 to 61 per cent in 2020, being replaced by a doubling in the share of transport energy use to 20.3 per cent over that period. Significantly, the modelling suggests that in the baseline scenario China, the world's biggest coal producer, will consume 40 per cent of world coal production by 2020 and import 129 million tons annually by 2030. The modelling also suggests that by 2020 primary energy demand will grow to 2.3 billion toe (high demand scenario) or 1.85 million toe (policy scenario).

Under each of the three scenarios, a lack of effective policy responses mean that nitrous oxides (NO_x), total suspended particulates (TSPs) and carbon dioxide (CO_2) emissions are expected to double by 2030, on a roughly linear trajectory. Sulphur dioxide (SO_2) emissions, however, are expected to rise sharply by 2010 before declining to current levels by 2030.

In **Chapter 5,** Jiang and Hu consider environmental issues and their impact on energy use in China. They calculated the sectoral cost of cutting carbon emissions in China and found that the cost would be highest for agriculture, followed by separate rural and urban categories. The cost for 'industry' is much lower. Put the other way round, industry can make huge emission savings if levied with specific carbon taxes, while the effect of taxes on agricultural emissions will be negligible. Adding a carbon tax will cut emissions drastically in the power industry and have a large impact on steel and cement emissions, while the effect on other industries will be less significant (for any given reduction in output).

Jiang and Hu show that NO_x pollution in Beijing (caused largely by automobile traffic) is the highest of any northern Chinese city, at three times the national standard. Concentrations of SO_2, TSPs and NO_x in Beijing rose in the mid-1990s and seem to have plunged in years 2000–02. Citing the *China Environmental Yearbook*, Jiang and Hu note that Beijing dropped from first to 16th on the northern Chinese comprehensive air pollution index in that period.

More than one-third of Chinese land is now affected by acid rain. Half of 47 major cities were hit by acid rain in 2002. The Huaihe River was found to be by far the most polluted major river, followed by the Yellow and Yangtze rivers.

Jiang and Hu note that CO_2 emissions fell from 1996 to 2000, before rapidly climbing again. There are major problems with China's huge reliance on coal, especially as most of the coal used in power generation does not go through washing and selection processes and has a high ash content.

In discussion, conference participants suggested that whenever there is an environmental problem there is a market failure. By shifting industry to China, the world is exporting associated environmental costs that are yet to be internalised into Chinese markets. Also, while the industry share of economies tends to fall with development, China probably has another 15–20 years of heavy industrialisation, which is moving its way steadily west across the nation.

Another question is whether the energy and pollution standards of the big cities are likely to be applied quickly across China as 'best practice' models. The optimism embedded in

Chapters 4 and 5 – that energy demand growth will decline – has implications for future energy policy. The regional and global environmental pressures on China to deal more efficiently with coal use, or restrict it, are going to be significant. This will increase pressure for substitution by natural gas.

In **Chapter 6**, Yong Zhao of China Huaneng Electric Power Group discusses energy market reform in the electric power sector in China. He provides an overview of the chaotic energy sector reform program, which has led to the fragmentation of what had been a unitary state-owned energy super-company. There are now six connected regional grids plus Tibet. Generation has been separated from transmission and distribution and is owned by a variety of state-owned, foreign and local private interests. The 2002 State Council document No. 5, Arrangement of Electric Power Institutional Reform, which was developed by a top-level State Council steering committee, has directed all reform policies since 2002.

Yet in 2003 the State Electricity Regulatory Commission (SERC) was established to regulate the power market independently. In 2005 it issued the Electricity Regulatory Code, which coexists awkwardly with a 1996 law. Direction from the SERC is frequently inconsistent with that from the National Development and Reform Commission (NDRC), which recently issued a new pricing edict. In July 2005 the State Council issued a clarification of the roles of the SERC and NDRC. This may be the first time the State Council has ever given a clarification of inter-agency roles.

Little has been achieved in assigning a monetary value to environmental costs. And China's fragmented, changing but centrally decreed pricing mechanism is, according to Yong, 'perhaps the most complicated in the world', creating a hazardous and distorted investment environment. Rising coal costs, for example, have led to large financial losses in the north but large gains in the south, but coal is still afforded privileges over other forms of generation. Nevertheless, Zhao observes, Huaneng is moving towards reducing its coal intensity, with a number of wind and solar generation operations. The incentives for it to do so remain unclear. There is still no nexus between generator and retail tariffs. Power shortages in the last few years are expected to shift to an energy surplus by 2007, following recent huge investment. Zhao also notes a lack of market information and transparency.

In **Chapter 7**, Ji-Chui Ryu of the Korea Energy Economics Institute (KEEI), gives a South Korean perspective on energy cooperation in Northeast Asia. On current trends, the prospect for close energy cooperation in the region cannot be said to be encouraging. Relations between China and Japan loom as a formidable barrier. There are territorial disputes and problems with North Korea's nuclear program. Russia has acted erratically on policy. The two Koreas, Mongolia and Russia are involved in an international forum established in 2001, but China and Japan are not, and much depends on the outcome of the six-party talks.

Dr Ryu discusses a road map for international cooperation designed by the KEEI in which traditional top-down structures like the Association of Southeast Asian Nations (ASEAN) and the Asia-Pacific Economic Cooperation (APEC) forum are considered. An alternative approach would be bottom up, like the European Union or the IEA.

There is an energy shortage crisis in North Korea, where usage dropped from about 25 to 15 million toe after Russia and China cut off oil and floods destroyed coal mines in the mid-1990s. Heating has depended on wood, leading to total deforestation and devastation in some areas. Transport is powered by oxen and humans. Ryu suggested that North Korea could be integrated with South Korean power grids – but North Korea would first need to dismantle its nuclear program, decouple energy from politics, join international bodies, and consult with South Korea and other countries on the structure of its energy systems. Alternatively, North Korea could connect to the Russian power grid (at a cost of $180 million).

In **Chapter 8**, Kensuke Kanekiyo, of the Institute of Energy Economics of Japan, discusses the energy outlook for China and Northeast Asia and Japanese perceptions of a regional energy partnership. He points out that the 2004 IEA Outlook predicts that energy consumption in Northeast Asia will exceed that in North America in the 2020s, but that in 2002 the IEA predictions substantially undershot real outcomes and are likely to do so again.

Korea and Japan are hugely dependent on energy imports, while China's 90 per cent self-reliance is declining rapidly. The lack of import options means that Northeast Asia is paying a premium of $1 per barrel over Europe and the United States. On top of this, there is an unusual blow-out in the spread between Arabian light and heavy crude (from $2 to $8 per barrel since mid last year) – further disadvantaging Asia.

Russia's surging economic growth is hugely reliant on the oil and gas industry (which accounts for more than half of exports) and it badly needs new markets because Europe is mature. But the regional barriers to an efficient local market are substantial: there is no regional cooperation; there is no joint response program; China's energy efficiency is poor; and the market is vulnerable to short-term fluctuations.

Kanekiyo suggests that there should be a Northeast Asia energy initiative at government level as well as a private sector forum; there should be a road map; and 'establishing confidence in the future market should be the starting point for cooperation'. Regional cooperation is needed to avoid unnecessary and potentially destabilising competition, to increase security for everybody and to exchange policy and technology ideas which would help late-comers improve energy efficiency. The starting point is easy: non-binding dialogues, research and information exchange. However, Kanekiyo notes, 'The issue is where this might lead to. Practically it can also be very difficult.'

Ultimately, the body should expand beyond Korea, Japan and China. This will make 'spoiler behaviour' less likely on a political whim. Long-term stable markets will require the involvement of suppliers, like Russia, Australia, and Indonesia. Kanekiyo notes: 'If you only have consumers in the group, incentives are quite different when the market is tight and when it is loose, and the group is unlikely to work. Outsiders would also alleviate political tensions. There is a huge risk and difficulty if we only include these three economies.'

2 Rapid Industrialisation and the Demand for Energy and Minerals: China in the East Asian Context

Ross Garnaut and Ligang Song

Introduction

Adequate supplies of natural resources have always been preconditions for economic growth. The requirements for energy and metallic mineral resources have been larger and more obvious with the modern economic growth that began in parts of the North Atlantic in the 18th century and has made its main home in East Asia in the late 20th and early 21st centuries. Energy is a major and essential input to all economic activity, including food production, manufacturing and transportation.

Along with growth in the amount of energy used in the process of economic development there have been changes in the form in which energy is utilised – a shift both in the sources of energy and in the transformations through which the energy sources pass as they are converted into economically valuable goods and services (Rosenberg 2000). The availability and price of energy are closely related to the long-term evolution of economic structure (MacKellar and Vining 1987).

The dependence of economic growth on expanded access to energy has generated recurrent anxiety over the adequacy of nations' resources for meeting their apparently insatiable appetites for energy (Nordhaus 2000). Through the 19th and the first half of the 20th centuries the easing of these anxieties was one motivation for imperialism. In the early 21st century, it is still capable of raising difficult issues about the deployment of national power.

Energy and resource economics have a long history as an area of specialisation within the discipline. Their elevation in the pecking order from time to time has been driven by real or perceived crisis (Stevens 2000). Concern over potential impact on British economic power prompted Jevons to write about British coal reserves in 1866. The first oil shock of 1973 pushed energy back up the agenda of economists. Concerns about climate change have boosted interest in the economics of energy and the environment since the mid-1980s. More recently China's industrial and trade expansion have led many to ask whether its ever-increasing demand for resources can be met without disruption to economic stability and growth in China and the world as a whole.

Is it likely or possible that the current phase of Chinese economic growth will be hampered by exhaustible resource constraints, as Slade (1987) suggested might be the fate of rapidly growing newcomers to industrialisation. Are the energy and other natural resources available to allow China, India and other developing countries to achieve the living standards of the advanced industrial countries? Or will global living standards eventually be limited by a 'finite amount of essential, depletable natural resources' (Nordhaus 2000, p. 529)?

Economists today, unlike other social scientists and the general polity, do not fear that the world economic growth will grind to a halt because the world 'runs out' of potential for expanding production of energy, metals or other natural resource-based products. Higher prices will induce expansion of output and substitution in supply and demand for scarce resources, as well as some modification of the rate and pattern of economic expansion. But while, in the end, supply will equal demand at some higher level of global economic output, the process of adjustment is of great importance.

This paper deals mainly with one corner of these issues: the growth in demand for resource-based products that can be expected to be associated with economic growth in China.

The paper examines the experience of growth in resources demand and the associated pressure on global markets from Japan, Taiwan and Korea during their periods of sustained, rapid economic growth for periods in the second half of the 20th century. It seeks to draw lessons from this experience for what we can expect from Chinese growth in the first half of the 21st century.

There are many parallels between the Chinese experience so far and that of Japan, Taiwan and Korea two, three and four decades ago. China is different mainly in its size. But that may turn out to be a decisive difference. It may cause the resources boom associated with the later decades of its period of sustained rapid growth to raise the prices of resource-intensive products by a large amount, not for a few years, but for several decades. This will have important implications for economic development and the distribution of incomes within and between all countries, and on power relations between states in the Asia Pacific and through the world community.

The economics of the mineral resource industries[1]

The natural resources that are used in the production of the energy and metals that are essential to economic development are not scarce in any absolute sense. All of the industrial metals are abundant in nature, to an extent that is unlikely to be challenged by human demands for the foreseeable future at any conceivable rate of global economic growth. And while it is possible that the growth of human demand might test the limits of some particular sources of energy – notably petroleum, especially in liquid form – the total potential supply of natural energy sources that are available for utilisation by humans exceeds any conceivable requirements.

All of the important economic questions about natural resource 'limits to growth' are about the costs of converting naturally occurring metallic minerals and the various sources of energy into forms that are suitable for supporting economic development, and the costs of transporting them to the loci of human demand.

For the fossil fuels, there are separate issues about the environmental costs of their use. It may be – indeed, it is likely – that the environmental limits to the rational use of fossil fuels are reached long before the absolute availability of the natural resources comes into question. If this were to lead to effective controls on the use of fossil fuels, the demands on other energy sources would be increased. Supply of energy from some combination of other sources could be expanded beyond practical limit at some cost. We recognise the environmental limits on the use of some sources of energy, but do not analyse them in this paper. We will treat them in some detail in other work on the implications of Chinese economic growth for global supplies of natural resources.

All of the economically valuable minerals are available abundantly in nature, but at varying concentrations, and in different chemical associations with other elements that affect the cost of extraction, concentration and purification. They are available in nature at varying depths below the earth's surface, and separated by varying distances and natural barriers from the locations in which they are in demand for economic activity.

The costs of supplying minerals to the places where there is demand for them have several elements. One is the cost of discovery and definition of the ore bodies that have the concentrations of the economically valuable element, and other characteristics, that make total costs of supply relatively low, and therefore make the ore body suitable for economic use. A second is the capital cost of building the mine and the processing facilities to convert the natural mineral into an economically valuable form. The third is the recurrent cost of producing and processing the mineral. The fourth is the cost of transporting the product of mining to the place where it is to be used.

In the early stages of use of minerals in modern economic activity, mines were usually located close to the main centres of economic activity – first of all in the North Atlantic. In these early stages, mining was confined to ore bodies of high concentration, close to the surface of the earth, in chemical forms from which they could be extracted at low cost with simple technology. The expansion of global industrial activity led to expansion of the locations of mining beyond the main industrial centres, to the mining of lower concentrations of minerals, and to technological innovation that expanded the types of ore that had economic value.

There are high capital costs in exploration and mine development. The supply price of investment is higher in some locations than in others – today, typically much higher in developing countries with less developed legal and political institutions and in which international investors have less confidence in the stability of property rights, contracts, the fiscal regime and the political order more generally.

It is typically much cheaper to expand production of valuable minerals from an established mine than to create new capacity to mine an ore body which, at the margin, has similar characteristics. It is obviously much cheaper to supply minerals from an ore body close to an established centre of industrial activity and joined to it by an established transport infrastructure. Transport economics plays a much larger role in the supply of commodities with low value relative to volume or weight (iron ore, bauxite) than to commodities with high value to weight (for example, gold).

These characteristics of the economics of the global minerals industries might be expected to lead to steadily increasing mineral prices with the expansion of global demand. Depletion of the best-located and highest-quality ore bodies would require the mining of higher-cost and more distant mines, located in countries where the supply price of investment was higher. The more global economic activity expanded, the faster would be the rate of increase in global mineral prices. Within this framework, more rapid modern economic growth in major countries – Japan in the third quarter of the 20th century and China in the late 20th and the 21st centuries – would lead to acceleration in the rate of increase in global commodity prices.

The reflection of these realities in commodity prices has been obscured by a tendency for technological and institutional change affecting the supply of mineral commodities to proceed more rapidly than similar change in the total economy. Political change has expanded the number of countries from which minerals can be drawn into world markets, and lowered the supply price of investment to many countries. The decentralisation of global economic activity away from the North Atlantic, especially to East Asia, has reduced the remoteness of many ore bodies, notably in Asia and the Pacific. Innovations in transport technology have reduced the costs of supplying minerals from remote locations. Developments in technology have reduced the costs of discovery of new ore bodies, and facilitated identification of potential mines that are so deep or otherwise obscured to humans that their presence has hitherto gone undetected. New processing techniques have allowed the extraction of minerals from chemical compounds that were once beyond economical human use. New construction technology has reduced the capital cost of establishing new mines. And innovations in mining methods and equipment have reduced the recurrent costs of mining.

The history of technological innovation in economic development tells us that necessity is the mother of innovation, so looming scarcity and rising prices of minerals could be expected to support high rates of innovation. But this provides no reason why technological change in mining should have proceeded so much more rapidly in mining than in other industries that the price of minerals relative to other minerals should actually have fallen over much of modern economic history. And yet it has – a fact that, pending explanation, we should put down to accident and not consider to be necessarily a permanent feature of global economic development.

The history of minerals and energy prices in modern times is characterised by wide cyclical fluctuations more than by secular tendencies to rise or fall. This derives from the long lead times in the generation of production from investment in exploration and mine development, and from uncertainty about future demand at times when exploration and mine development decisions are taken. Once the investment has been committed, the owner of a mine has an economic interest in continuing production from it so long as the price of the product covers recurrent costs, even if it makes little contribution to recoupment of the cost of capital. Production levels are therefore maintained even if demand growth is unexpectedly low – as a result of recession, revolution or other dislocation, or a change in growth trajectory, in major economies. This can keep prices at levels well below the total cost of production for long periods, while global demand catches up with earlier expectations and investment in new capacity is discouraged. On the other hand, if one or more major economies grow at an unexpectedly rapid rate, prices can remain well above the total cost of production for the long period that is required to find and to develop new mines.

So we can characterise the behaviour of resources prices over time in the following manner. There is a tendency for mineral prices to rise over time with global economic growth, as a result of requirements to bring lower-quality and more poorly located ore bodies into production. This tendency is stronger the more rapid is global expansion of economic activity. It is offset to some extent by institutional and technological innovation, which proceeds more rapidly at some times than others. *A priori*, one might expect more rapid institutional and technological improvement in mining than other industries simply because, in its absence, the real prices of mineral products would be rising, thus increasing the incentive to innovate. But there is no reason why the technological improvement should proceed so much more rapidly in mining than in other industries that real prices of mineral products actually fall. Indeed, one would be surprised to find consistent evidence over long periods that that has occurred.

Around these determinants of long-term tendencies in real prices of mineral products, there are wide and sometimes long-lasting cycles in prices, resulting from market participants' failure to anticipate correctly the growth in global demand.

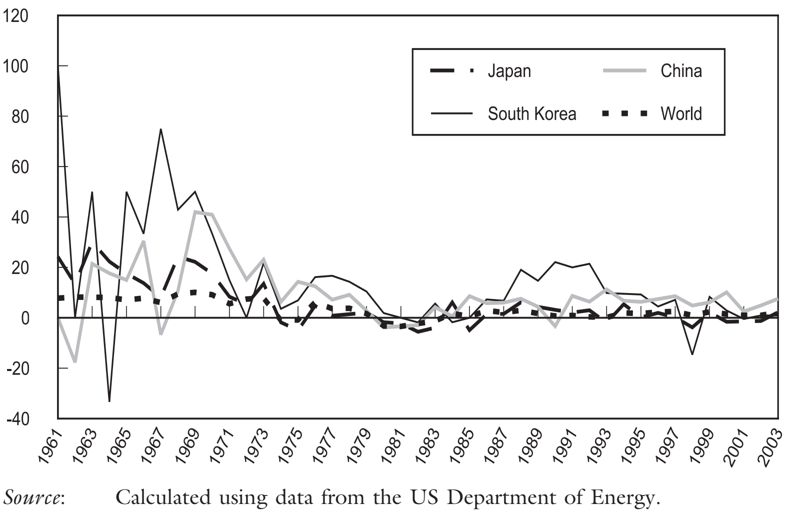
The discussion so far has been in terms of a single mineral commodity. In reality, the many natural sources of energy and the many metallic minerals are substitutes for each other, and for non-mineral products, in supply and in demand. These tendencies introduce powerful corrective forces if the real price of one product rises or falls a great deal.

Resource prices and Northeast Asian demand

The extraordinarily rapid economic growth in Northeast Asia over the past half century – at first in Japan, then in the newly industrialising economies, with South Korea showing the largest growth, followed by China – has added significantly to growth in global demand for energy and metallic minerals. The Northeast Asian economies now loom large enough in global demand for unanticipated fluctuations in the growth in their demand to affect global prices.

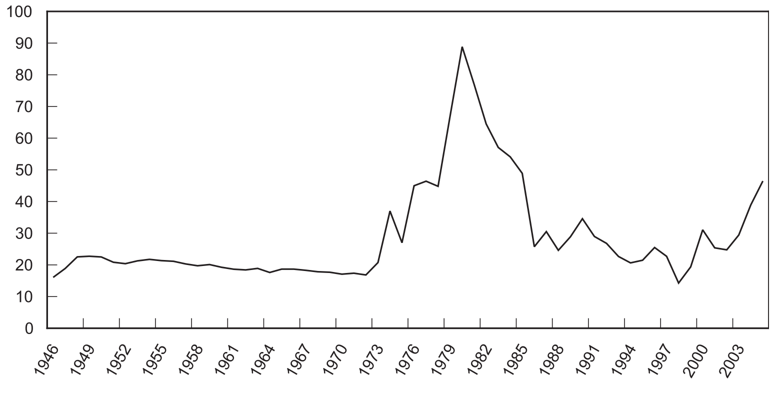
Figure 2.1 presents data on global demand for petroleum over the period in which the Northeast Asian economies have been growing strongly. The most striking story to be taken from the chart is that global demand growth is highly sensitive to price, independently of growth in global economic output. The period of rapid Japanese economic growth, ending in 1973, was characterised by rapid growth in global energy demand, commonly around 8 per cent per annum, and well in excess of world economic growth. Growth in Japanese energy demand was very strong, commonly contributing around 2 per cent per annum to growth in total global demand, but the rapid pace of consumption increases elsewhere meant that this

Figure 2.1 Growth rates of demand for petroleum: Northeast Asian and the world (per cent)



Source: Calculated using data from the US Department of Energy.

Figure 2.2 Crude oil prices adjusted for inflation, 1946–2004 ($/barrel)

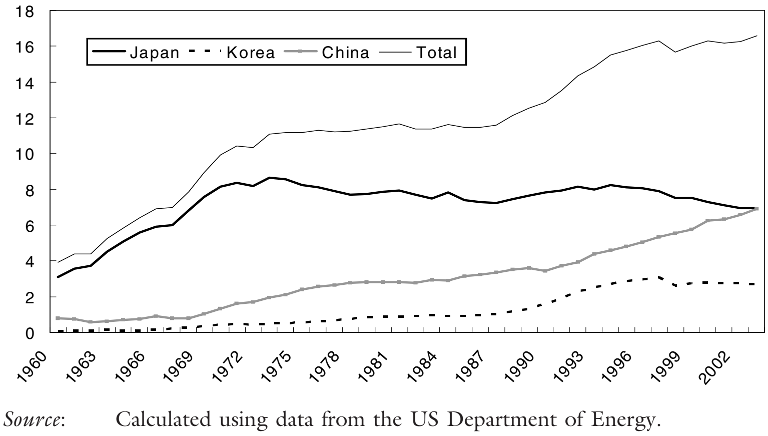


Source: Plotted using data from <http://www.iea.org/Textbase/stats/oilresult.asp and www.eia.doe.gov/>.

was only one-quarter of the world total. This happened to be a period of stable oil prices in real terms (Figure 2.2), which ended with the 'oil shock' of 1973. Over the two decades to 1973, global supply was able to keep pace with rapid increases in demand as new discoveries were made in the Middle East and as major US and British oil companies turned themselves into effective multinational corporations.

Japan contributed a significant part of the growth in global consumption in the 1960s and early 1970s (Figure 2.3). It is therefore part of the cause of the tightening in world markets in the early 1970s that set the scene for the large lift in oil prices. But the shift that generated the higher prices was more evident in supply than in demand conditions.

Figure 2.3 Shares of petroleum consumption in the world, Japan, Korea, China and Northeast Asia as a whole, 1960–2003 (per cent)



Source: Calculated using data from the US Department of Energy.

The much higher energy prices from 1973 to 1986 (gradually extending from oil to energy in all its forms) had a dramatic effect in reducing growth in consumption. World energy use fell from 1979 to 1983 – at first as the United States and some other major economies went into recession, but still as global economic activity recovered. This was a time when Northeast Asia moved more or less in line with global demand – after the deceleration of Japanese growth, and at a time of deliberate and effective phasing out of energy-intensive industries and processes in Japan, and before Korea and China were large enough to make a mark on the global economy. From 1987, rapid expansion in the Korean and Chinese economies began to contribute a large proportion of the growth in global demand for energy, but at a time when demand growth in the rest of the world was weak. Continued strong growth in Chinese demand came to be associated with tightness in global markets only in the early 21st century, when reasonably strong growth in consumption was again evident in the rest of the world – encouraged by historically low prices in the immediate aftermath of the East Asian financial crisis.

The story of growth in the global demand for copper in the second half of the 21st century is also an interesting one. Per capita global consumption was exceptionally strong through the period of sustained rapid growth in Japan, with reasonably strong growth in the North Atlantic economies, from the early 1950s to 1973. Per capita copper consumption then grew slowly, dipping sharply during the recession of the early 1990s (which coincided with the collapse of the Soviet economy), and again in the United States recession of 2000–01. It has since resumed strong growth, with China the major influence.

The global price of copper in real terms has fluctuated widely with cyclical and periodic variations in consumption growth. In this long run perspective, there have been four distinctive periods for global copper prices since the late 19th century. Prices fluctuated around 180 cents per pound in today's values in the rapid global economic expansion from the recession of the early 1890s until the First World War. They fluctuated around a much lower level through the relative stagnation of the 1920s and 1930s – with a mean of about 100 cents per pound in today's prices. The price trend was steadily upward from the Second World War until the oil crisis of 1973. It reached a historically high average of above 200 cents per pound over the last decade of this period, corresponding to the time of sustained rapid Japanese growth after Japan had become large enough to influence global markets. The trend was then steadily down, to Great Depression levels near and below 80 cents in the years straddling the turn of the century. Since then, we may have entered a fifth period, marked by price revival, with the current (October 2005) spot price of 180 cents being shockingly high by the standards of the immediate past, but no more than normal for earlier periods of sustained global prosperity, in the quarter century leading up to the First World War, and the two decades preceding the first oil crisis.

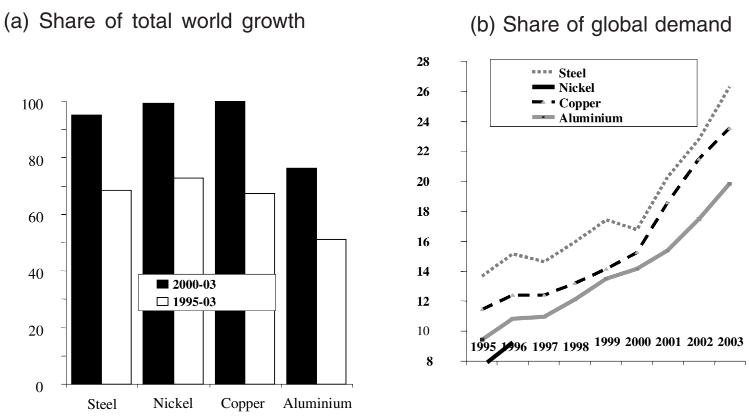
Copper prices, much more than energy or oil, have fluctuated widely with cyclical variations in global economic activity. In this, copper and other metals are affected by their intensive use in capital goods, the demand for which is highly sensitive to the business cycle. Similar cyclical volatility is evident in prices for steel.

A closer look at resource demand in Northeast Asia and China

The preceding section suggested that, for both energy and copper, strong growth in Chinese demand has been associated with a new era of rising real global prices in the early 21st century. Figure 2.4 underlines the importance of China to the recent period of rising real mineral prices. It complements Figure 2.3, which revealed the large position of China in recent growth in global energy consumption. It shows that China accounted for a majority of the growth in world consumption for each of the main industrial metals in the decade from 1995, and for virtually all of the growth for several metals in the early years of the 21st century.

China has achieved this large position in global markets when it is in the early stages of what is likely to be a long period of rapid economic growth, and when its per capita consumption of energy and metals is low by the standards of the advanced industrial countries (Table 2.1). This follows, of course, from China's demographic size: China's population is almost twice as large as that of all of the developed countries combined.

Figure 2.4 China's shares of world demand and growth of key metals, 1995–2003 (per cent)



Source: Macquarie Research Metals and Mining 2004.

What effect will China's continued economic growth have on global energy and metal demand? Here we look at the experience of East Asian and other advanced economies in their periods of rapid growth, industrialisation and urbanisation, and discuss ways in which China may be similar to and different from those which have gone before it.

In seeking to draw lessons from the experience of other countries, we quickly come up against an awkward fact: China consumes far more of virtually all goods than other countries which have, or when they had, per capita incomes similar to China's. Work undertaken a little over a decade ago suggested at that time that China's consumption per capita of most foodstuffs was comparable to that of other East Asian economies when their per capita incomes, as measured by the standard national accounts, had been three times as high as China's in the early 1990s. The consumption of energy and metals was comparable to that of other economies when their per capita incomes were four or five times as high as China's at that time (Garnaut and Ma 1993). While the legacy of central planning and price distortion may have contributed to some upward bias in metals and energy use, the divergences across countries could not be explained without acceptance that there was a degree of underestimation of income in the Chinese national accounts used by the international financial institutions. The apparent underestimation of Chinese income was less pronounced but still present in the international purchasing power parity estimates of national output and incomes.

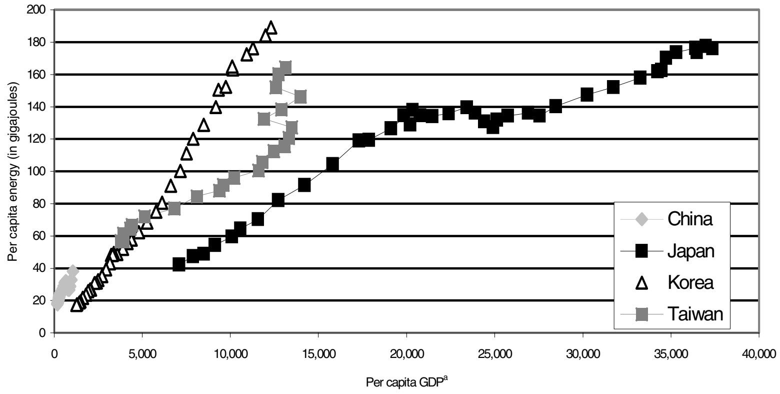
In the years since then, there has been some upward adjustment to Chinese national income as reported by the Chinese domestic statistical agency and the international financial institutions. However, the levels of consumption for virtually all goods remain high for a country with China's reported per capita output and income.

Table 2.1 International comparison of energy consumption per capita, 2003 (toe)

Year	Coal	Petroleum	Natural gas	Hydro- and other power	Total
United States	1.95	3.11	1.93	0.83	7.82
France	0.21	1.57	0.66	1.91	4.34
Germany	1.06	1.52	0.93	0.52	4.03
Japan	0.88	1.95	0.54	0.59	3.95
United Kingdom	0.66	1.29	1.45	0.36	3.76
China	0.61	0.21	0.02	0.06	0.90
World average	0.41	0.58	0.37	0.19	1.55

Note: toe = tons of oil equivalent.
Source: China Energy Research Institute.

Figure 2.5 Total energy consumption intensity



Note: a Based on national accounts GDP at 2000 constant US dollar price.
Source: Authors' calculations.

Figure 2.5 shows that Chinese per capita energy use has risen rapidly in recent years, to levels attained by Japan when its per capita income was almost $7,000 in constant dollars of the year 2000. Energy demand in all of the Northeast Asian economies expanded more rapidly than income until, in Japan's case, average incomes reached almost $20,000. Energy consumption relative to income has increased more rapidly in Taiwan and Korea than in Japan, and more rapidly again so far in China. The general pattern is for per capita energy and metals consumption to rise more rapidly than per capita GDP during the period of rapid growth associated with the movement to and through middle incomes, but to fall behind as the global frontiers of average productivity and income levels are approached (Slade 1987). This pattern is evident in the experience of Japan (Figure 2.3), but not yet in that of Taiwan or Korea.

Japan, Korea and Taiwan all experienced rapid increases in the share of fluid energy forms in total energy use through their periods of rapid growth. So far, China has followed only weakly on that path (Table 2.2) although the growth in oil consumption was fast enough for it to overtake Japan as the second largest in the world in the early 21st century (Figure 2.1). China remains exceptionally dependent on coal as a source of energy (Table 2.2). Its large domestic reserves of coal and limited domestic petroleum resources will ensure that China will remain different from the global norm in this respect. The distinctive Chinese reliance on coal is evident in the comparison with Japan in Table 2.3, and with the other Northeast Asian economies in Figure 2.6.

Table 2.2 China's energy consumption breakdown, 1980–2004 (per cent)

Year	Coal	Petroleum	Natural gas	Hydro- and other power	Total
1980	72.2	20.7	3.1	4.0	100
1985	75.8	17.1	2.2	4.9	100
1990	76.2	16.6	2.1	5.1	100
1995	74.6	17.5	1.8	6.1	100
2000	66.1	24.6	2.5	6.8	100
2004	67.7	22.7	2.6	7.0	100

Source: China Statistical Summary and Energy Research Institute.

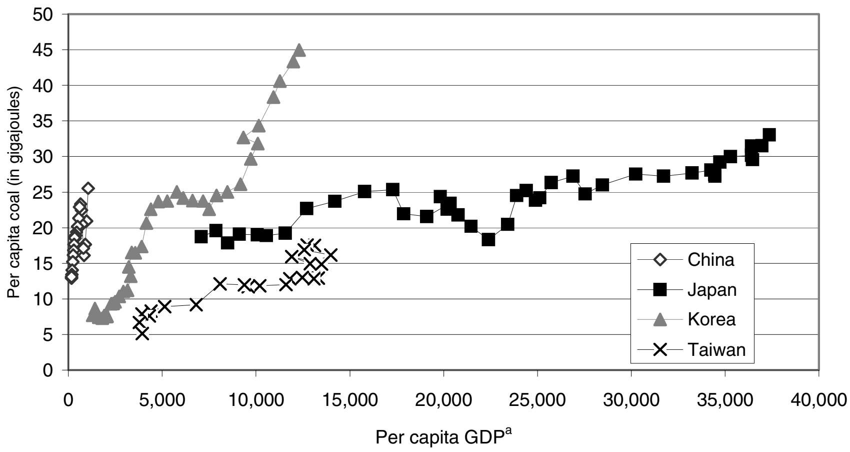
Table 2.3 Japan's primary energy supply, 1955–90 (per cent)

Year	Coal	Petroleum	Natural gas	Hydro-power	Nuclear	Other	Total	Imports
1955	48.3	16.7	0.4	27.1	0.0	7.6	100	20.7
1960	44.2	33.4	1.0	16.6	0.0	4.9	100	46.0
1965	29.3	55.9	1.3	11.8	0.0	1.7	100	74.0
1970	21.3	69.9	1.3	6.0	0.4	1.1	100	90.6
1975	17.4	71.6	2.7	5.6	1.6	1.0	100	93.7
1980	17.6	64.7	6.4	5.4	4.9	1.1	100	88.9
1985	19.6	55.4	9.7	4.9	9.1	1.3	100	84.2
1990	17.3	56.6	10.6	4.4	9.8	1.4	100	86.8

Source: Table 2 from Murota and Yano (1993).

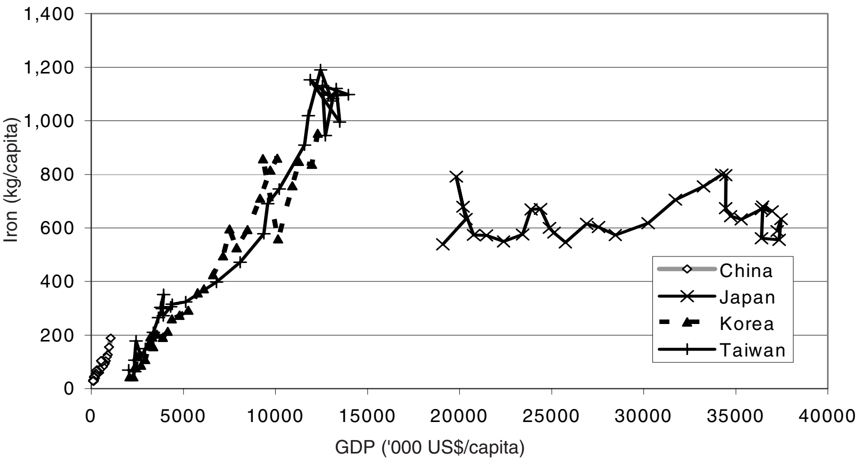
While there are important similarities in the relationship between resource use and economic growth across the Northeast Asian economies, there are also differences. Figure 2.7 reveals higher income elasticity in metals demand in Taiwan and Korea than in Japan. The data suggest that China so far is following a Taiwan–Korea pattern for aluminium demand (not shown), but an intermediate position for steel. The difference between Taiwan–Korea and Japan seems to derive to a considerable extent from the much greater international orientation of Taiwan and Korea: the continued strong growth in exports, and their size relative to GDP, together with the considerable metals content of those exports, has

Figure 2.6 China's coal consumption in comparison with East Asia economies



Note: a Based on national accounts GDP at 2000 constant US dollar price.
Source: Authors' calculations.

Figure 2.7 Metal demand and economic growth in Northeast Asia (using purchasing power parity exchange rates for China)

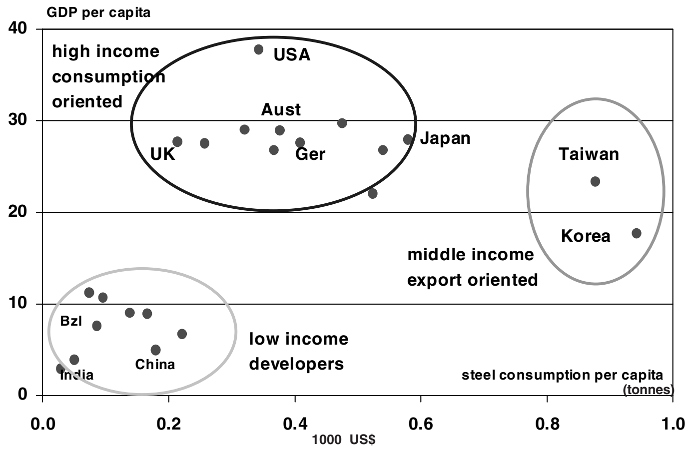


Source: Macquarie Research Metals and Mining (2004).

maintained strong demand growth for metals through the period when services have come to occupy a large place in domestic demand growth.

On a global scale, it is Taiwan and Korea rather than Japan that are distinctive in the relationship between incomes and resource use. Figure 2.8 reveals that Japanese per capita steel consumption is high by the standards of other developed countries, but much less than

Figure 2.8 Steel consumption and level of development (national accounts GDP)



Source: Westpac.

that of Taiwan and Korea. Japan's per capita electricity consumption is close to the general relationship between consumption and per capita GDP (Figure 2.9).

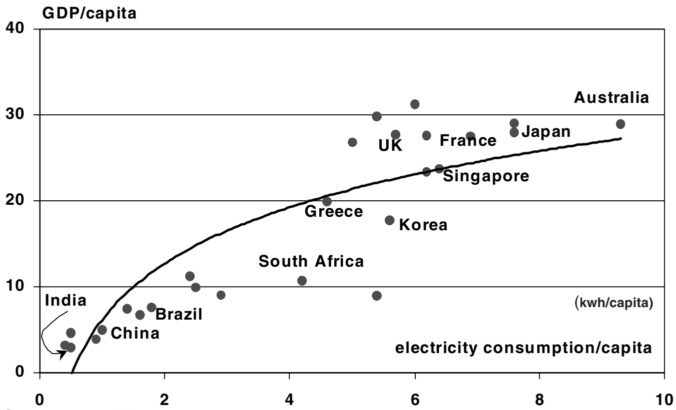
However one looks at the comparative data, the expectation must be that the rapid growth in Chinese demand for metals and energy will continue as incomes rise in the decades ahead. The analysis in the following section suggests that the Chinese experience may contain some of the elements of that of Taiwan and Korea, in which economic development was associated with exceptional growth in demand for resources.

A further clue to likely future growth in demand for energy and metals can be found in analysis of the typical relationship between urbanisation and resource consumption. The extent of urbanisation in China (defined as the proportion of the population living in urban areas) is low for China's income levels (Figure 2.10). This is to a considerable extent the result of controls on internal migration. These have loosened and urban growth has been rapid in the reform period. The urban population more than trebled, from 172 million to 524 million, between 1978 and 2003. Continued rapid urbanisation can be expected to underpin demand for resources in the decades ahead.

Determinants of resource intensity of Chinese economic activity

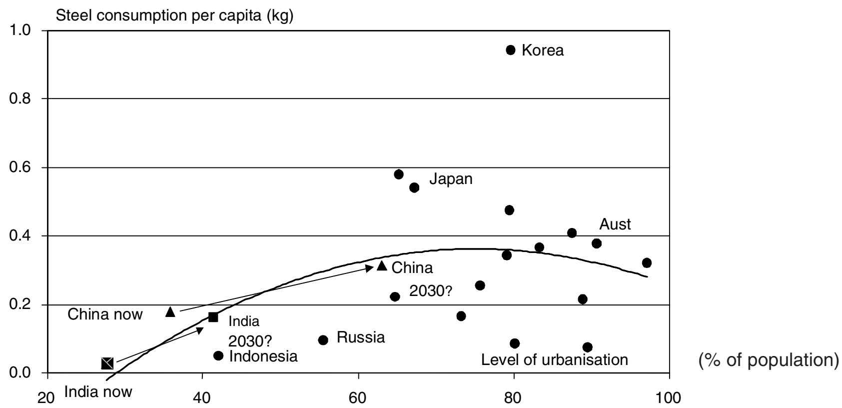
We have noted that per capita resource use in China has been showing some similarity to that of other Northeast Asian economies in their periods of rapid growth. What factors will contribute to similarities and differences in future?

Figure 2.9 Electricity consumption and level of development (national accounts GDP) ('000 USD)



Source: Westpac.

Figure 2.10 Steel consumption and urbanisation, 2002



Source: Westpac.

The legacy of central planning and price distortion has provided some artificial stimulus to metals and energy consumption. This has been largely unwound over the past two decades of reform, but energy prices remain artificially low, and the degree of distortion has increased through the recent period of rising world oil prices. Low energy prices have provided minor stimulation to the use of metals through the encouragement that they have provided to consumption of metallic consumer durables, first of all automobiles. The likely unwinding of remaining price distortions in the years ahead will dampen energy consumption growth.

The unwinding through reform of artificial constraints on rural to urban migration will be a significant factor in the opposite direction, encouraging the use of both energy and metals.

Chinese input–output tables reveal a much higher direct and indirect metal content in investment than in other components of GDP (Table 2.4). By 2000, the metal product contribution to each unit of investment output was twice as high as the metals component of total GDP. The coal and petroleum content of investment was also much higher than of GDP.

The extraordinarily high investment share in Chinese growth is therefore highly stimulative to metals consumption. The investment share in GDP is higher in Northeast Asia (and in Singapore) than in any other economies, now or in any historical period. It is already higher in China than at any stage of development of any other Northeast Asian economy. Investment continues to grow more rapidly than total output. While it is not possible for the investment share of GDP to rise without limit, it will remain extraordinarily high, and probably above the unprecedented levels reported for 2004 in Figure 2.11 (Garnaut and Huang 2005).

The unusual level of and growth in investment has contributed to per capita consumption of fossil fuels and especially metals being high for China's income. It will help to underpin high levels of resources use for a long period into the future, although it will not for much longer be a separate source of rising consumption.

We have commented that the high export orientation of Taiwan and Korea together with their strong and strengthening comparative advantage in metal manufactures has contributed to the continued rapid growth in per capita consumption of metals, beyond the income levels when per capita metals consumption began to slow in Japan. The metals value added in Chinese exports is currently little higher than in total GDP, because China's comparative advantage remains strong in labour-intensive products. But this comparative advantage is evolving into more capital-intensive and therefore more metals-intensive products as rapid growth continues and Chinese incomes rise.

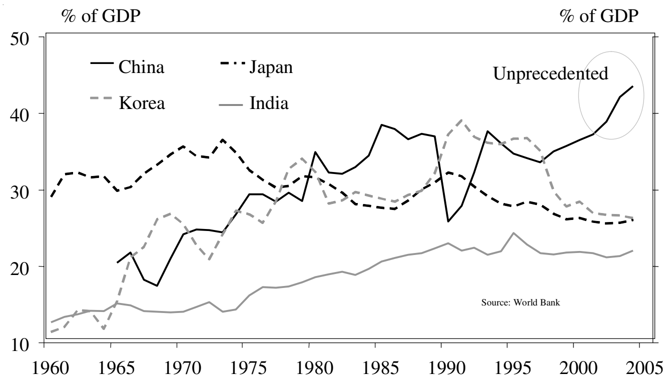
Chinese export orientation is and will continue to be stronger than Japanese, but is less pronounced than in Taiwan or Korea. The 'export factor', to the extent that it is influential

Table 2.4 China: shares of resource sectors in total investments, exports and outputs (per cent)

Sector	Investment		Exports		Total output	
	1997	2000	1997	2000	1997	2000
Coal and petroleum	2.09	5.58	1.51	1.92	1.91	3.35
Metal product	11.29	13.56	6.94	7.81	6.25	6.28

Source: Calculated using the Input-Output Tables of China for 1997 and 2000.

Figure 2.11 Long run investment shares of GDP, 1960–2005



Source: Calculated using data from Garnaut and Huang (2005) and the World Bank.

in a mix of factors, will therefore tend to place China on a path of metals consumption growth somewhere between the high levels of Japan and the extraordinarily high levels of other Northeast Asian economies.

Who will fuel China?

While there are risks to the sustainability of rapid economic growth in China, there is a reasonable prospect that growth will proceed at average rates near the average for the past quarter century (9 per cent per annum) for several decades (Garnaut 2005).

The above analysis suggests that China's per capita rates of consumption of energy and metals will have approached the average for the developed world by the end of that time. In the absence of major changes in behaviour in response to higher prices or realisation of negative environmental effects, the expansion in China's own consumption will have raised global energy demand by something like 40 per cent of today's level. With the same qualifications about responses to price, on the expectation that its pattern of growth in demand for metals will be somewhere between that of Japan and Korea, China's proportionate impact on global metals markets will be somewhat larger. At its peak, the trend increase in Chinese demand may be augmenting global energy demand by about 3 per cent per annum.

Where would the supplies come from and what would be the nature of the impact on global markets?

We have drawn on historical analogy in this paper, and we will do so again. Given the slowdown in growth in established developed economies, even this rate of growth in Chinese demand would not push the total rate of increase in global energy consumption to the high levels of the last decade of rapid economic growth in Japan, 1963–73. Those high rates of increase in energy demand were supported by the low-cost expansion of petroleum production. There was some tightening in oil markets over time, but prices did not move until the political shocks of 1973.

The long lead times in exploration and development mean that we know now that there are no opportunities in the decade ahead painlessly to expand global oil expansion in the manner of the years of rapid growth in Japan. This time, the international market response will be more varied and complex. Prices will rise above the average levels of the past two decades. This will lead to economisation in the use of oil, as did the high prices in the decade after 1973. It will lead to more rapid development of the many alternative sources of energy all over the world. Amongst much else, there will be heavy investment in expanding production from China's own coal reserves, and in nuclear energy generation in China.

The increases over the past two years have already taken oil prices to levels where economisation in the use of energy occurs at a rate that is evident in the global numbers. Prices have already reached levels at which investments in many alternative energy sources are profitable. The increases over this period may turn out to be unnecessarily large or small, but there are reasonable prospects that we have seen most of the necessary adjustment in relative prices. For the global economy, the greatest costs of higher prices are borne in the adjustment to change, and we are in the process now of bearing a major part of those costs.

The experience of the 1960s and early 1970, covering the last decade of rapid economic growth in Japan, may provide a closer guide to prospective global market developments for metals than for energy. The strong growth in postwar demand led to average real prices that were twice as high for most metals as the average during the long stagnation from 1914 until the years of recovery from the Second World War. This induced steadily expanding supplies, including from countries which had hitherto played marginal roles in global markets. New forms of long-term contracts and project finance underpinned the development of major new sources of coal and alumina in Australia and iron ore in Australia and Brazil.

The big lift over the past two years has taken copper prices to just 10 per cent below the high averages of the 1960s and early 1970s. There have also been large price increases for other metals – some a bit more than for copper, some a bit less. For all metals, there have been large increases in investment in exploration and mine development, and increasing output from established mines. As in the 1960s, new institutional arrangements (the Chinese multinational corporation) and new suppliers (Papua New Guinea for nickel and several African and Latin American and Central Asian countries for a wide range of metals) are the focus of large investments. As with oil, much and probably most of the price adjustment has already occurred, and there is no reason to doubt global markets' capacity to meet the new demands on them.

We should end with one note of caution. China's rapid growth involves economic, social and political change on a scale that is unprecedented in world history. It is unlikely to proceed over decades without bumps in the road, and an occasional dead end and detour. With China in a few decades consuming annually as many resource-based products from world markets as the whole of the currently developed world, the rest of the world will feel every bump through energy and metals as well as other markets.

Notes

We thank Shiro Armstrong and Sheng Yu for their assistance in processing the data used in the paper.

1 Some of the concepts introduced in this section are explained in more detail in Garnaut and Clunies Ross (1983), especially Chapter 3.

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3 International Supplies of Energy for China: Developments and Prospects

Tony Beck and Malcolm Gray

Introduction

As rapid economic growth continues, China's energy requirements are changing the shape of regional and international energy markets, resulting in both new pressures and new opportunities. Like many other countries, China is facing the challenge of finding secure and sustainable sources of energy to support its growing economy. While the physical reserves of the main energy commodities – oil, coal, gas and uranium – are generally adequate to support growing global demand, concerns about cost, supply security and environmental sustainability are becoming more pressing.

The challenge for China is also the global challenge. In this paper we explore the developments and prospects for international supplies of energy to China, taking each energy commodity in turn, giving particular attention to the emerging market for natural gas.

Climate change

Apart from supply and price issues associated with future energy supplies, there is growing concern about greenhouse gas emissions and the impact of climate change. Both the producers and consumers of fossil fuels are increasingly aware of the need to reduce emissions. The most concerted international effort to manage global emissions is the Kyoto Protocol, which sets legally binding emission targets for developed country members alongside various programs and mechanisms to assist with emission management in developing countries.

An important Kyoto mechanism which China has demonstrated a propensity to utilise is the Clean Development Mechanism (CDM). The CDM allows annex II countries (rich countries) to generate tradeable emission credits from emission reduction projects in non-annex II countries (such as China). Such market mechanisms may be the forerunner to a global emissions market that will place a price on emissions and provide market incentives to improve energy efficiency and control emissions. If such a market develops it will add to the cost of fossil fuels, especially emission-intensive fuels such as coal, and encourage substitution by cleaner energy fuels such as natural gas, hydroelectricity and nuclear energy.

China faces a challenging time over the next 25 years as it tries to meet its growing energy demand in a secure and sustainable manner. If current policies continue, the world's energy needs will be almost 60 per cent higher in 2030 than they are now, with China accounting for over 20 per cent of the growth. Fossil fuels will continue to dominate the energy mix, meeting most of the increase in overall energy use both within China and at the global level (IEA 2004).

Given this continuing dependence on fossil fuels, concerns about energy security (especially related to oil) and environmental sustainability (especially related to coal) are expected to grow. Even without these concerns it will be a challenge to finance and build the huge amounts of new infrastructure needed to extract, transport and utilise the energy commodities involved.

China is already an important player in the market for oil. In economic terms, China is a 'large country' with growing Chinese demand leading to a tightening of international supplies and upward pressures on prices. This influence will continue to grow over the period to 2030 not only in the oil market but in energy markets generally. China's share of world primary energy demand will increase from 12 per cent to 16 per cent, its share of world oil demand will increase from 7 per cent to 11 per cent, and it will continue to be the world's largest coal market. This means that China will account for 21 per cent of world growth in primary energy demand, 53 per cent of incremental coal demand and 19 per cent of incremental oil demand over the period (IEA 2004).

With this growing share of energy demand will come increasing market influence. As with oil, China will need to anticipate that its growing demand will put upward price pressure on most energy commodities.

Coal

The dominant feature of China's energy market (other than its sheer size) is the abundance of domestically available coal. For the last two decades around 70 per cent of China's energy consumption has been fuelled by coal. China is the world's largest coal producer and the second largest coal exporter after Australia. Such abundant domestic supplies of coal have dampened the impact of China's rapid industrialisation on international energy markets. However this situation began to change in the last years of the 20th century as energy fuels other than coal, as well as imported 'clean coal', became more significant in China. Not only is China's energy demand growing rapidly, but international energy markets are becoming more responsive to developments in China.

The global situation

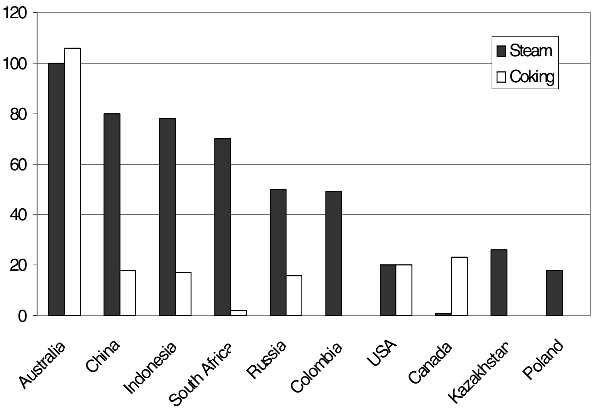
Globally, coal accounts for almost a quarter of the world's primary commercial energy consumption and is expected to remain a major contributor until at least the middle of the century.

Over 4 billion tons of coal is currently produced (a 38 per cent increase over the past 20 years). Global coal production is expected to reach 7 billion tons in 2030, with China accounting for around half the increase. Steam coal production is projected to account for around 5.2 billion tons, with coking coal accounting for 624 million tons and brown coal 1.2 billion tons (WCI 2005). Production is not dominated by any one region, with the top five producers being China, the United States, India, Australia and South Africa. Growth in coal production has been greatest in Asia, while Europe has actually seen a decline in production.

Much of global coal production is used in the country in which it was produced, with only around 18 per cent of hard coal production destined for the international market (the main exporters being Australia, China, Indonesia, South Africa, Russia and Columbia, as shown in Figure 3.1).

With the necessary investment in mining and transport systems, China could continue to be the largest producer and a major exporter of coal for the foreseeable future. International Energy Agency (IEA) projections show that coal production in China could increase from 1,389 megatons (Mt) in 2002 to 2,490 Mt in 2030 given an investment of $130 billion. Exports would increase steadily to around 130 Mt in 2030, with the main focus on Asian markets.

Figure 3.1 Major coal exporters (Mt)



Source: IEA (2004).

Demand

Coal's vital role in power generation is set to continue. It currently fuels 39 per cent of the world's electricity and this proportion is expected to remain at similar levels over the next 30 years. Consumption of steam coal is projected to grow by 1.5 per cent per year between 2002 and 2030 while demand for coking coal in iron and steel production is set to increase by 0.9 per cent per year over this period.

The biggest market for coal is Asia, which currently accounts for 54 per cent of global coal consumption (China being responsible for a significant proportion of this). Many countries do not have natural energy resources sufficient to cover their energy needs, and therefore need to import energy to help meet their requirements. Japan, Taiwan and South Korea, for example, import significant quantities of steam coal for electricity generation and coking coal for steel production.

Coal will continue to play a key role in the world's energy mix, with demand in certain regions set to grow rapidly. Growth in both the steam and coking coal markets will be strongest in developing Asian countries, where demand for electricity and the need for steel in construction, car production and household appliances will increase as incomes rise (WCI 2005).

Trade

Because of the relatively high transport costs associated with coal (due to coal's very high ratio of mass and volume to value) coal producers generally aim to satiate domestic markets before turning to export markets. China's export surplus is therefore uncertain and could become a deficit if domestic supply growth fails to meet growth in demand. Under these circumstances China may need to seek additional supply from the global coal market. While coal is available from a range of countries, transportation costs are sufficiently high that competitiveness demands relatively local suppliers. The best placed countries to supply China with coal are those in the Asia Pacific region (including Australia and Indonesia).

However it is not just a lack of indigenous coal supplies that prompts countries to import coal; obtaining specific types of coal is also important. Major coal producers such as China, the United States and India, for example, import quantities of coal for quality, logistical and environmental reasons.

Coal is traded all over the world, with coal shipped long distances by sea to reach markets. Over the last 20 years, seaborne trade in steam coal has increased on average by about 8 per cent each year, while seaborne coking coal trade has increased by 2 per cent a year. Overall international trade in coal reached 718 Mt in 2003; while this is a significant amount of coal, it still accounts for only about 18 per cent of total coal consumed.

Owing to the large share of total delivered price accruing to transportation costs, international trade in coal is divided into two regional markets: the Atlantic and the Pacific. The (smaller) Atlantic market is made up of importing countries in western Europe, notably the United Kingdom, Germany and Spain, while the (larger) Pacific market consists of developing and Organisation for Economic Co-operation and Development Asian importers, notably Japan, Korea and Taiwan. The Pacific market currently accounts for about 60 per cent of world steam coal trade. The two regional markets tend to overlap when coal prices are high (i.e. when transportation costs are lower relative to total cost) and supplies plentiful, with South Africa acting as a natural point of convergence between the two markets (WCI 2005).

The IEA (2004) projects that the volume of hard coal traded internationally will increase steadily to 2030, driven mainly by the continuing industrialisation of developing Asian countries and the decline of coal mining in Europe. Total trade is expected to increase to 1,063 Mt in 2030. Projections for patterns of trade suggest that there will be an increase in exports from northwest China to Asia and imports to southeast China (IEA 2004).

International market pressures

The dynamic impacts of China's growth on international coal markets are complex and contradictory. As China grows, both demand for and production of coal rise. China's production of coal is projected to be sufficient for China to remain a major exporter; however, its demand is shifting away from brown coal toward clean coal, which China imports. Growth in industrial, construction and manufacturing industries is driving demand for coking coal, and steam coal demand is driven more generally by increased energy demands. However improving incomes and urbanisation, and increased awareness of environmental issues, are driving demand away from coal as a primary source of energy.

Oil

Oil, in contrast to coal, is not overwhelmingly abundant in China. It has therefore historically not been as dominant as coal. However the importance of oil in China has increased significantly over the last five years, largely driven by growth in China's transport industry. As China begins to require higher proportions of imported oil, the international and Chinese energy markets are becoming more entwined. Given the vastness of China's energy demand, the international oil market is highly responsive to changes in China (the world's second largest consuming nation); given China's increasing dependence on imported oil, it is increasingly vulnerable to changes in the international market.

Over the last two years the oil market has entered a period of instability and uncertainty which may signal a fundamental change in the global oil market. Recent increases in energy prices, particularly for oil, could well be indicative of energy markets in the future because the global distribution of oil reserves and production capacity indicate that the market share (and corresponding capacity to influence market prices) enjoyed by members of the Organization of the Petroleum Exporting Countries (OPEC), particularly Middle Eastern producers, will grow over time. Concerns regarding the vulnerability of oil production and transport are also likely to continue, especially as signs of political stability in the key producing regions remain unforthcoming.

Consequently, China is already looking to diversify oil sources as a primary strategy to improve supply security. Two countries that are likely to become more important as suppliers of energy for China in the future are Russia, with its capacity to supply China by pipeline from its Siberian fields, and Canada, with its vast reserves of oil in the form of oil sands.

Demand

The main oil consumers continue to be the advanced economies – the United States, Europe and Japan – which together consume about half of the annual oil output. But consumption in the major developing economies has been growing at a faster pace as their economies grow rapidly and their use of energy, including oil, in the transport industry and residential sectors expands (IMF 2005).

China's consumption of petroleum products in 2003 was 5.7 million barrels per day (mbd), surpassing that of Japan for the first time and making it the second largest national consumer. The IEA projects that China's oil demand will reach 13.3 mbd by 2030, with import demand of almost 10 mbd, as much as the United States imports today. As the source of around 40 per cent of world oil demand growth over the past four years, Chinese oil demand already is a significant factor in world oil markets and this is expected to continue.

Supply

Proven oil reserves are sufficient to meet world demand at current levels for over 40 years. However, this figure significantly underestimates the volume of oil that may be eventually recoverable with improved technology or at higher oil prices. On this basis the IEA estimates that remaining oil resources could cover 70 years of average annual consumption between 2003 and 2030. Table 3.1 shows the distribution of world oil reserves.

In considering the future oil supply situation it is useful to differentiate between OPEC producers[1] and non-OPEC producers.

Table 3.1 Proven world oil reserves at the end of 2004 (trillion barrels)

Region	Amount
Middle East	733.9
Europe and Eurasia	139.2
Africa	112.2
South and Central America	101.2
North America	61.0
Asia Pacific	41.1

Source: BP Statistical Review of World Energy 2005.

OPEC producers

OPEC countries account for about 70 per cent of proven oil reserves; they currently produce 40 per cent of total world output and supply about 55 per cent of oil traded internationally. Their output share was around 50 per cent in the 1970s but the oil shocks of that era reduced demand; in the early 1980s, OPEC, in particular Saudi Arabia, responded by cutting production to stabilise prices.

Over the last two years spare production capacity has been eroded by surging oil demand. OPEC now produces close to its capacity, which is slightly lower than it was in the mid-1970s.

In the short term, to about 2010, the call on OPEC is expected to stay roughly unchanged at current levels of 32 mbd. The call on OPEC is projected to grow to about 61–74 mbd by 2030, implying a more than doubling of OPEC oil production. This would require a significant amount of investment, particularly by the Middle East OPEC members, which have the largest oil reserves (IMF 2005).

However, OPEC may choose to limit production to benefit from the resulting higher prices. The International Monetary Fund (IMF) has conducted a modelling study of OPEC responses to demand pressures (IMF 2005). It concludes that if OPEC bases its production decisions on maximising the net present value of future profits then OPEC's optimal market share will be between 41 per cent and 46 per cent. This corresponds to an OPEC output of 52–59 mbd, well below the initial hypothetical call on OPEC of 61–74 mbd referred to above. The IMF concludes that once non-OPEC production peaks, there will probably be a strong upward pressure on prices. Based on the above scenario, oil prices expressed in 2003 dollars would range between $39 and $56 a barrel in 2030, with the shortfall in OPEC production of 12.5 mbd offset by reduced oil demand (8.5 mbd) and higher non-OPEC supply (around 4 mbd).

Thus, while long run forecasts of oil supply and demand are subject to substantial uncertainties, there is a strong likelihood that the oil market will continue to be tight into the future, leaving China, and other major oil importing countries, facing increasing and possibly volatile prices and a growing dependence on Middle East sources.

Non-OPEC producers

Expansion of non-OPEC production will be constrained by the decline of many traditional fields and by limited and relatively high cost reserves. Additional capacity is planned in Africa, the Commonwealth of Independent States (CIS) and Latin America in the medium term. However, it is not clear if non-OPEC production can be sustained in the long run (IMF 2005).

The IEA expects non-OPEC oil production to rise from 50 mbd in 2004 to 57 mbd in 2010 and stay broadly constant thereafter. The US Department of Energy (DOE) anticipates more growth in non-OPEC production, with output increasing from 50 mbd in 2004 to 56 mbd in 2010 and about 65 mbd in 2025.

Even if the more optimistic DOE projection eventuates, reliance on the OPEC supply to meet growing demand will increase over time, giving OPEC increased power in the market to manage both volume and price.

New oil sources

About half of China's oil imports come from the Middle East, mainly Saudi Arabia, Oman and Iran. In order to secure future supplies, Chinese national oil companies have been investing in exploration and production in Russia, the Caspian countries, Indonesia, Africa and Latin America.

Apart from traditional OPEC sources there are two significant new sources that will be prospective for China: Russia and Canada.

The Russian Federation has the seventh largest proven conventional oil reserves in the world and is the largest non-OPEC producer (BP 2004). Various sources estimate Russian proven oil reserves at 60–69 billion barrels (IEA 2004), equivalent to 5 per cent of total proven reserves and around a quarter of Saudi Arabian reserves (the world's largest). Adding probable reserves (those which have less probability of being produced profitably) brings the estimated reserves to 116 billion barrels, with West Siberia accounting for about 74 per cent and the rest split among fields to the east and west of this region (IEA 2004).

Of interest to China is the expectation that West Siberia's share of reserves will decline while East Siberia's share is expected to increase significantly. These resources are not expected to come into production until the second decade of the century (Kim 2005).

Since 2000 Russia has been increasing its oil output to become the world's largest crude oil producer and the second largest exporter. This has important implications for supply security and provides some scope for supply diversification. Russian oil production is projected to continue to grow to 2020, although at a slower rate than over the period 1999–2003. Production is expected to reach 10.4 mbd in 2010 and 10.7 mbd in 2020, with non-CIS exports stabilising at around 6–7 mbd. These projections by the IEA and the Russian government assume an easing of the current high prices. If high world prices were to be sustained for a long period, additional investment could lead to a greater expansion in Russian oil output and exports.

The Sino-Russian pipeline currently planned will be an important initial link to Russian supplies. Up to 2 mbd could eventually flow from Russia to China through this and other pipelines (IEA 2004).

An important future role could be played by non-conventional oil sources, especially Canada's oil sands, which make up about half of the proven reserves of non-OPEC countries (if non-conventional oil is taken into account) and 14 per cent of total proven reserves. The production cost of such oil has fallen considerably over the past decades, in many areas to about $10–15 a barrel including producer taxes (National Energy Board 2004). Potential output growth from this source is very high, but achieving high output from the fields is a complex and time-consuming task since significant investment in extracting and refining infrastructure is needed, together with large quantities of water and natural gas (IMF 2005). The IEA estimates that it takes five to seven years for investment in oil sands projects to come on stream, and therefore the speed of price responsiveness may be slow.

Uranium

A number of countries are showing renewed interest in nuclear power as electricity demand and concern about greenhouse gases from fossil fuel grow. China has a growing nuclear power sector that is set to play an even greater role in national electricity generation in the decades ahead, especially in the coastal areas which are remote from coalfields and where the economy is developing rapidly.

China also has a well-developed uranium mining sector that currently supplies most of China's uranium requirements. While there is scope to expand domestic production, increased imports of uranium may be required in the future.

Supply

Reserves of uranium are widely dispersed. Globally, important reserves can be found particularly in Australia, Kazakhstan, Canada, South Africa and Namibia.

Changes in costs or prices, or further exploration, may alter measured resource figures markedly. Thus, for any mineral, including uranium, any predictions of the future availability which are based on current cost and price data and current geological knowledge are likely to be conservative.

With those major qualifications, Table 3.2 gives an indication of known uranium resources. It can be seen that Australia has a substantial part (about 30 per cent) of the world's low-cost uranium, Kazakhstan 17 per cent, and Canada 12 per cent.

The Nuclear Energy Agency (NEA) and International Atomic Energy Agency have published figures indicating that total reserves could be significantly greater than the economic reserves listed above (see OECD et al. 2005). If conventional resources are considered, estimated reserves total 9.7 million tons (beyond the 3.5 Mt known economic resources), which is some 140 years supply at today's rate of consumption. This still ignores the technological factor mentioned above.

Current usage of uranium is about 68,000 tons per year. Thus the world's present measured resources of uranium in the lower cost category (3.5 Mt), used only in conventional reactors, are enough to last for some 50 years. This represents a higher level of assured resources than is normal for most minerals. On the basis of present geological knowledge,

Table 3.2 Known recoverable resources of uranium[a]

	Amount (tons)	Share of world supply (%)
Australia	1,074,000	30
Kazakhstan	622,000	17
Canada	439,000	12
South Africa	298,000	8
Namibia	213,000	6
Brazil	143,000	4
Russian Federation	158,000	4
United States	102,000	3
Uzbekistan	93,000	3
World total	3,537,000	

Notes: a Reasonably assured resources plus inferred resources.
Source: OECD et al. (2005).

further exploration and higher prices will certainly yield further resources as present ones are used up (UIC 2005).

Widespread use of fast breeder reactors could increase the utilisation of uranium 60-fold or more. This type of reactor can be started up on plutonium derived from conventional reactors and operated in closed circuit with its reprocessing plant. Such a reactor, supplied with natural uranium for its 'fertile blanket', can be operated so that each ton of ore yields 60 times more energy than in a conventional reactor.

Nuclear weapons as a source of fuel

An important source of nuclear fuel is the world's nuclear weapon stockpiles. Since 1987 the United States and countries of the former Union of Soviet Socialist Republics (USSR) have signed a series of disarmament treaties to reduce the nuclear arsenals of the signatory countries by approximately 80 per cent.

The weapons contain a great deal of uranium enriched to over 90 per cent U-235 (about 25 times the proportion in reactor fuel). Some weapons have plutonium-239, which can be used in diluted form in either conventional or fast breeder reactors. From 2000, the dilution of 30 tons of military high-enriched uranium is displacing about 9,000 tons of uranium oxide per year from mines, which represents about 11 per cent of the world's reactor requirements.

Reactor fuel requirements

The world's power reactors, with combined capacity of some 365 gigawatt hours (GWh), require about 68,000 tons of uranium from mines (or the equivalent from stockpiles) each year. While this capacity is being run more productively, with higher capacity factors and reactor power levels, the uranium fuel requirement is increasing, but not necessarily at the same rate. The factors increasing fuel demand are offset by a trend for higher burn-up of fuel and other efficiencies, so demand is steady. Reducing the tails assay in enrichment reduces the amount of natural uranium required for a given amount of fuel. Reprocessing of spent fuel from conventional light water reactors also utilises present resources more efficiently, by a factor of about 1.3 overall. Over the 18 years to 1993, the electricity generated by nuclear power increased 5.5-fold while uranium consumption increased only just over threefold). It is likely that the annual uranium demand will grow only slightly to 2010.

Gas

Gas is a fuel that is becoming increasingly sought after for a number of reasons. It is a relatively clean fuel in terms of both local pollutants and levels of greenhouse gases emitted. It has lower capital costs and greater operational flexibility than coal. It can help to diversify energy sources and enhance security, especially as there are a number of prospective supply sources around the Asia Pacific region. However substitution toward gas is constrained by large initial capital requirements, both at the export and import ends and at the transportation stage.

Gas markets are currently in the early stages of development, having been dominated to date by long-term bilateral contracts. New, more flexible market arrangements are only now being established to facilitate supply and demand matching over shorter-term fluctuations. To secure trading relationships, investors and their financiers will require clear, predictable and transparent policy and legal frameworks for investment protection and taxation. Also important will be effective training, education and immigration initiatives to cope with capacity and skill shortages. Successfully addressing these market and infrastructure issues can potentially facilitate the take-off of gas as a major substitute for other energy fuels in China and the Asia Pacific region.

Demand

Recent work by APEC (2005) has highlighted the importance of gas in meeting the future energy needs of the Asia Pacific region:

- *Energy security.* A major oil supply disruption is not expected but, if one did occur, it would have severe economic, social and environmental consequences for most energy importing economies – hence the focus on energy supply options such as natural gas. This is a major reason why the Asia-Pacific Economic Cooperation (APEC) forum, at the highest political level, supports the increased utilisation of natural gas. For many economies, indigenous natural gas will not solve supply–demand imbalances. They will have to rely increasingly on imported gas in the future, just as many rely today on imported oil.
- *Climate change.* There is now little dispute about the science of climate change and the effects of greenhouse gas build-up in the atmosphere. While dispute continues over the best way of dealing with the problem, it is now almost universally accepted that greenhouse gas emissions from energy production should be minimised in the interests of tempering the effects of climate change. It might be necessary to reduce greenhouse gas emissions to 40–60 per cent below 1990 levels to achieve long-term climatic stability. Increased utilisation of natural gas will have an important part to play in this.
- *Natural gas and sustainability.* Taking account of the economic, energy security and environmental implications of energy production and utilisation, APEC policymakers have expressed a clear preference for natural gas as the fuel to lead their economies in the direction of more sustainable energy systems for at least the next quarter century.

Reflecting these attributes, natural gas already makes a significant contribution to primary energy consumption in Europe (approaching 40 per cent) and North America (25 per cent) (Symon 2005). It is expected that worldwide consumption of natural gas will almost double by 2030, overtaking that of coal within the next decade (IEA 2004). Most of the demand growth will be for use in power stations, but gas-to-liquid processing will also grow in importance.

In Asia, however, natural gas supply has been limited by the distance of many demand centres from major gas fields. Long-distance pipelines have not been practical and liquified natural gas (LNG) has been an expensive option. Just 10 per cent of Asia's primary energy consumption is met by natural gas, although LNG business in the Asia Pacific represents 70 per cent of the world LNG trade (Symon 2005). This situation is likely to change with growing demand in a number of Asia Pacific countries, including China, Taiwan, Korea, the United States, Mexico, Singapore, Thailand and Japan.

Supply

Gas reserves are sufficient to meet the projected increase in global demand but significant investment will be needed to bring it to market.

Production will increase most in Russia and the Middle East, which between them hold most of the world's proven gas reserves (see Table 3.3). However other potential supply sources include Australia, Indonesia, Malaysia, Canada and Brunei Darussalam.

As with oil, Russia is likely to be an important non-OPEC source of gas. Russian gas reserves rival those of the Middle East; at the end of 2003 they amounted to 47 trillion cubic metres or around 27 per cent of total proven reserves in the world.

Table 3.3 World gas reserves (trillion cubic metres)

Region	Amount
Middle East	71.72
Europe and Eurasia	82.38
Africa	13.78
Asia Pacific	13.47
North America	7.31
South and Central America	7.19

Source: BP (2004).

Three-quarters of Russia's gas reserves and a similar proportion of production are located in West Siberia, although it is expected that West Siberia's share of total gas production will decline over the medium to long term. The development of gas fields in European Russia, the Yamal Peninsula and, importantly for China, East Siberia and the Far East is expected to become a priority in the next decade.

As with gas developments elsewhere, the expansion of Russian gas production is critically dependent on attracting sufficient investment to maintain and expand the required exploration, production and distribution systems. Russia's gas sector is dominated by Gazprom, the largest gas-producing company in the world, which holds licences for fields containing more than 55 per cent of Russia's proven reserves and produces 86 per cent of Russia's gas. The company needs to make significant investments if it is to maintain current levels of production in the medium to long term as production from mature gas fields declines and infrastructure degrades (Kim 2005). Beyond this, the development cost of new, large gas fields (all of which are located in the Arctic zone) is estimated at \$35–40 billion (OECD 2004).

Given the required levels of investment, gas output is expected to expand from around 634 billion cubic metres (bcm) in 2004 to 655 bcm in 2010 and 801 bcm in 2020 (IEA 2004).

East Siberia and the Far East are the major potential sources of gas for China. Together they are scheduled to produce up to 50 bcm of gas a year by 2010 and up to 110 bcm by 2020 (Government of the Russian Federation 2003). A large-scale project has been proposed for a pipeline from East Siberia to Dalian and Beijing. However, Gazprom (which was appointed by the Russian Government as a coordinator of gas developments in East Siberia and the Far East) is reportedly prioritising Sakhalin projects. Japan is likely to be the major importer for Sakhalin gas, although it could also be a source for North China (Kim 2005).

Need for infrastructure investment

A key feature of the natural gas trade is the huge investment necessary to facilitate that trade, whether it be LNG systems or large-scale pipelines. The IEA estimates that the cumulative investment needs for global gas-supply infrastructure to 2030 will amount to \$2.7 trillion, about \$100 billion per year.

Associated with this investment are long lead times in exploration and development and in establishing transport systems and complex commercial arrangements. Major investment is required in both exporting and importing countries and in the linking transport system.

In the APEC gas importing economies, there is growing recognition of the importance of infrastructure investment. China is moving fast to install LNG and pipeline infrastructure. In North America, there are plans for more than 50 LNG receiving terminals (although, at least in the United States, public acceptance may be more important than market demand in determining how many terminals are ultimately built). Thailand is in the process of building new gas trunklines and is evaluating LNG, as are Singapore and New Zealand (APEC 2005).

The Asia Pacific market

It has been said that the LNG trade in the Asia Pacific region is 'poised for take off'. There is excellent supply and demand potential and there are advantages in terms of energy security and reducing environmental damage. However, the scale of the infrastructure investment needed and the relative immaturity of the market mean that progress is not straightforward. Commercial and regulatory processes across the region need to be addressed to ensure that they facilitate the development of the trade rather than impede it.

The ResourcesLaw (2004) report to the APEC Energy Working Group summarised what is needed for a successful natural gas project to proceed:

> For a successful cross-border natural gas project to eventuate, a gas demand profile, matched to a similar supply profile, has to be achieved. In the private sector, this has to translate into a bankable project, with adequate risk-weighted returns to the investors over the life of the project. This same consideration is true for the gas field developer, who will have to prove up and maintain adequate gas reserves for the project life.
>
> The major challenge for cross-border gas projects is to secure a creditworthy, long-term offtaker or capacity-taker who is able to 'underpin' the project. Given the very large volumes of gas to be used, this typically requires substantial switchable base load capacity and cannot rely on the gradual building of reticulation systems and the gradual build-up of gas demand, nor on peaking power stations. Factoring in the build-up period can be a substantial challenge for all parties to a gas project. In this regard, long-term 'take-or-pay' contracts remain vital for bringing gas to market.

The challenge of establishing the necessary business and policy conditions to encourage large-scale investment in gas infrastructure has prompted APEC to work on best practice frameworks and capacity building for both gas exporters and importers. The authors of the report advise that in each gas exporting economy, investors and their financiers will require clear and predictable policy and legal frameworks for investment protection, for taxation, and for export of the natural gas produced. To encourage investment in the gas sector, each importing economy will need to have:

- an industry vision that is clear and well articulated and that matches national strategic goals;
- a clear vision for energy market design and regulation;
- clarity in its regulatory reform agenda;
- consistency in environmental enforcement and other laws;
- as much transparency as possible;
- well-thought-through training, education and immigration initiatives to cope with capacity and skill shortages in the energy industry; and
- well-structured and accessible collections of data.

Each importing economy will have its own strategic priorities. The first requirement is for economies to make their industry vision and industry strategy clear and transparent.

Greater supply and demand diversity and technological change are being accompanied by greater commercial contract flexibility. Rigid long-term contracts are being complemented by shorter-term contracts and more flexible terms and conditions that allow supply and demand to match shorter-term fluctuations. Links with oil prices are becoming weaker. Recent contracts with China, for example, place less weight on oil prices than traditional Japanese contracts do (Symon 2005).

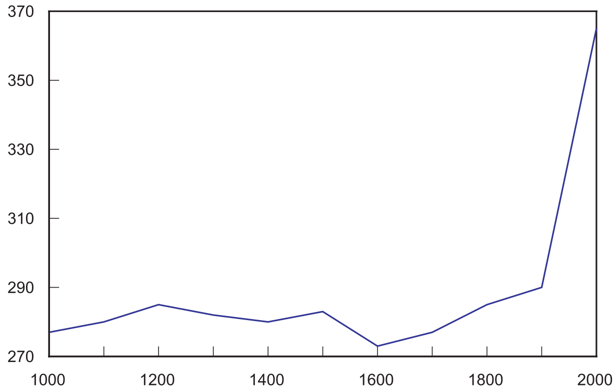
Involvement in the US market will continue this trend, with producers likely to have to sell cargoes on a short- and spot-term basis, accepting US market prices and hedging against risk with various futures and other financial instruments.

Accounting for climate change

While the future availability and price of coal are not likely to be a serious issue for China, and increased imports of other fossil fuels is likely to be possible, 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; however the carbon dioxide (CO_2) emissions from fossil fuel combustion (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, implying that China's share of global emissions will increase from 14 per cent to 19 per cent over the period to 2030 (IEA 2004).

Of all the fossil fuels, coal is the most carbon intensive. Emissions from coal account for a large share of greenhouse gas emissions generated by human activity. There is growing awareness among coal producers and consumers of the need to reduce or offset emissions from fossil fuel use. Atmospheric concentrations of greenhouse gases are already 30 per cent

Figure 3.2 Atmospheric carbon dioxide concentrations, 1000–2000 (parts per million)



Source: Redrawn from IPCC (2005).

above 18th century levels; projections by the Intergovernmental Panel on Climate Change 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 3.2) (IPCC 2005).

Aiding in this effort are the flexibility mechanisms established under the Kyoto Protocol, namely international emissions trading and the CDM.

The CDM allows for investment in emission-abating projects in developing country Kyoto Protocol parties, and for the sharing of the resulting emission credits, known as certified emission reduction units or CERs. The projects must achieve real, measurable, long-term benefits related to the mitigation of climate change, and reductions in emissions must be additional to any that would occur in the absence of the project activity. The project must also contribute to the sustainable development of the host country. Credits can be generated as soon as abatement begins and can continue until the end of the first Kyoto commitment period (2012). Many national governments, including China, India and Korea, are keen to attract CDM investment and have established designated national authorities to facilitate the process.

In approving baseline and monitoring methodologies for different types of projects, the CDM Executive Board aims to promote consistency, transparency and predictability and to provide the rigour to ensure that emission reductions are real and measurable. This has proved to be a slow and time-consuming process. The current focus is on bringing transaction costs down by streamlining approval and set-up procedures and by standardising baseline and emission accounting methodologies to cover different categories of technology. So far four 'consolidated' methodologies have been approved. They cover landfill gas activities, grid connected electricity generation from renewable sources, fossil fuel substitution in cement manufacture and waste gas and/or heat for power generation.

Government agencies and private sector participants undertake most of the planning, implementing, monitoring and verification of the projects. These organisations, depending on the nature of their involvement, can gain a share of the value of the emission credits generated, thus providing the necessary motivation for transfer of expertise and technology.

The value of the CERs is determined by the international Kyoto emissions market, which has developed rapidly since the protocol came into force. For registered projects where the seller guarantees delivery, prices can be up to $18 per ton of carbon dioxide emissions (CO_2e) saved. Where the seller does not take on much risk, prices are more commonly in the range US$5–8 (Point Carbon 2005).

Mechanisms such as the CDM, together with the growth of national and regional emissions trading schemes such as the European Union Emissions Trading Scheme, could well prove to be the foundation of a global emissions market that will eventually put a price on greenhouse gas emissions and strengthen the market incentive to reduce emissions.

In the longer term there are a range of technologies that have the potential to reduce greenhouse gas emissions. Apart from nuclear power, these include energy efficiency initiatives, renewable energy technologies, fuel switching to lower emitting fuels and capture and storage of emissions. Successful long-term strategies will need to adopt all of these technologies.

Conclusion

China faces a challenging time over the next 25 years as it seeks new energy sources to meet its growing energy demand in a secure and sustainable manner. Given that the world's energy needs are expected to be almost 60 per cent higher in 2030 than they are now, this is a challenge China will share with many other countries.

China's share of demand for all the major energy commodities will also grow significantly over the period to 2030: overall its share of world primary energy demand will increase from 12 per cent to 16 per cent. With this growing share of demand will come increasing market influence, putting upward price pressure on most energy commodities.

Fossil fuels will continue to dominate the energy mix for both China and the world as a whole, meeting most of the increase in overall energy use. Given this continuing dependence on fossil fuels, concerns about energy security (especially related to oil) and environmental sustainability (especially related to coal) are expected to grow. Even without these concerns it will be a challenge to finance and build the huge amounts of new infrastructure needed to extract, transport and utilise the energy commodities involved. This is particularly the case for the developing natural gas market.

Notes

1 The OPEC countries are Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, and Venezuela.

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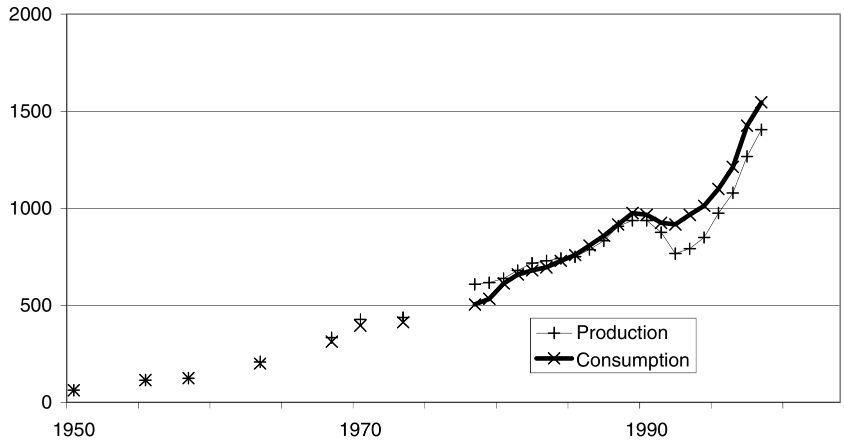
4 Scenarios for Chinese Energy Demand and Supply to 2020

Kejun Jiang and Xiulian Hu

Background

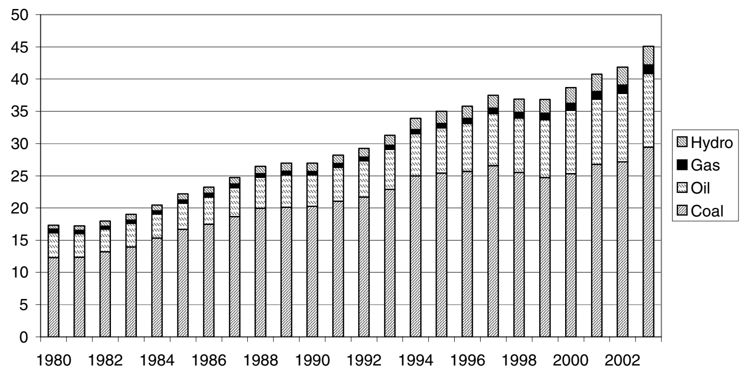
Because of China's rapid economic growth, total primary energy consumption increased from 400 million tons of coal equivalent (Mtce) in 1978 to nearly 1,320 Mtce in 2004, an annual increase of 4.7 per cent (see Figure 4.1) (NBSC 2004a, 2004b). Coal is the major energy source, providing 70.7 per cent of total primary energy use in 1978 and 69 per cent in 2004 (see Figure 4.2). As can be seen from Figure 4.1, recent years have witnessed a dramatic surge in the rate of increase of energy use in China. This has been accompanied by widespread energy shortages.

Figure 4.1 Energy production and consumption in China



Source: Authors' calculations.

Figure 4.2 Primary energy use in China by energy type



Source: Authors' calculations.

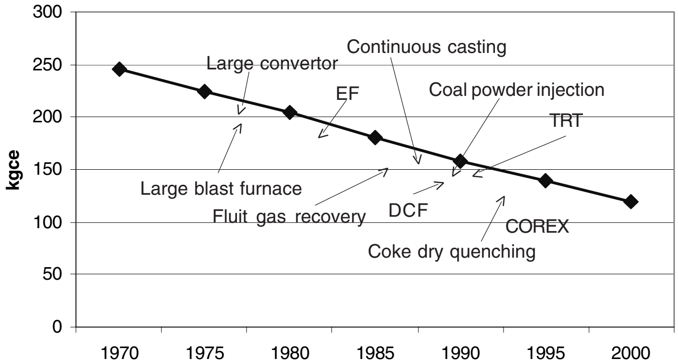
China is the largest coal producing and consuming country in the world. Between 1980 and 2004, total raw coal output increased from 620 million tons (Mt) to more than 1900 Mt, an average annual growth of 4.8 per cent per year. Prior to 2000 the share of coal in total energy use decreased, but it increased again between 2000 and 2004, from 66 per cent to 72 per cent. China's heavy dependence on coal has led to serious environmental problems and represents a burden for the transportation system.

From 1980 to 2004, the total installed capacity of electric power generation increased from 65 gigawatts (GW) (of which hydropower accounts for 20 GW, or 31 per cent) to 440 GW (of which hydropower accounts for 100 GW, or 23 per cent). In the same period, electricity output increased from 300 terawatt hours (TWh) (of which hydropower accounts for 58 TWh, or 19 per cent) to 1,870 TWh (of which hydropower accounts for 220 TWh, or 12 per cent). Newly installed capacity in 2004 was 50 GW; newly installed capacity in 2005 and 2006 is expected be around 60–70 GW (Anon. 2005).

Between 1980 and 2004, total crude oil output increased from 106 Mt to 175 Mt (annual growth of 2.1 per cent). Of the total oil output in 2002, 49 Mt is produced on land and 18 Mt is produced offshore. Crude oil output in China accounts for 4.7 per cent of the world total.

Energy efficiency improvement and energy conservation are given high priority in China's energy development strategy, as is the efficient and clean use of coal and other fossil energy sources. The purpose of developing clean coal technology is to improve coal utilisation efficiency, to reduce environmental pollution and to promote economic development. High efficiency and clean technology will be crucial for China to achieve a low-emission

Figure 4.3 Technology progress and energy efficiency improvement in steel making industry



Note: DCF = direct current furnace ; EF=electric furnace; kgce = kilograms of gas equivalent; TRT = top gas pressure recovery turbine.
Source: Authors' calculations.

development path. Figure 4.3 illustrates the way in which energy efficiency improvements in the steel making industry have been driven by the adoption of advanced technology.

It is quite important to understand the reason for the rapid increase of energy use over the last several years. One key factor is that the production of major energy-intensive products has increased quickly since 2000. For example, steel output was 128 million tons in 2000 and 320 million tons in 2004. The development of other energy intensive products (such as chemical fibres, paper, coal, steel products, cement, plastics and machine tools) follows similar trends.

The rapid increase in energy demand in recent years has stimulated many discussions on future energy demand which have quite divergent results from previous energy scenario studies. The purpose of this paper is to provide energy demand scenarios up to 2020 by reflecting recent development trends, especially in energy intensive products. We also aim to differentiate between domestically satisfied consumption and China's energy import requirements using a global energy model. Because China is a member of the World Trade Organization (WTO), we try to reflect expectations about China's industrial transformation resulting from its role in global markets (Lu et al. 2003). We also discuss policy options, based on the scenario study and relative studies on policy assessment.

The models

We obtained our forecasts by combining two components of the Integrated Policy Assessment Model for China (IPAC): the IPAC emission model and the IPAC/AIM technology model. Combining these two components of the IPAC allowed us to project future energy and pollutant emissions on the basis of various quantitative scenarios and policy option analyses.

IPAC emission model

The IPAC emission model is a global model developed for the study of greenhouse gas emission scenarios (Jiang et al. 2000a; Nakicenovic and Swart 2001). It divides the world into nine regions[1]: the United States (US), Pacific OECD (OECD-P), Europe OECD and Canada (OECD-W), Eastern Europe and Former Soviet Union (EFSU), Middle East (ME), China, other Asia (SE Asia), Africa, and Latin America (LA). Emission sources can be disaggregated such that major sources, including energy activities, industries, land use, agriculture and forests can be simulated in the model framework. The model consists of three modules: the macroeconomic module, the end-use module and the land-use module.

The macroeconomic module was based on the Edmonds–Reilly–Bams model, a macroeconomic, partial equilibrium model which forecasts energy demand over the long term (Edmonds and Reilly 1983; Edmonds et al. 1996). It uses GDP and population as future development drivers, combined with other energy-related parameters, to forecast energy demand based on the supply and demand balance.

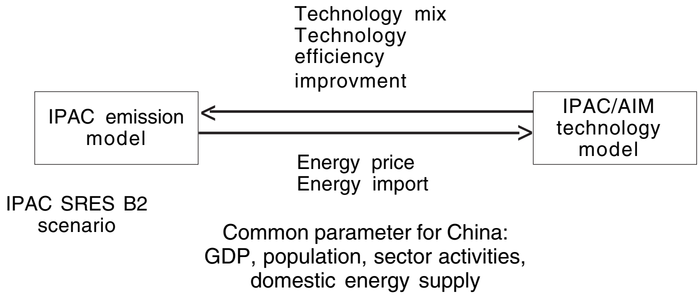
The end-use module was originally part of the Asia-Pacific Integrated Model (AIM), a bottom-up, energy-technology model developed by the National Institute for Environment Studies and Kyoto University in Japan.

The land-use module was developed from the Agriculture Land Use Model developed by the Pacific-Northwest National Lab to model greenhouse emissions from land use (Edmonds et al. 1996).

IPAC/AIM Technology Model

The IPAC/AIM technology model is a single region model for China, based on the AIM end-use model (AIM Project team 1996; Hu et al. 1996; Hu at al. 2001). The model includes three modules: energy service demand projection, energy efficiency estimation, and technology selection. Demand is disaggregated to the industrial, agricultural, service, residential and transportation sectors; these sectors are further divided into sub-sectors. For both the demand and supply sides more than 400 technologies are considered, including existing as well as potential technologies. The model searches for the least-cost technology mix to meet the given energy service demand. The most up-to-date information on these technologies was collected from a large number of printed sources, as well as by consulting experts directly.

Figure 4.4 Link between models



Note: AIM = Asia-Pacific Integrated Model; IPAC = Integrated Policy Assessment Model for China.

Linking the models

Linking the two models provides both detailed analyses of various sectors and a global analysis of China's energy future. The same policy scenarios and related model assumptions were used for both models. Energy demand for China was determined by the IPAC/AIM technology model by calculating demand from sectors with detailed technology information. Energy price and energy import data are derived from the IPAC emission model. The global energy analysis is given based on the IPCC SRES 82 scenario (Nakicenovic and Swart 2001), while the China energy analysis is revised in this study. Figure 4.4 presents the link between two models.

Model assumptions

The major assumptions used in this study (including population, GDP growth and mix) are given in Tables 4.1 and 4.2. The assumptions for population come from other studies. The assumed GDP growth rate is consistent with government targets and research by the Development Research Center (Zheng et al. 2004; Tan et al. 2002; Qu 2003; Liu et al. 2002).

In order to analyse energy trading, we used the IPCC SRES B2 scenario as a global scenario (Jiang et al. 2000a). The IPCC SRES scenario is a scenario family developed by the Intergovernmental Panel on Climate Change in 2001; it includes seven scenario groups. The B2 scenario reflects a world with good intentions which it is not always capable of implementing. This storyline is most consistent with current national and international developments.

Table 4.1 Assumed population (million)

	2000	2010	2020	2030
Population	1,285	1,393	1,472	1,539
Urban	413	531	633	754
Rural	872	862	839	785

Source: Assumptions by authors, based on a review of relevant studies.

Table 4.2 GDP growth in China (per cent)

	2000–10	2010–20	2020–30
GDP growth rate	8.1	6.7	5.6

On balance, the B2 world is one of central tendencies that can be characterised as neutral progress among SRES scenarios. Human welfare, equality and environmental protection all have high priority, but the world proves unable to tackle these concerns at a global level and resolves them as best it can regionally or locally. Generally, high educational levels promote both development and environmental protection. Education and welfare programs are widely pursued, leading to reductions in mortality and, to a lesser extent, fertility. This results in a central population projection of about 10.4 billion people by 2100, consistent with the United Nations median projection. Gross world product (GWP) grows at an intermediate growth rate of 2 per cent per year, reaching about $235 trillion in 2100.

The B2 storyline also presents a generally favourable climate for innovation and technological change, especially in view of high educational levels compared to today and relatively efficient markets at the regional level. B2 is a world of 'regional stewardship' that, in some regions, is particularly frugal with energy and many other natural resources. Consequently, energy system structures differ among the regions. Overall, high priority is given to environmental protection, although global policies prove elusive and regional policies vary widely. The major assumptions are summarised in Tables 4.3, 4.4 and 4.5.

For the developing Asia Pacific region, the B2 scenario assumes that economic development utilises resources so as to maintain equity for the future, while maintaining

Table 4.3 Key scenario drivers assumed for developing Asia Pacific and the world in the IPAC emission model

Item	Assumptions
Asia Pacific population	4.7 billion in 2050 5.0 billion in 2100
Asia Pacific annual GDP growth rate	5.7 per cent from 1990 to 2050 3.8 per cent from 2050 to 2100
World population	11.7 billion in 2100
World GDP	$250 trillion in 2100
GDP / capita trends	Disparity remains GDP / capita of OECD becomes 7 times that of non-OECD (it is now 13 times)
Autonomous energy efficiency improvement	1.0–1.2 per cent
International trade	Low trade across regions High trade cost
Urbanisation	Increase in developing world before 2050, decrease in developed world

Source: IPAC = Integrated Policy Assessment Model for China; OECD = Organisation for Economic Co-operation and Development.

balance among regions as well as between urban and rural areas. Such an approach is based on the recognition of environmental issues and sustainable development. This scenario can be described as regional stewardship from a global perspective, based on a natural evolution of the present institutional policies and structures. It is characterised by limited population growth, medium economic growth, inequality reduction, weak global governance but strong national and regional governance, a strong de-urbanisation trend, strong pursuit of environmental improvement, and encouragement of renewable energy use. It is a low per capita economic development scenario. In this scenario, the per capita GDP in the region is only one-fifth that of the OECD countries in 2100.

All of China's emission scenarios were developed under the IPCC SRES B2 scenario. In the IPAC emission model, international energy trade was included in the study based on the cost effective availability of resources (Jiang et al. 2000a, 2000b; Jiang et al. 1999).

Scenario definitions

In order to analyse future energy demand and emissions in China, we consider three scenarios. The first two are a baseline scenario and a high demand scenario, which we

Table 4.4 Assumptions for B2 scenario for the developing Asia Pacific region and the world

Item	Assumptions
Resource availability	
Oil/gas	Medium
Biomass	High
Energy exploitation cost	Medium
Non-carbon renewable energy cost	
Nuclear	High
Solar and others	Medium
Biomass availability	Medium
End-use technology efficiency improvement	Medium
Social efficiency improvement	Medium
Transport conservation	High
Dematerialisation trend	Medium
Land-use productivity improvement	Medium
Meat-oriented food habit	Low
Desulphurisation degree	High

Source: Compiled by authors.

Table 4.5 Factors influenced by key driving forces

Driving force	Sector	Factor	Policies to promote the change
Social efficiency change	Industry	Value-added change by sub-sectors within the sector (as service demand in some sub-sectors, including 'machinery', 'other chemical', 'other mining', 'other industry' Product structure change within one sector (as service demand in most industrial sectors)	Various policies relative to value added such as price policy, national plan for key industry, promote well working market. Market oriented policies, national development policies.
	Residential and commercial	Energy activity change within the sector (such as change of use of heating and cooling; use of more efficient electric appliances etc.)	Public education, price policies
	Transport	Change of transport mode (more public transport, non-mobility etc.)	Transport development policies, public education
		Traffic volume conservation (use private cars less)	
Technology progress	For all sectors	Progress in efficient use of technology (unit energy use improvement)	Technology R&D promotion, market-oriented policies, international collaboration.
		Technology mix change (more advanced technologies)	Market-oriented policies, environmental regulation
		Fuel mix change (more renewable energy and nuclear energy)	National energy industry policies, import and export policies, tax system

Source: Compiled by authors.

developed considering the uncertainty of demand for energy-intensive products given China's rapid economic development and the impact of WTO accession. The third scenario is a policy scenario. The three scenarios are defined as follows.

- *Baseline scenario*. In this scenario, future economic activities follow a business as usual trend. There would be better international trading and China's economy will 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.
- *High demand scenario*. In this scenario, there is a high demand for energy in the future. The major driving force is China's assumed role as a centre for manufacturing following WTO accession. This will bring more energy-intensive production to China – for example, steel, non-ferrous products and building materials. The scenario also assumes greater technology transfer and more R&D on high-efficiency energy use technologies.
- *Policy scenario*. This scenario assumes low energy demands. It covers various energy and emission control policies, reflecting energy supply and environmental constraints.

The basic assumptions for the three scenarios, such as population and GDP growth, are the same. Table 4.6 shows the assumed output for the various sectors for the three scenarios.

Policy options to be considered in the policy scenario are given in Table 4.7 . They are based on our assessment of potential policies in China as well as technology trends (Qu 2003; Liu et al. 2002; IPCC 2001, 2002).

Table 4.6 Energy-intensive product assumptions in the model

	2002	Baseline scenario / policy scenario 2020	High demand scenario 2020
Steel (Mt)	182.4	380	430
Copper (Mt)	1.63	4.5	5.2
Aluminium (Mt)	4.51	10	12
Ethylene (Mt)	5.43	12	14
Ammonia (Mt)	36.75	57	70
Chemical fertiliser (Mt)	37.9	48	52
Cement (Mt)	725	1,100	1,300
Glass (million cases)	234.4	480	520
Vehicles (million)	3.25	11	15

Note: Mt = million tons.
Source: Compiled by authors.

Table 4.7 Policy options used in the modelling study

Policy options	Explanation
Technology promotion	Increase end-use technology efficiency by using new technologies
Energy efficiency standard for buildings	New buildings reach 75 per cent increase standard in 2030
Renewable energy development policy	Promote use of renewable energy
Energy tax	Introduce vehicle tax by 2005 and energy tax by 2015
Public transport	In cities the share of public transport in 2020 will be 6–11 per cent higher than in 2000
Transport efficiency improvement	High fuel efficiency vehicles will be widely used, including hybrid vehicle, compact cars, advanced diesel cars
Power generation efficiency	Efficiency of coal fired power plants will increase to 38 per cent by 2030
Natural gas incentive	Enhance natural gas supply, localisation of technology to reduce cost
Nuclear power development	Promote national program by setting a target of 40 gigawatts by 2020

Source: Compiled by authors.

Energy demand

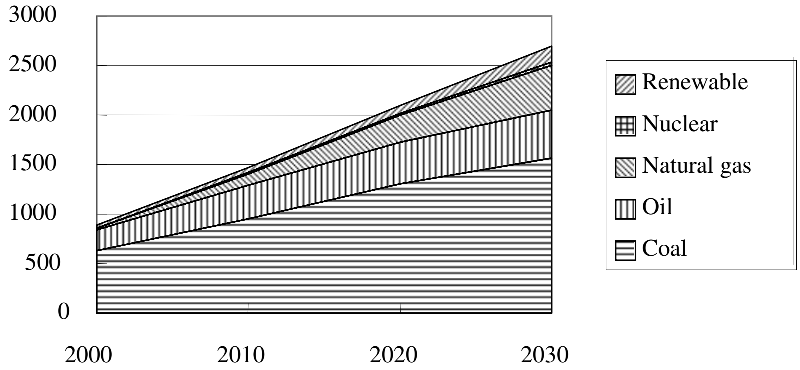
In this section, we present our results on energy demand under the three scenarios used. We also briefly discuss energy production.

Baseline energy scenario

Figure 4.5 gives the results of the modelling for primary energy demand under the baseline scenario. It shows that primary energy demand could go to 2.1 billion tons of oil equivalent (toe) in 2020. The annual growth rate from 2000 to 2020 is 3.6 per cent, while the energy elasticity of GDP is 0.62. Coal will be the major component of energy in China (1.3 billion toe in 2020), with a 62 per cent share in total energy demand. There is a rapid increase in the demand for natural gas in China, with its share in total primary energy use increasing from 4 per cent in 2000 to 8.3 per cent in 2030 (an annual growth rate of 10 per cent).

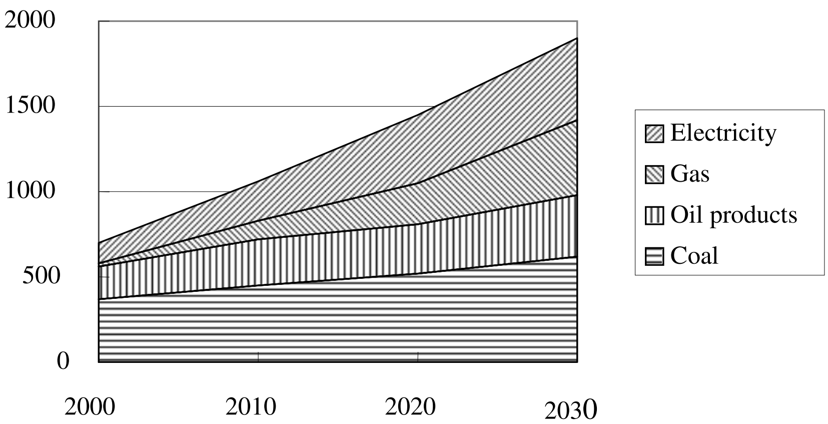
Figure 4.6 gives the results of the modelling for final energy demand under the baseline scenario. It shows that electricity and natural gas increase rapidly under the baseline scenario. Electricity demand increases from 112 million toe in 2000 to 478 million toe in 2020. Natural

Figure 4.5 Primary energy demand (baseline scenario) (Mtoe)



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

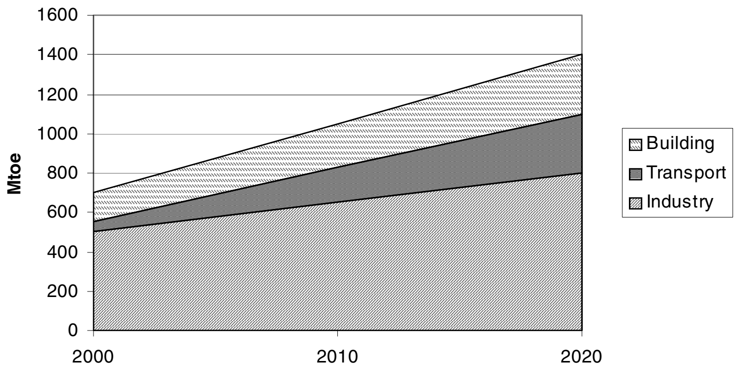
Figure 4.6 Final energy demand in China (baseline scenario) (Mtoe)



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

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 in 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 105 million toe in 2000 to 457 million toe in 2030.

Figure 4.7 Final energy demand by sector



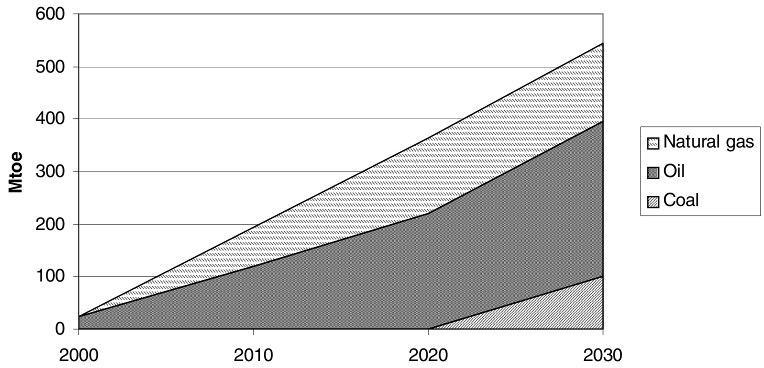
Note: Mtoe = million tons of oil equivalent.
Source: Authors' calculations.

Figure 4.7 shows final energy demand by sector under the baseline scenario. It shows that in 2020 industry will still be the major user of energy, accounting for 60.8 per cent of total energy consumption in 2020, compared with 70 per cent in 2000. The share of energy use in transport will increase to 20.3 per cent in 2020 compared with 11 per cent in 2000. Share of energy use in building will show a small decrease, from 19.2 per cent in 2000 to 18.9 per cent in 2020.

We also simulated future energy production in China using the baseline scenario. The results show that coal production could reach 1.31 billion tons of coal equivalent (tce) by 2020. This is higher than predicted by Chinese coal industry experts, who estimate an upper bound of coal production of 1.2 billion tce by 2020. In either case, coal demand could exceed domestic coal production in China. Oil production is projected to be 190 million tons in 2020. This is within the forecast of experts from the oil industry, which range from 180 to 200 million tons in 2020. Natural gas production will be 133 billion m^3 in 2020. The production of natural gas is within the range of natural gas production forecast by energy experts, which ranges from 130 to 150 billion m^3 in 2020. Nuclear power generation will increase quickly in future, but still represents a small share, because of its high cost. The model results shows that nuclear power generation could reach 256 TWh in 2020, compared with 16.7 TWh in 2000. The installed capacity will be 39,400 MW in 2020. Hydropower output will increase from 224 TWh in 2000 to 555 TWh in 2020, with capacity reaching 154 GW in 2020.

We also simulated the price of energy under the baseline scenario, although precise and accurate forecasts are difficult. Taking into account domestic production costs, transport costs and international market prices and learning curve effects, our simulation predicts the price of solar power decreasing by almost 50 per cent from 1990 prices. Oil prices are

Figure 4.8 Energy imports and exports (baseline scenario)



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

expected to remain approximately steady over the next several decades, while prices of coal and natural gas will increase somewhat.

Using the calculated energy demand and production estimates under the baseline scenario, we calculated the need for future energy imports. Figure 4.8 gives the results. Fossil energy imports could reach 375 million tce annually in 2020 (for comparison, in 2000, the United States imported 870 million tce). The main component will be oil, which will reach 230 million tons in 2020. Natural gas imports will amount to 154 billion in 2020. Even coal will be imported after 2020, with 129 million tons of coal needed annually by 2030.

High demand scenario

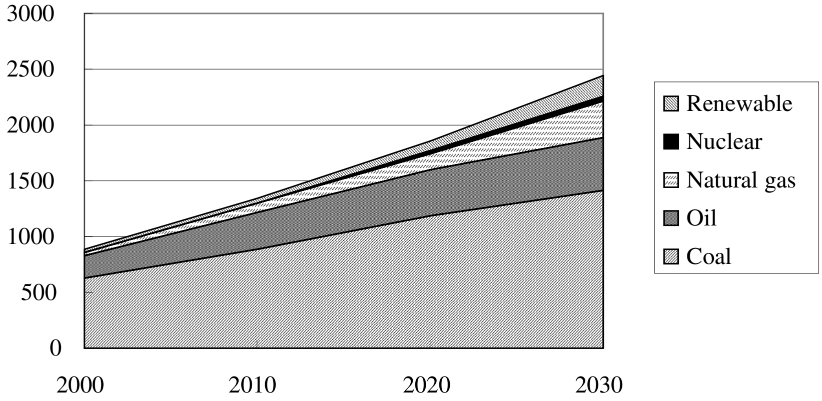
For the high demand scenario, primary energy demand in 2020 is 2.3 billion tce, which is 210 million tons higher than the baseline scenario. Of the total primary energy demand, coal provides 62.1 per cent, oil 19.8 per cent, natural gas 12.9 per cent, and nuclear 1.1 per cent. Because this scenario assumes better integration in international markets, there is greater reliance on imported energy such as natural gas and oil (see Figure 4.9 and 4.10).

Total fossil energy imports will amount to 445 million tce in 2020. As shown in Figure 4.11, coal imports will be increasingly important, reaching 189 million tce in 2030.

Policy scenario

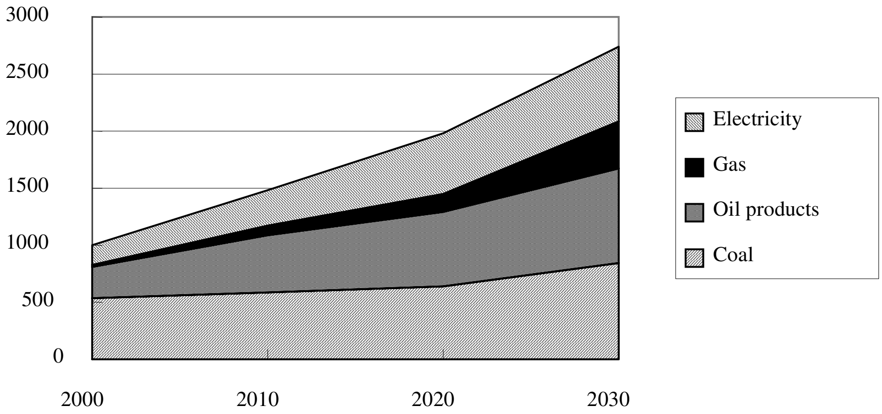
The policy scenario results are determined assuming the adoption of energy and environmental policy measures. In 2020, this scenario will result in an energy demand nearly 245 million

Figure 4.9 Primary energy demand (high demand scenario)



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

Figure 4.10 Final energy demand (high demand scenario)

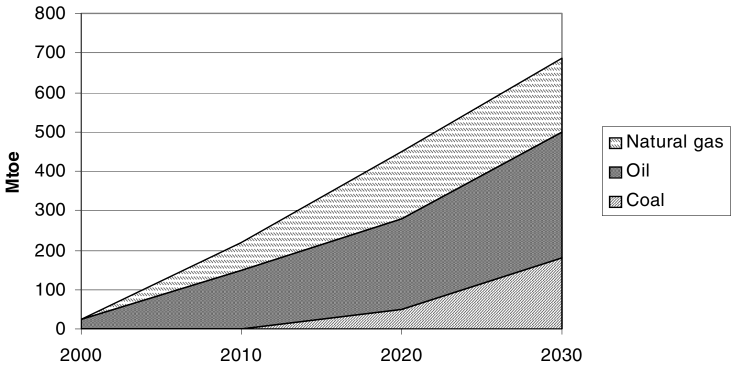


Note: Mtoe = million tons of oil equivalent.
Source: Authors' calculations.

tce lower than that under the baseline scenario. In order to reach the lower energy demand scenario, it is important to introduce appropriate energy policies – and to do so early, because energy technologies have a long life span.

Let us turn to the effects for policy options used in the policy scenario, by comparing with the baseline and high demand scenarios. A package of policy options could be adopted

Figure 4.11 Energy imports (high demand scenario)



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

now to reduce the growth rate of energy demand (see Table 4.8). These options could include a policy to promote the penetration rate of high energy efficiency technologies; fiscal energy and environment policies, including vehicle fuel taxes, subsidies for renewable energy, emission taxes and resource taxes; and policies to promote public involvement. All of these policy options will be important if China is to go to a low energy demand scenario.

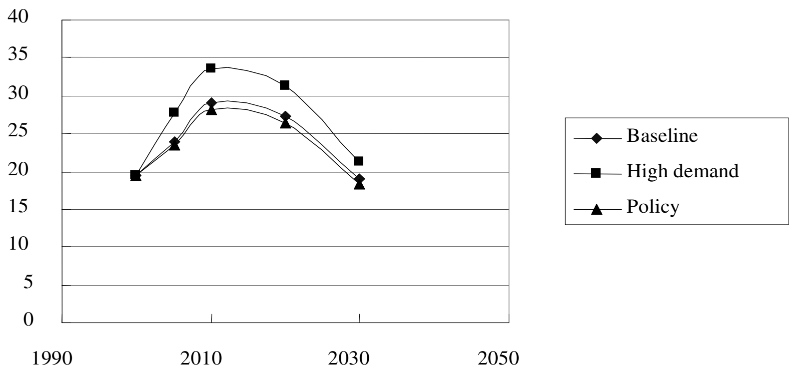
Emissions

When calculating energy demand, we also calculated the emissions of various pollutants under the various scenarios. Figure 4.12 to 4.15 show SO_2, NO_x, total suspended particulate (TSP) and CO_2 emissions from energy activities. SO_2 emissions will keep increasing until 2010 with the rapid increase of coal use in China. After 2010, more and more desulphurisation technologies will be used, so there will be lower SO_2 emissions from fossil fuel use. SO_2 emissions for the baseline scenario in 2010 are 4.5 million tons lower those using the high demand scenario, but still represent an increase of 9.45 million tons from 2000. Achieving government targets will be a major challenge. Without any control policy, NO_x emissions will continue to rise, as will TSP emissions.

Conclusion

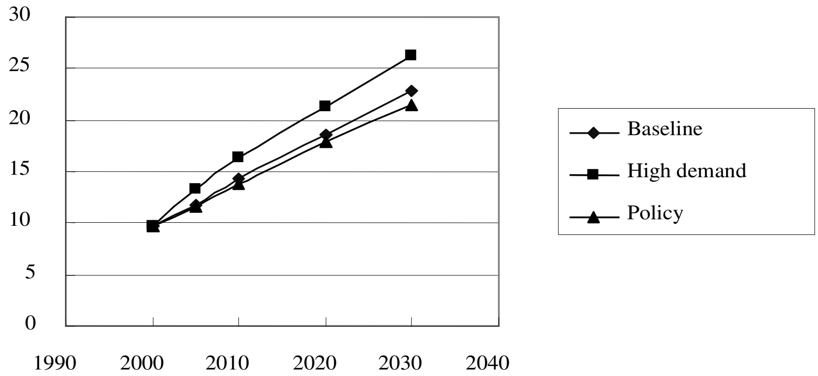
This study shows that primary energy demand in China in 2020 may range from 1.9 billion tce to 2.4 billion tce. Such a large demand will bring serious supply pressures. However, the

Figure 4.12 SO_2 emissions in China



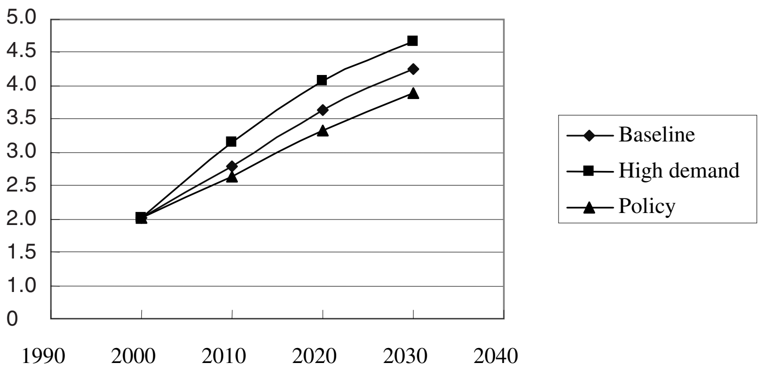
Note: SO_2 = sulphur dioxide.
Source: Authors' calculations.

Figure 4.13 NO_x emissions in China



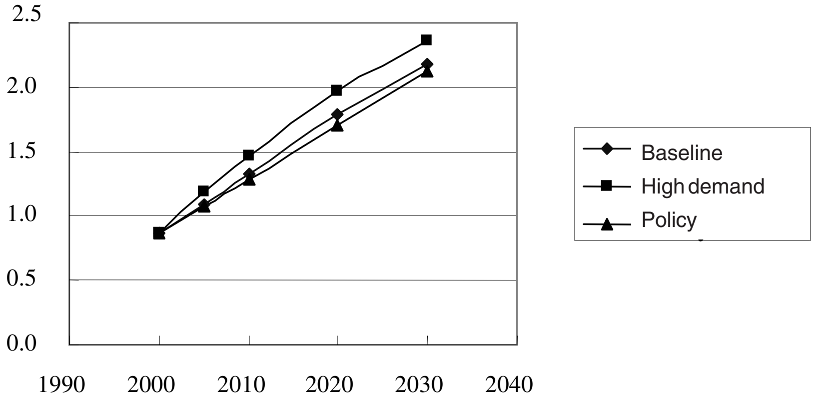
Note: NOx = nitrous oxides.
Source: Authors' calculations.

Figure 4.14 TSP emissions in China



Note: TSP = total suspended particulate.
Source: Authors' calculations.

Figure 4.15 CO_2 emissions in China



Note: CO_2 = carbon dioxide; Mtce = million tons of coal equivalent.
Source: Authors' calculations.

actual amount will depend on technological progress, the development of an energy-intensive sector, and the adoption of appropriate policies now and in the immediate to near future.

By 2020 the domestic oil supply is projected to reach up to 200 million tons, with natural gas at 160 billion m^3, and coal at 2.8 billion tons. For the lowest energy demand scenario, this would require China to import 200 million tons of oil and 100 billion m^3 of natural gas; for the high energy demand scenario, it require imports of nearly 400 million tons of oil, 260 billion m^3 of natural gas, and 300 million tons of coal.

Such large energy demands and imports place very significant pressure on the energy supply industry in China. There is a need for a well-designed strategy for energy systems and energy industry development in China. This study suggests six main policy options.

- *Energy conservation.* With a rapid increase in energy demand, the top priorities should be energy conservation, efficient technology development and diffusion. China should begin by implementing some countermeasures (or enforcing those which currently are not strictly adhered to) – for example, energy efficiency standards for buildings, requirements for renewable energy use in buildings and the imposition of a fuel tax for vehicles.
- *Development.* The energy supply industry will undergo rapid development in the next several decades. The energy supply industry in China should fully appreciate the pressure it will face. A long-term development strategy is essential. There should be a clear policy framework for energy development.
- *Security.* As with other developed countries with large energy imports, China should establish an energy security system. A central component of such a system is maintaining significant oil

reserves. The size of such reserves should be decided in the context of global oil demand and China's import requirements.

- *Diversification of energy sources.* A multi-energy system should be established to diversify energy supply. Renewable energy should be developed as an alternative energy source. Biofuel for vehicles could reduce energy imports.
- *Technological progress.* This must receive much more emphasis in order to reduce future energy requirements.
- *Further policy options.* Options such as energy taxes, resource taxes, and export taxes for energy intensive products should be considered

Environmental issues will be a major factor in energy development in China. With economic development, environmental problems could worsen with rapid increased energy demand given that there are no strong countermeasures to abate pollution. Energy activities – especially in coal mining, transport and combustion – already cause serious environmental problems. If there is more than 2.5 billion tons of coal production and combustion in China in 2020, the environmental impact will be very considerable. China will need to find innovative options to abate the impact. We suggest that the following factors should be taken into account.

- China should establish a comprehensive clean energy system, covering the entire energy cycle (from extraction to final consumption) with government intervention.
- China should prepare various national laws, regulations and standards to complement that clean energy system. So far the legal system is very weak and cannot adequately promote a clean energy system.
- There should be an emphasis on clean coal technology to mitigate emissions from coal combustion. Only a few countries in the world use coal on a large scale, and the development of clean coal technology relies on these few countries. China is the biggest country in the world to use coal; in the future, its coal use will increase rapidly, potentially taking more than 40 per cent of world total coal use in 2020. Therefore clean coal technology is crucial for China. China should have a clear development plan to promote clean coal technology. It is preferable to work closely with other countries on new clean coal technology.
- Clean energy utilisation technologies should be further diffused in China. Some technologies already show large commercial potential in other countries. They should be introduced at an early time into China.
- Vehicle emission standards should be introduced in China to control emissions from transport.

Table 4.8 Technologies contributing to energy saving and greenhouse gas emission reduction in short and middle term

Sector	Technology
Steel industry	Large equipment (coke ovens, blast furnaces, basic oxygen furnaces etc). Equipment for coke dry quenching; continuous casting machines, top recovery turbines; continuous rolling machines; equipment for the recovery of coke oven gas, open hearth gas and basic oxygen furnace gas; direct current electric arc furnace
Chemical industry	Large equipment for chemical production, waste heat recovery systems; ion membrane technology, existing technology improvements
Paper making	Co-generation systems, facilities for residue heat utilisation; black liquor recovery systems; continuous distillation systems
Textile	Co-generation systems; shuttleless looms; high speed printing and dyeing
Non-ferrous metal	Reverberator furnaces; waste heat recovery systems; Queneau-Schumann-Lurgi process for lead and zinc production
Building materials	Dry process rotary kilns with pre-calciner processes; electric power generators with residue heat; coal-burn processes; Hoffman tunnel kilns
Machinery	High-speed cutting; electric/hydraulic hammers; heat preservation furnaces
Residential	Cooking by gas; centralised space heating systems; energy saving electrical appliances; efficient lighting; solar thermal systems for hot water; insulation of buildings; energy-efficient windows
Services	Centralised space heating systems; centralised cooling heating systems; co-generation systems; energy-saving electrical appliances; efficient lighting
Transport	Hybrid vehicles; advanced diesel trucks; low energy use cars; electric cars; fuel cell vehicles; natural gas cars; electric railway locomotives; public transport development
Common use technology	High-efficiency boilers; fluid bed combustion technology; high-efficiency electric motors; speed adjustable motors; centrifugal electric fans; energy-saving lighting
Power generation	Supercritical units; natural gas combined cycles; pressure fluid bed combustion boilers; wind turbines; integrated gasification combined cycles; smaller-scale hydropower; biomass-based power generation

Source: Compiled by authors.

China has adopted a role as the manufacturing centre of the world – a role which is very likely to increase in significance. With that role comes a high dependence low cost energy-intensive and resource-intensive products. This trend must be controlled if China is to avoid becoming primarily a country providing raw materials and causing major damage to the environment. External costs need to be internalised so that firms can plan to avoid possible environmental and economic damage.

Notes

1 The United States, Pacific OECD, Europe OECD and Canada; Eastern Europe and former Soviet Union;, Middle East; China; other Asia; Africa; and Latin America.

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5 Environmental issues and their impact on Chinese Energy use

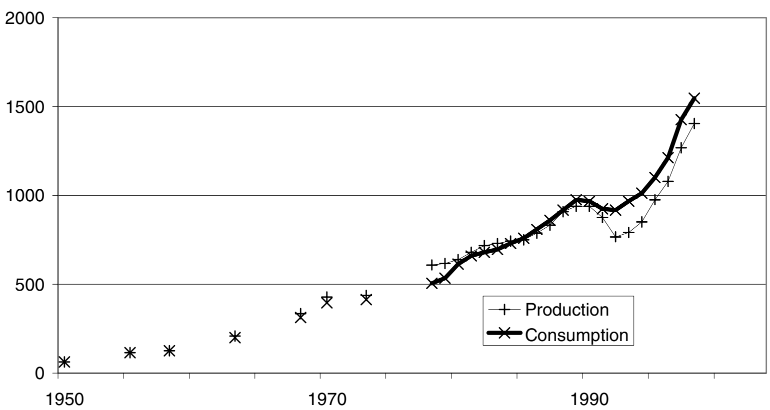
Xiulian Hu and Kejun Jiang

Introduction

Human environmental impact is in large part determined by our energy requirements. The Holdren–Ehrlich identity is one way to decompose anthropogenic environmental impacts. According to this identity, the environmental impact is determined by population, economic activity (GDP) and an environmental impact coefficient. Given China's obviously large population, and rapidly growing GDP, its environmental coefficient is of crucial importance. China must be able to increase per capita income with lower and lower impacts on the environment.

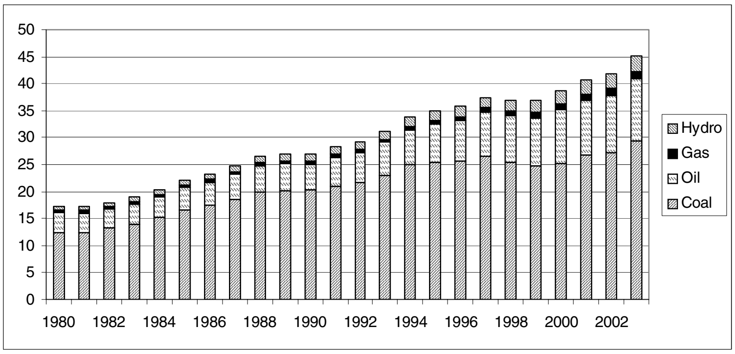
Because of rapid economic growth, total primary energy consumption increased from 400 million tons of oil equivalent (Mtoe) in 1978 to nearly 1,320 Mtoe in 2004, with an annual average rate of increase of 4.7 per cent (see Figure 5.1) (NSB 2004a, 2004b). Coal is the major energy source, providing 70.7 per cent of total primary energy use in 1978 and 69 per cent in 2004 (see Figure 5.2). Recent years have witnessed a dramatic surge in the rate of increase of energy use in China and widespread energy shortages.

Figure 5.1 Energy production and consumption in China



Notes: CO2 - carbon dioxide; ppm = parts per million.
Source: Adapted from IPCC (2005).

Figure 5.2 Annual volumes (million tCO_2e) of project-based emission reduction transactions (up to 2012 vintages) and annual average price in US$ per tCO_2



Source: World Bank (2005: 20); IETA (2005).

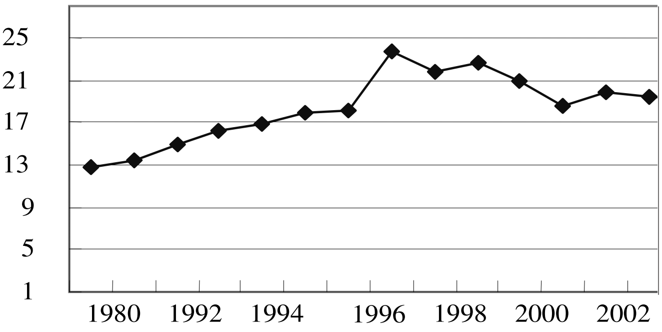
China is the largest coal producing and consuming country in the world. Between 1980 and 2004, total raw coal output increased from 620 million tons (Mt) to more than 1,900 Mt, with an average annual growth rate of 4.8 per cent per year. Prior to 2000, the share of coal use in total energy use decreased, but it subsequently increased again, from 66 per cent in 2000 to 72 per cent in 2004. The heavy dependence on coal has led to serious environmental problems and represents a burden for the transportation system.

From 1980 to 2004, total installed capacity of electricity power generation increased from 66 gigawatts (GW) (of which hydropower was 20 GW, accounting for 31 per cent) to 440 GW (of which hydropower was 100 GW, accounting for 23 per cent). In the same period, electricity output increased from 300 terawatt hours (TWh) (of which hydropower was 58 TWh, accounting for 19 per cent) to 1,870 TWh (of which hydropower was 220 TWh, accounting for 12 per cent). In 2004, newly installed capacity reached 50 GW, and newly installed capacity in 2005 and 2006 is expected be around 60–70 GW (Anon. 2005a).

Between 1980 and 2004, total crude oil output increased from 106 Mt to 175 Mt (with an average annual growth rate of 2.1 per cent). Of the total oil output in 2002, 149 Mt is produced on land and 18 Mt is produced offshore. Crude oil output in China accounts for 4.7 per cent of the world total.

Energy efficiency improvement and energy conservation are given high priority in the Chinese energy development strategy, as is the efficient and clean use of coal and other fossil

Figure 5.3 SO_2 emissions in China (Mt)



Note: Mt = million tons.
Source: Anon (2003).

energy sources. The goals of developing clean coal technology are to improve coal utilisation efficiency, to reduce environmental pollution and to promote economic development. High efficiency and clean technology will be crucial if China is to achieve a low emission development path.

With rapid economic growth, environmental problems have occurred in many cities and regions in China. Air pollution, water pollution and soil degradation are the most serious problems. Because of the large proportion of coal in China's energy mix, China is the largest emitter of sulphur dioxide (SO_2). More then 11 provinces have suffered acid rain damage. Figure 5.3 shows SO_2 emissions in China.

In many large cities, air pollution is a serious problem. Besides SO_2 emissions, PM10 (respirable particulate matter under 10 microns in diameter), nitrous oxides (NO_x) and carbon dioxide (CO_2) emissions are a major problem in many cities. For example, Beijing has some of the worst air pollution in the world, and air pollution caused by transportation has worsened since the mid-1980s. In recent years, sources of air pollution in Beijing have changed from coal burning (whose primary pollutant is SO_2) to transport (whose primary pollutant is NO_x). As shown in Table 5.1, in recent years the annual concentration of NO_x in Beijing has been higher than that of any other northern city in China, exceeding the national standard by 3.02 times in 1998. These NO_x emissions are mainly caused by transport pollution. The concentrations of SO_2 and total suspended particulates (TSPs) are also worse than the national standard. Although there has been improvement over the last decade, by 2002 the number of Chinese cities reaching air quality standards was still below 40 per cent (Table 5.2). In addition to poor air quality, Chinese cities suffer from emission induced acid

Table 5.1 Annual concentration of air pollutants in Beijing, 1986–2002

	1986	1990	1996		1997		1998		2000		2002	
	Concentration[a]	Concentration[a]	Concentration[a]	Position[b]	Concentration[a]	Position[b]	Concentration[a]	Position[b]	Concentration[a]	Position[b]	Concentration[a]	Position[b]
SO_2	0.124	0.122	0.099	15	0.124	7	0.119	7	0,119	7	0,068	15
TSPs	0.346	0.374	–	–	–	–	0.379	20	0.379	20	–	–
NO_x	0.071	0.098	0.0117	1	0.0133	1	0.151	1	0.151	1	0.076	1
Comprehensive air pollution index	–	–	4.309	10	6.612	3	6.898	3	6.989	3	3.74	16

Notes: –= not available; NO_x = nitrous oxides; SO_2 = sulphur dioxide; TSPs = total suspended particulates.
a 10^{-3}g/m^3.
b Beijing's rank among all northern cities in China for concentrations of specified pollutants
Source: Anon. (2003).

Table 5.2 Air pollution in 47 'major environment protection cities'[a] in China

	1995	1998	2002
SO_2 average concentration (mg/m$_3$)	0.076	0.060	0.047
TSP/PM10 average concentration (mg/m^3)	0.287	0.252	0.110
NO_x/NO_2 average concentration (mg/m^3)	0.051	0.051	0.037
Share of cities exceeding SO_2 concentration standard (%)	48.9	36.2	23.4
Share of cities exceeding dust concentration standard (%)	72.3	63.8	61.7
Share of cities reaching air quality standard (%)	21.3	27.7	38.3

Notes: NO_x = nitrous oxides; NO_2 = nitrogen dioxide; PM10 = particulate matter less than 10 microns in diameter); SO_2 = sulphur dioxide; TSPs = total suspended particulates.
a Cities where legislation has been passed to require more stringent environmental regulations.
Source: Anon. (2003).

rain (Table 5.3) and serious pollution problems in major rivers (Table 5.4). Pollution in rivers increases the costs of providing water suitable for drinking and irrigation, exacerbating drought conditions.

Table 5.3 Frequency of acid rain in cities in 2002

Days with acid rain (%)	Number of cities	Share of cities (%)
0	276	49.7
1–20	103	18.6
21–40	58	10.5
41–60	32	5.8
61–80	43	7.7
81–100	43	7.7

Source: Anon. (2003).

Table 5.4 Pollution in selected rivers

	Yangzi River		Yellow River		Songhuajiang River		Huaihe River	
	No. of samples	No. of samples exceeding standard	No. of samples	No. of samples exceeding standard	No. of samples	No. of samples exceeding standard	No. of samples	No. of samples exceeding standard
Ammonia and nitrogen	82	19	36	22	36	15	86	66
Manganese	82	22	36	19	35	29	86	71
Oxygen demand for 5 days	82	19	36	17	36	16	86	69
Mercury	76	4	30	2	29	0	41	1
Lead	77	4	30	2	29	0	41	1
Volatile hydroxy-benzene	80	9	30	9	31	14	83	29
Petroleum	78	29	32	24	23	14	73	-

Source: Anon. (2003).

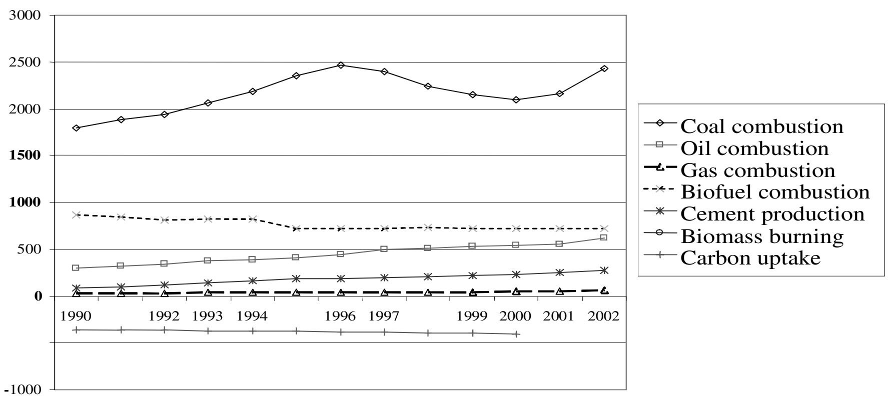
China has begun to make environmental protection a policy priority. Sustainability has become a key concept for the Chinese government, and the government has formulated policies and measures toward specific goals for sustainable development.

China is also paying more 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, there have been five 'joint implementation' projects conducted in cooperation with Japan, Norway and the United States.

China has the second highest levels of greenhouse gas emissions in the world, mainly as a result of fossil fuel combustion. This is mainly due to China's large population, which is more than four times that of the United States, the world's largest emitter. Chinese decisions nevertheless profoundly affect global emissions growth, and these decisions are, as elsewhere, driven by trends in economic development, local environmental protection, and technological change. Development policy in China has reduced the country's 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.

By using Intergovernmental Panel on Climate Change (IPCC) emission factors and some revised emission factors in China, CO_2 emissions were calculated and are shown in Figure 5.4 (Streets et al. 2001). As shown in Figure 5.4, there was a reduction in the levels of greenhouse gases in China over the late 1990s. However, this is not due to policies focused on climate change. Local policies for energy development and environment could contribute more fully to the response to climate change. So far development has been the main priority faced by China and other developing countries. Local environmental problems already encourage people to gain an understanding of sustainable development. However, the issue of climate change is still not at the forefront of people's minds, partly because of limited human and financial resources. The international negotiation process has made climate change a

Figure 5.4 CO_2 emissions in China (tons of carbon)



Note: CO_2 = carbon dioxide.
Source: Anon. (2003).

topic of more and more political interest, but there is a need to find a way to combine climate change policies with local development policies.

Pollution

China's large energy requirements place pressure on energy supplies and result in environmental problems. In 2003 SO_2 emissions were roughly 21.7 million tons (an increase of 12.5 per cent from 2002), while flue dust smoke was 10.63 million tons (a 5 per cent increase) and industrial soot emissions were 10.16 million tons (an 8 per cent increase) (see Table 5.5).

Environmental issues associated with coal development

Coal has developed as China's primary source of energy, with coal combustion having severe environmental impacts (especially in coal mining areas). Air pollution in urban and rural areas has become more and more serious. Coal production in 2002 was over 1.3 billion tons, equal to nearly 40 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. Coal has had five main detrimental impacts.

- *Damaged land resources due to coal exploration.* Up to 2000, about 48,000 hectares (ha) of land had collapsed. On average, 0.2 ha will collapse for every 10,000 tons of coal mined. Annual

Table 5.5 Major pollutant emissions, 2000–03 (million tons)

Year	SO_2 emissions			Soot emissions		
	Total	Industry	Residential	Total	Industry	Residential
2000	19.9	16.1	3.8	11.6	9.5	2.1
2001	19.5	15.7	3.8	10.7	8.5	2.2
2002	19.3	15.6	3.6	10.1	8.0	2.1
2003	21.7	–	–	10.63	–	–

Note: – = not available; SO_2 = sulphur dioxide.
Source: Anon. (2003).

collapse of land has increased by more than 20,000 ha; however, the rate of recovery is now only about 20 per cent.

- *Damaged water resources due to coal exploration.* Nineteen per cent of water resources in bedrock have been polluted to some extent in North China. Waste water discharged from various coal mine and coal washing processes is a major contributor to water pollution.
- *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 anthropogenic methane emissions. Chinese methane emissions from the coal industry account for 20–30 per cent of global coal mining related methane emissions.
- *Coal combustion as a major source of air pollution.* In 2001, SO_2 emissions were 19.5 million tons, around 85 per cent of which were due to coal combustion. Acid rain covered more than one-third of China's land area.

Environmental issues associated with the oil and natural gas industries

Although coal has been and continues to be the major source of energy (and thus pollution) in China, both oil and natural gas are rising in significance. There are many environmental issues associated with oil and natural gas, with negative environmental impacts occurring during all stages – exploration, exploitation, processing, transport and consumption.

During oil and gas exploration there are risks of spills causing major environmental problems. Additionally, waste water and leakages have significant environmental impacts. During transport, evaporation and leakage from oil stocks can cause further impacts. Evaporation mainly comes from oil tanks during the loading and unloading process. Vaporised substances include hydrocarbons and sulphurated hydrogen. Transportation also carries further risks of accidental leakage, such as a pipeline break or the overturn of an oil tanker. Washing water and mud in oil tanks can also cause environment damage.

The processing of oil and gas has negative environmental impacts, with waste water, exhausted gas and waste residue being major pollutants from oil refineries. Around 3–4 tons of waste water per ton of oil processed was discharged during the 1980s in China. Major pollutants in exhausted gas include SO_2, hydrogen sulphide NO_x, CO_2 and hydrocarbon components, and dust. Finally, waste residue (mainly toxic chemical waste) can damage soil, water and air quality.

Environmental issues associated with the power generation industry

Power generation in China ranks second in the world after the United States. In 2002 China generated 1,654 TWh, 95 per cent of which came from coal fired power plants. Power generation consumed 656 million tons of coal in 2002.

China has a very low use of clean coal technologies. Most of the coal used in power generation does not go through washing and selection processes, resulting in a high ash rate from coal use. Therefore coal used in power generation is a major source of SO_2, NO_x and dust, which are important causes of acid rain in China. Additionally, coal is a major emitter of CO_2.

In 2002, 6.7 million tons of SO_2 were emitted due to power generation, accounting for 34.6 per cent of the national total (Anon. 2003). Dust emissions amounted to 2.9 million tons, accounting for 29 per cent of the national total. Additionally, an estimated 4.7 million tons of NO_x were emitted from power generation. In 2002 1.9 billion tons of waste water and 146 million tons of waste residue were discharged in the power generation sector.

Impact of environmental protection requirements on energy development

Environment and energy regulations

After the end of the 1950s, with the significant development of heavy industry in China, environmental problems became a major issue. By 1975, pollution had become more serious than ever before, with several major accidents. Influenced by the Global Environment Conference in Stockholm, the Chinese government began to recognise the environmental problem and developed countermeasures to control the problems.

In 1973, the State Department hosted the first national environment protection conference. Subsequently, the government announced the introduction of Regulations on Protection and Improving the Environment (Tentative Version), which became the basis of the Environment Protection Law, promulgated in 1979. This legislation represented a new era in environmental protection in China – one based on law. It summarised practices for environmental protection, highlighted experience in other countries, made regulations on objectives, and set tasks, principles and policies for the regulation of environmental protection. The law also established basic standards and countermeasures, established institutions and organisations with environmental responsibilities, called for scientific research and encouraged people to profile environmental issues and raise awareness about them.

The Environment Protection Law established the responsibility of polluters and implemented charges for pollutant discharges. It established the principle of 'three same time' for construction projects as a fundamental legal regulation. In 1985, environmental law making entered an active period. More than 10 environmental and resource laws were established. By 1993, the scale of environmental law in China already contributed significantly to the prevention of pollution and the protection of natural systems.

During the 1980s three environmental general policies were established, including 'make prevention a priority and also use countermeasures', 'make polluters responsible for treatment', and 'enhance environmental management'. The three general policies formed the basis of other policies such as 'resource integrated utilisation policies', 'preventing industrial pollution by combining with technology retrofit policies', 'city environment integrated management policies' and 'environmental industry policies'. In 1986, the State Department announced the Environmental Protection Technology Policy Framework. These policies are the basis of most environmental management instructions throughout China.

In 1995, environmental policies in China shifted to sustainable development, relying on technological progress and increasing investment. The focus of environmental protection changed from industrial pollution prevention and treatment to combining industrial pollution prevention and treatment with environmental protection. The government published the China 21 Agenda, the China Environment Protection Action Plan, the National Ninth Five Year Environment Protection Plan and the 2010 Environment Protection Target Framework.

As general law making in China progressed after 1990, the government made many new environmental laws. Those introduced between 1993 and 1997 included the Air Pollution Prevention Law, the Water Pollution Prevention Law, the Solid Waste Pollution Prevention Law, the Environment Noise Pollution Prevention Law, the Coal Production Law, the Mining Resource Law, the Flood Prevention Law, the Energy Conservation Law and the Earthquake and Disaster Prevention Law. In the meantime, the State Department announced the Water and Soil Conservation Implementation Regulation, the Detailed Rules on Mining Resource Law, the Hydrophilic Wild Animal Protection Implementation Regulation, and the Wild Plant Protection Regulation.

This period also saw environmental protection issues covered by many other laws, such as the Township Enterprise Law, the Electricity Law, the Road Law and the Construction Law.

Environment policies in China can be classed in two groups: one is control policies which use regulation and command to apply environmental standards; the other is economic incentive policies, which use market incentives in an attempt to internalise environmental costs and change the behaviour of consumers.

In general, there are five levels of environmental policy in China: laws made by the Chinese Congress; 'principal guidance' by the central government; policies announced by the State Department; policies announced by ministries; and policies made by local congress within the framework of national policies.

Chinese environmental policies have six main characteristics.

- National social economic development strategies describe sustainable development.
- Environmental protection should be merged into national social economic development planning for economic policies and indicators, by fully implementing China Agenda 21.
- Environmental protection measures will increasingly rely on market instruments to achieve their desired impacts.
- The reform of state-owned enterprises will be accelerated and government administration of environmental management in enterprises will be improved.
- Administration will be improved and reasonable intervention will be better implemented.
- Environmental management institutions will be improved.

The announced target for environmental protection is that China should halt the degradation of the environment, and be ready to begin rehabilitation, by 2010.

Given the major impact of energy production, transportation and energy use on the environment, energy policies will play a key role in achieving this target. In addition to demand side policies to encourage energy conservation and reduce the proportion of coal in end use by shifting to renewable energy development, the government has introduced environment-oriented policies to control pollution. There are three major environment policies in the energy sector.

- '*One control' and 'two reaching standard'*. This policy began in 1996. 'One control' is an emission quantity control which is applied to 12 pollutants. The 'two reaching standard' required all industrial pollution sources to reach the national standard by 2000 and required all major cities (of which there are 47) to reach the national standard for air quality and ground surface water quality by 2000. Air pollution measures involve smoke and dust, industrial dust and SO_2; water quality involves chemical oxygen demand, petroleum, cyanide, arsenic, mercury, lead, chrome and cadmium. Solid waste refers to industrial solid waste. By 2000, emissions of the 12 pollutants were lower than the national standard and had reached the target. However, only 16 of the 47 cities reached the national air quality standard and only 29 cities reached the ground surface water quality standard, far behind the targets.
- *Acid rain and SO_2 pollution control zone.* In order to prevent increased acid rain and SO_2 pollution, an acid rain control zone and an SO_2 pollution control zone were established in

a revision to the Air Pollution Prevention Law published in August 1995. The Air Pollution Prevention Law was revised again in April 2000, capping total pollution emissions. The 'two control zone' policy applies to 1.09 million km^2, 11.4 per cent of China's total land area. The target of the 'two control zone' policy was for industrial emissions of SO_2 to reach the national standard by 2000 and for total quantity control to be applied. Total SO_2 emissions are expected to reach the national standard by 2010 and be lower than those of 2000, mitigating the acid rain situation. Major countermeasures include making it illegal to construct coal mines with a sulphur content higher than 3 per cent; the mandatory construction of coal washing plants for coal mines with a sulphur content higher than 1.5 per cent; and construction of desulphurisation technology for power plants with sulphur contents higher than 1 per cent. Additionally, coal fired power plants are not allowed to be constructed near cities. Countermeasures also call for further research, policymaking, monitoring, and training.

- *Sulphur trading market.* A pilot emission trading system was established in 2001. This is an extension of sulphur control policies in China.

Impacts of environmental requirements on energy use

In order to meet national and local regulations and policies on the environment and various energy policies relating to energy efficiency, the government issued new regulations on new and renewable energy development.

Energy development and conservation

Historically China has been a centrally planned society. Government instruction therefore strongly affects all activities, including energy activities. The energy industry is currently being restructured; the government has announced more and more policies and countermeasures involving standard and market-based policies. The aim is to increase energy efficiency in order to provide sufficient energy to support economic development while at the same time protecting the environment. There are 10 main policies and countermeasures.

- *Energy efficiency planning.* Energy efficiency planning is part of the National Five Year Plan. It focuses on energy use per industrial output value, energy requirements for major industrial products and the capacity for energy conservation. It also includes some targets for rural energy production, and outlines requirements for energy conservation in specific sectors and enterprises.
- *Energy efficiency standards.* By the end of 1998, the government had announced nearly 100 efficiency standards. It had also published a catalogue for machinery and electronic products

that mentioned 608 energy saving products and 610 products whose use should be discontinued.

- *Favourable prices.* The government made provisions for favourable prices for independent power plant investors: prices could be decided based on payback of loans and profit levels.
- *Tax incentives.* There are tax incentives for co-generation, energy efficient buildings, the import of wind turbines, and small hydro and biogas facilities. Some provinces have no tax levy for wind farms in their first two years of operation.
- *Favourable loans.* There are favourable loans for energy conservation projects, with interest rates averaging 30 per cent less than other loans.
- *Price incentives.* There are price incentives for energy saving by enterprises. This policy began in 1985, with prices 8–10 per cent of value by energy saving.
- *Subsidies.* There are subsidies for energy saving stoves in rural area, for biogas promotion and for the production of briquettes for use in cities. .
- *Energy conservation projects.* Governments are organising important energy conservation projects. Examples are retrofitting better cement industry technologies, retrofitting fans and pumps, projects on energy conservation in China supported by the World Bank and the Global Environment Facility, green lighting, renewable energy commercialisation, forest energy projects, a pilot project for straw utilisation, plans for clean production, and promoting the adoption of clean vehicles.
- *Deregulation of energy prices.* There has been a move to accept the principle that energy prices should be decided by the market, with increased energy prices acting as an incentive to conserve energy usage. Beginning in 1990, energy prices generally adopted a market-based system, moving away from the earlier government controlled system. Currently, only some large power plants and residential users face government controlled prices.
- *Reform of important energy industries.* The system of administration of China's oil industry has changed with the historical transformation of management mechanisms in the oil companies. There are three major companies for oil and natural gas production in China. Power generation reform is ongoing; the major activities for reform are the separation of government functions from power generation and the separation of power generation from distribution. This reform is intended to increase competition and open up the power industry in China.

Energy-intensive sectors

Energy is not used uniformly across all industries in China. Focusing on key energy-intensive industries is an important part of China's energy conservation effort. There are five major policies on energy conservation in energy-intensive sectors.

- *Improving energy management.* In most energy-intensive sectors, national administrations (including ministries and industry associations) are pressuring enterprises to bring energy conservation into their enterprise management. A key part of this process is making management accountable for enterprise energy statistics, exceeding the set energy quota and transforming energy conservation technologies.
- *Setting graded energy consumption quotas in goods and products.* This has occurred with various energy-intensive products. For example, in 1990 the State Standardisation Administration set graded quotas of energy consumption and statistical and calculation methods for 22 major building material products (such as cement, cement products, plate glass, sanitary building ceramics, sintered bricks and tiles) which are applied to energy consumption quota management.
- *Discarding technologically outdated equipment.* Sector administrations have established regulations for discarding outdated equipment. For example, in 1999 the State Economic and Trade Commission issued the Catalogue of Backward Production Capacity and Products for Elimination, which banned the use of outdated equipment and required organisations already holding such equipment to discard it at fixed times.
- *Incentive policies.* In 1985, the state established a special fund for 'Basic Energy Saving Construction' as well as a special fund for energy saving technologies. In 1995 the government established a favourable loans system for basic energy saving infrastructure construction projects. This system provided loans at 30 per cent below the cost of standard commercial loans. An Award for Energy Saving of Enterprises was established. The state has also actively promoted clean production among enterprises, giving preference to its investment for projects which could optimise energy consumption and conservation, environmental protection, and comprehensive utilisation of resources. In 1993, the State Taxation Administration promulgated the Notice on Exempting some Wall Materials from Value-Added Tax (VAT). In the same year, the Ministry of Finance and the State Taxation Administration jointly issued the 'Notice Exempting some Products which Utilise Resources from VAT'. The two documents provide that raw building materials mixed with no less than 30 per cent of coal gangue, bone coal, fly ash, and industrial slag are exempt from VAT.
- *Technological innovation for energy conservation.* This is commonly used in many energy-intensive sectors. In the building material sector, 14 energy conservation measures have been applied to vertical cement kilns. For example, people have carried out comprehensive energy conservation innovation in vertical kilns, and have installed power-generating equipment by residual heat in middle-hollow kilns. There has also been some renovation of rotary kilns – for example, changing from wet kilns to dry or semi-dry manufacturing.

Transportation

Since the 1980s, China has adopted active investment and industrial development policies, and greatly promoted the development of the communications and transport industry. This has been achieved under five main policies.

- *Policy on Automobile Manufacturing Industry.* Promulgated in 1994, this policy encouraged automobile manufacturers to improve technology levels and to use energy saving and low pollution technologies and products.
- *Notice Preventing the Manufacture and Sale of Automobiles Fuelled by Leaded Gasoline.* This document, issued by the Administrative Office of the State Council, stipulates that, as of 1 January 2000, all gasoline producers in China should produce lead-free gasoline with a gasoline grade of 90 or above and, from 1 July 2000, stop selling and using leaded gasoline.
- *Suggestion on Application of a Smooth Traffic Project to China's Urban Road and Transport Management.* This document was disseminated by the Ministry of Public Security and Ministry of Construction in 2000.
- *Rules on energy saving in the railways.* Under the Temporary Detailed Rule on Railway Energy Saving Management, issued in 1986, and the Detailed Rule on Implementation of the Law of Energy Conservation among the Railway System, issued in 1998, all 14 railway bureaus adopted energy saving management methods. There is also the Policy on Railway Energy Saving Technologies, promulgated in 1999.
- *Rules on energy saving in shipping.* These include the Regulation on Publication of Energy-Saving Products among the Fields of Automobiles and Ships, issued in 1992; the Measure on Popularisation and Application Management of Energy Saving Products (Technologies) used by Automobiles and Ships, issued in 1995; and A Detailed Rule among the Transport Industry on Implementation of the Law of Energy Conservation, issued in 2000.

In urban transport, major large cities have basically replaced carburettor motor cars with electric sprayer cars. Some large cities have popularised the principle of 'public transport first', designating special lanes for public buses and improving transport efficiency. In Shanghai, Beijing and some other major cities, advanced intelligent transport management systems have been applied, greatly improving transport management and the efficiency of urban transport networks.

Electric power sector

Environmentally beneficial development policies have been implemented in China's power sector since 1995. Priority has been given to developing hydropower, optimising thermal power, properly developing nuclear power, strengthening electric network development and developing new and renewable energy generation in accordance with local conditions.

- *'Development of hydropower shall be given priority'*. Between 1995 and 2000, the installed power generating capacity in China increased from 217 GW to 319 GW, with an average annual growth rate of 8.0 per cent. Of this growth in generating capacity, the installed hydropower generating capacity increased from 52.2 GW in 1995 to 79.35 GW in 2000, with an average annual growth rate of 8.7 per cent. By the end of 2000, the capacity of large and medium-sized hydropower projects under construction amounted to 31.679 GW.
- *'Nuclear power shall be developed properly'*. In 1994, Qinshan Nuclear Power Station, the first nuclear power plant in China, was put into commercial operation. By 2000, China's nuclear power generating capacity was 2.1 GW with a further 6.6 GW under construction.
- *'Wind power shall be promoted'*. In the 1980s, China began to build demonstration on-grid wind power farms with imported generating sets. Since the 1990s, the government has implemented a series of preferential policies to encourage the development of wind power generation. These include connecting wind power farms to the power grid, using the grid to purchase all electricity generated by wind farms, and setting prices to cover all costs, loan repayments, and rational profits.
- *'Efficiency improvement for coal fired thermal power generation'*. In 2000, coal fired thermal power generation accounted for 80 per cent of total national power generation in China, and coal will remain the main source of electricity in coming years. To this end, China has adopted two major steps: shutting down small coal fired generating units, and replacing them with large and high-efficiency units. In the early 1990s, the Chinese government called for the replacement of small thermal generating units with larger, more advanced ones or the transformation of small coal fired generating sets into co-generation sets. Since 1995, the government has promulgated several regulations restricting the construction of small coal fired generating units and shutting down those which already exist. According to early estimates, from 1996 to 2000 about 13.1 GW of small coal fired generating units were replaced and around 10 GW of small coal fired generating sets with a unit size below 50 megawatts (MW) were forced to shut down.
- *'Technological retrofit for large and medium-sized thermal generating units'*. Since 1989, China has technically retrofitted domestically manufactured 200- and 300-MW thermal generating units. By 2001, about 20 per cent of 200-MW units had been retrofitted, resulting in an average fuel rate reduction of about 14.29 tons of coal equivalent (tce) per kilowatt hour.
- *'Development of co-generation'*. Between 1995 and 2000, installed co-generation capacity increased from 16.538 GW to 28.676 GW, with an annual growth rate of 11.6 per cent. Policy measures are in place to encourage co-generation.

- *'Promotion of clean coal generation technologies'*. China currently has a 15-MW experimental PFBC-CC[1] plant, and is preparing to build a 100-MW PFBC-CC demonstration station and a 300–400-MW IGCC[2] demonstration station. The manufacturing technologies for a 300-MW CFBC[3] generating unit have been introduced into China and the localisation of manufacturing equipment has started. In order to accelerate the development of clean coal generation technologies, the State Planning Commission issued a preferential policy for clean coal generation technology and demonstration projects in July 2002. The policy includes custom duty and VAT reductions or exemptions for imported equipment for demonstration projects. In the construction of demonstration projects, preferential loans are given to clean coal combustion technologies as a priority so as to reduce the cost of relevant projects.
- *'Reducing transmission and distribution losses'*. China's power grids are generally equipped with outdated devices resulting in comparatively high transmission and distribution losses. In response to this situation, China has significantly increased capital investment for updating and constructing urban and rural grids in recent years.
- '*Promotion of demand side management'*. Great efforts have been made to promote demand side management since it was introduced into China in the early 1990s. Numerous experiments and demonstration projects have been carried out. In December 2000, the State Economic and Trade Commission and State Planning Commission jointly issued the Management Method for Electricity Saving, incorporating demand side management in the form of regulation. In 2002, the State Economic and Trade Commission issued the Directive for Promoting demand side management, clarifying the responsibilities of government, power enterprises, energy service intermediaries and electricity users in implementing demand side management.

Building energy conservation

By the end of 2000, houses in Chinese cities occupied an actual building area of 7.66 billion m^2; for rural regions, the comparable figure was 31 billion m^2. In 2000 alone, the area expanded by 1.82 billion m^2. In the same year, 1.11 billion m^2 of housing had a district heating supply; heat for other houses was mainly through scattered small boilers. Coal accounted for more than 90 per cent of the energy consumption for heat supplies; natural gas and electric power accounted for only a very small portion. Air conditioners are increasingly common in residential dwellings and public buildings.

China began to promote the construction of more energy-efficient buildings in the 1980s. In November 1992, the State Council issued a notice on stepping up the renovation of wall materials and disseminating energy saving building technologies. In 1995, the Ministry of Construction promulgated the Policy on Building Energy Saving Technologies, which put forward draft concrete policies on technologies for building layouts, surrounding facilities and heat supply air conditioners. In February 2000, the Ministry of Construction issued a regulation on the management of energy conservation in residential buildings.

In 1986, the former Ministry of Urban and Rural Construction and Environmental Protection issued the Standards on Energy Saving Layout for Residential Houses. The document stipulates that energy consumption for the heating of newly built residential houses should be reduced by 30 per cent from the local standard universally applied from 1980 to 1981. In 1995, the Ministry of Construction revised the document, setting a target for residential energy consumption for building heating in northern areas of a saving of 50 per cent compared to the previous standard.

Since the late 1990s, technologies for building insulation have progressed substantially in China. Plastic windows, aluminium windows, middle-hollow glass windows and other types of windows have been widely used in the country, showing obvious advantages in temperature control and heating supply measurement. At the same time, there has been tangible progress in developing technology for applying solar energy in buildings.

To develop and spread highly efficient electric lighting products to satisfy increasing demands for lighting quality, save illumination electricity and reduce environmental pollution, the State Economic and Trade Commission, together with several ministries and commissions, such as the State Development and Planning Commission and the Ministry of Construction, launched the Green Lighting Project in China in October 1996. From 1996 to 1998, 267 million highly efficient electric lighting products were installed in China, saving up to 17.2 billion KW in electricity.

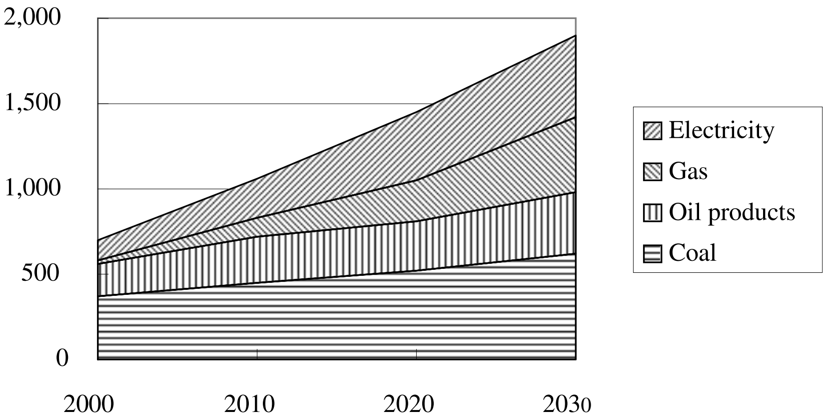
The above technologies provide a relatively comprehensive set of energy saving products for buildings which should aid China in its goal of curbing energy consumption.

Energy and emission scenarios

Energy demand is calculated using the Integrated Policy Assessment Model for China (IPAC). Baseline scenario results are given in Figures 5.5 and 5.6. Primary energy demand in the baseline scenario could go to 2.1 billion toe in 2020 and 2.7 billion toe in 2030. The expected annual growth rate from 2000 to 2030 is 3.6 per cent, while the energy elasticity of GDP is 0.58. Coal will be the major component of energy in China (2.2 billion tce in 2030), with a 58 per cent share in total energy demand. There is a rapid increase in natural gas demand in China, with its share in total primary energy use expected to increase from 4 per cent in 2000 to 17.3 per cent in 2030 (annual growth rate of 10 per cent).

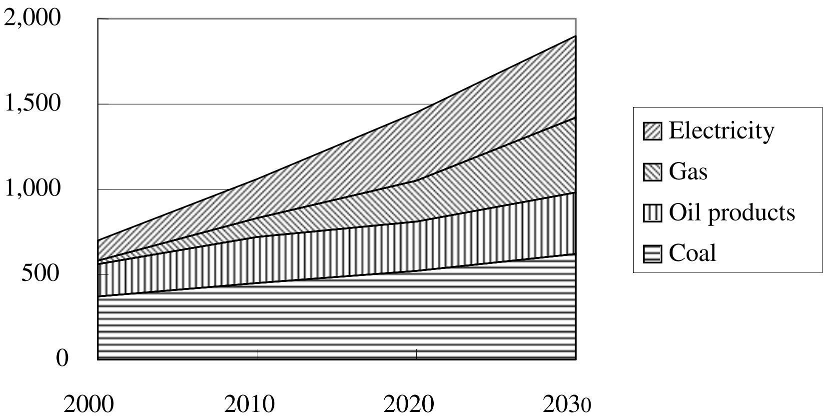
With respect to final energy use, electricity and natural gas increase rapidly. Electricity demand increases from 112 million toe in 2000 to 478 million toe in 2030. Natural gas

Figure 5.5 Primary energy demand in China (baseline scenario) (Mtoe)



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

Figure 5.6 Final energy demand in China (baseline scenario) (Mtoe)

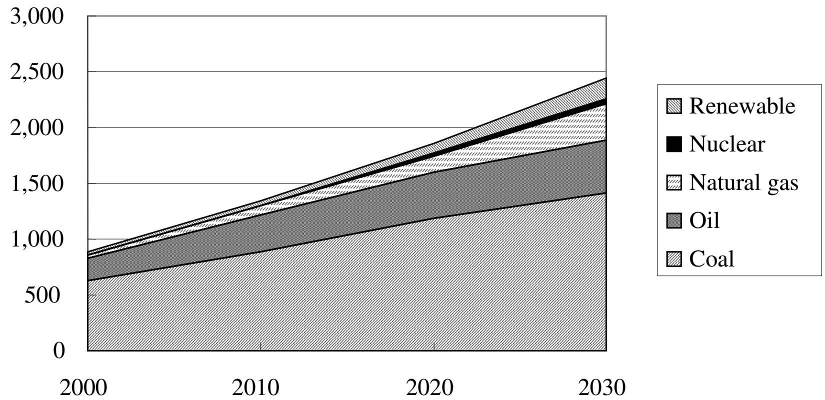


Note: Mtoe = million tons of oil equivalent.
Source: Authors' calculations.

demand increases from 21 million toe in 2000 to 437 million toe in 2030. Coal and oil demand increases 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. 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 105 million tce in 2000 to 457 million tce in 2030.

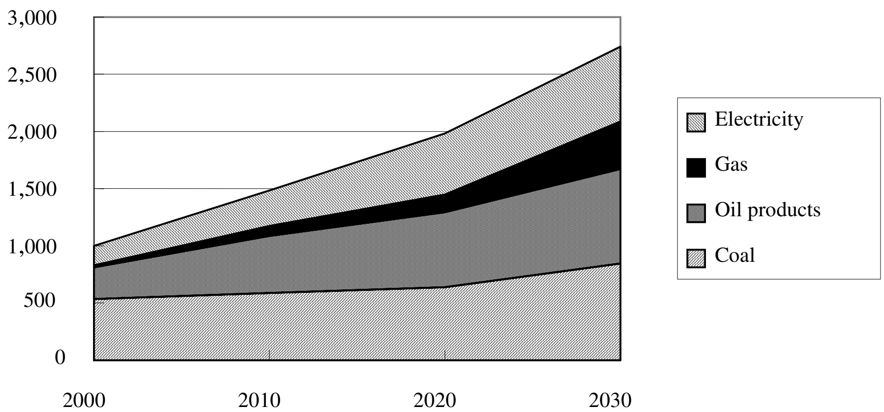
The policy scenario results based on the adoption of energy and environmental policy measures are described in Figures 5.7 and 5.8. In 2020 there is nearly 245 million tce less energy demand than in the baseline scenario, and there is 280 million tce less in 2030. There is great pressure to apply suitable policy options in order to reach the lower energy demand scenario. It is also important to implement the recommended policies quickly. If this is not done, China is likely to suffer from unsuitable technologies for many years, due to their long lifespan and large capital cost..

Figure 5.7 Primary energy demand (policy scenario) (Mtoe)



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

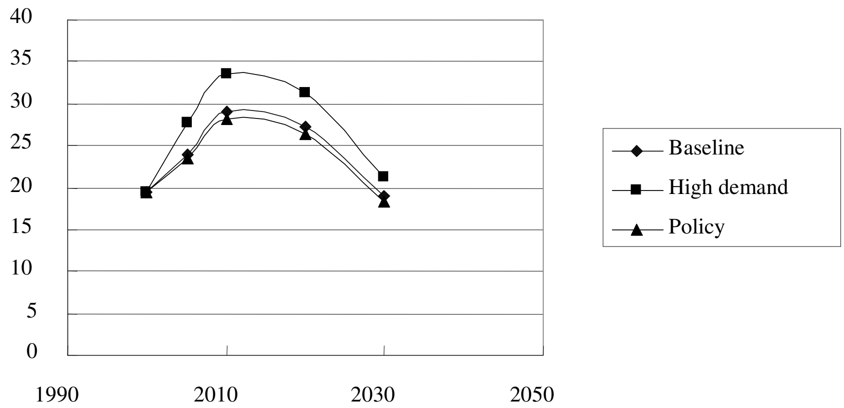
Figure 5.8 Final energy demand (policy scenario) (Mtce)



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

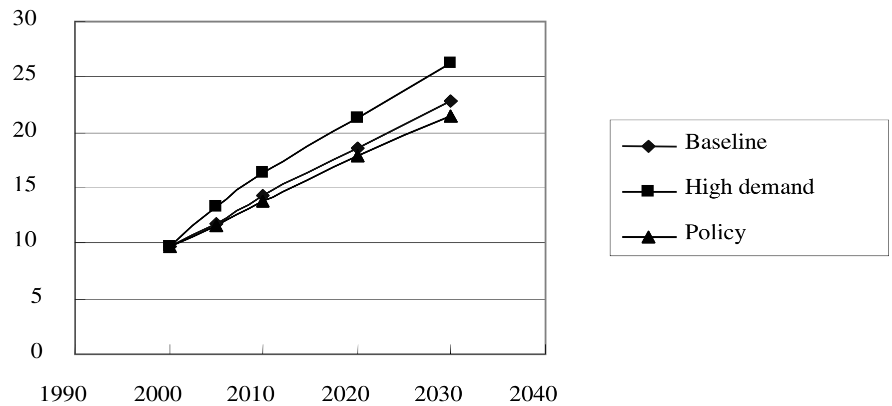
Figures 5.9–5.12 show SO_2, NO_x, TSP and CO_2 emissions from energy activities, calculated using our figures for projected energy demand. SO_2 emissions will continue to increase before 2010 with the rapid increase of coal use in China. After 2010, more and more desulphurisation technologies will be used and therefore SO_2 emissions will become much less significant. SO_2 emissions for the baseline scenario in 2010 are 4.5 million tons lower than the high demand scenario, but this is still 9.45 million tons higher than in 2000. This will be

Figure 5.9 SO_2 emissions in China (million tons of sulphur)



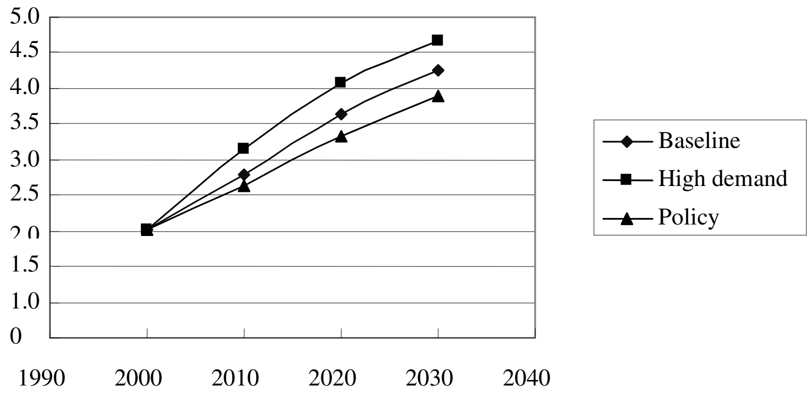
Note: SO_2 = sulphur dioxide.
Source: Authors' calculations.

Figure 5.10 NOx emissions in China (million tons of NO_2)



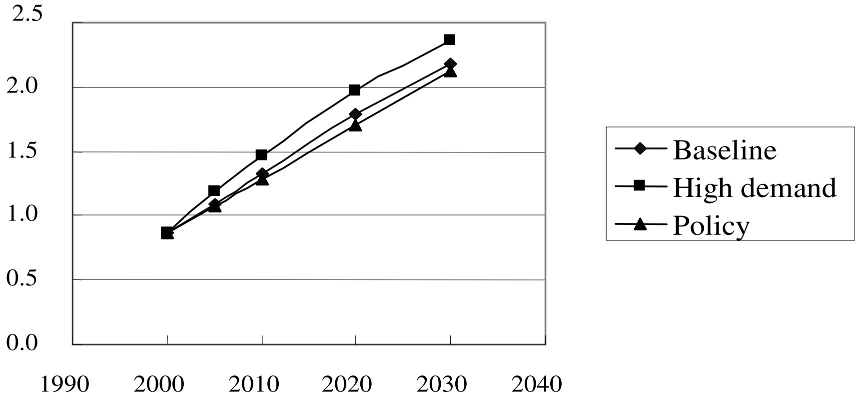
Note: NOx = nitrous oxides; NO_2 = nitrogen dioxide.
Source: Authors' calculations.

Figure 5.11 TSP emissions in China (million tons of CO_2)



Note: CO_2 = carbon dioxide; TSP = total suspended particulate.
Source: Authors' calculations.

Figure 5.12 CO_2 emissions in China (billion tons of carbon)

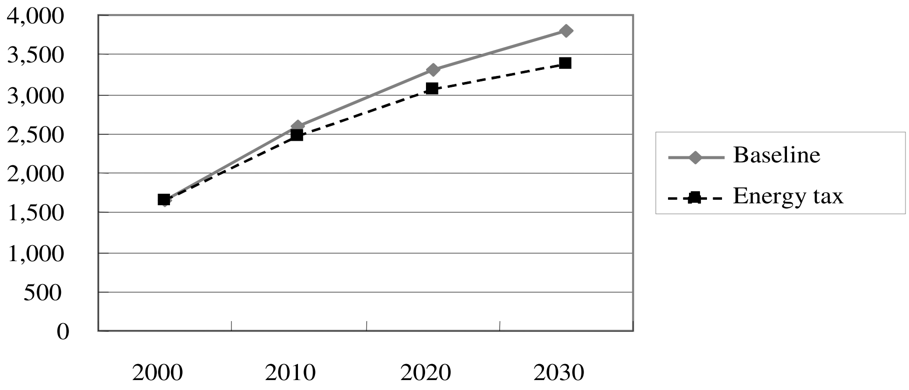


Note: CO_2 = carbon dioxide.
Source: Authors' calculations.

a major challenge for the government's targets. NO_x emissions continue to rise because there is no policy to control them. The same trend is seen for TSP emissions.

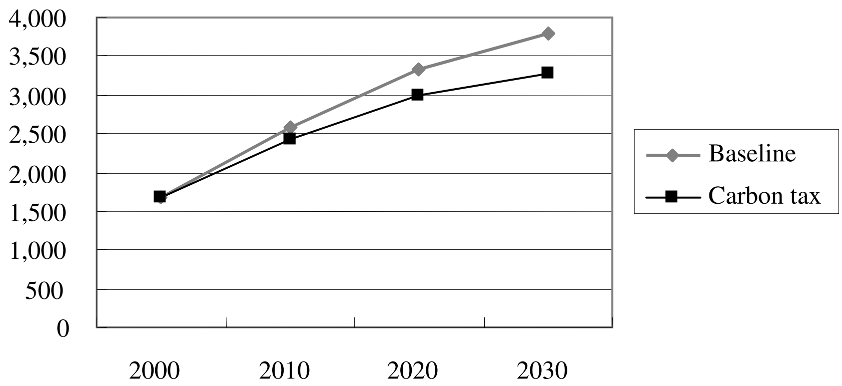
The IPAC modelling team at the Energy Research Institute (ERI) have produced long-term energy and emission scenario studies.[5] Figure 5.13 and 5.14 present the results. They show that there are very different possible pathways for future energy consumption and emissions in China.

Figure 5.13 Impact of carbon tax on energy demand (Mtce)



Note: Mtce = million tons of coal equivalent.
Source: Authors' calculations

Figure 5.14 Impact of vehicle fuel tax on energy demand (Mtce)



Note: Mtce = million tons of coal equivalent.
Source: Authors' calculations

Future perspectives

With the rapid growth in per capita GDP in China, environmental problems will become more and more important in China's socioeconomic development. Energy related activities are one of the major emission sources, so energy use will be further impacted by environmental issues. Domestic environmental problems such as air pollution, water pollution, land damage and toxic material emissions could be a major concern in the near future and therefore have a strong impact on energy use in China. Recently climate change issues have been getting much more attention in the world, including in China. From a long-term viewpoint, climate change will have a significant impact on energy use in China.

Technologies are also identified in the IPAC modelling study for energy conservation. Table 5.6 presents the energy conservation technologies available for the near future.

The emergence of some new technologies could change the pathway for future energy activities. The long-term scenario study for China suggested that the following key technologies are important in dealing with climate change:

Table 5.6 Technologies contributing to greenhouse gas emission reduction in the short and medium term

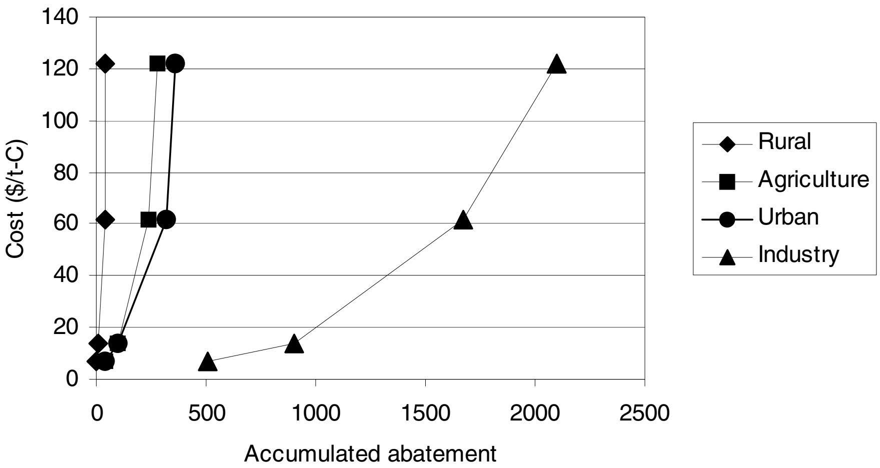
Sector	Technology
Steel industry	Large equipment (coke ovens, blast furnaces, basic oxygen furnaces etc.). Equipment for coke dry quenching; continuous casting machines; top recovery turbines; continuous rolling machines; equipment for the recovery of coke oven gas, open hearth gas and basic oxygen furnace gas; direct current electric arc furnace
Chemical industry	Large equipment for chemical production; waste heat recovery systems; ion membrane technology; improvements in existing technology
Paper making	Co-generation systems; facilities for the utilisation of residue heat; black liquor recovery systems; continuous distillation systems
Textiles	Co-generation systems; shuttleless looms; high-speed printing and dyeing
Non-ferrous metal	Reverberator furnaces; waste heat recovery systems; use of the Queneau-Schumann-Lurgi process for lead and zinc production
Building materials	Dry process rotary kilns with pre-calciner processes; electric power generators with residue heat; coal-burn processes; Hoffman tunnel kilns
Machinery	High-speed cutting; electric hydraulic hammers; heat preservation furnaces
Residential	Cooking by gas; centralised space heating systems; energy saving electric appliances; high efficiency lighting
Service	Centralised space heating systems; centralised cooling heating systems; co-generation systems; energy saving electrical appliances; high-efficiency lighting
Transport	Diesel trucks; low energy use cars; electric cars; natural gas cars; electric railway locomotives
Common use technology	High-efficiency boilers, fuel-cell bus technology; high-efficiency electric motors; speed adjustable motors; centrifugal electric fans; energy saving lighting

- modern renewable energy production (solar energy etc.);
- advanced nuclear power generation;
- fuel cell technology;
- IGCC / advanced clean coal technologies and carbon capture and sequestration;
- advanced gas turbines;
- unconventional natural gas and crude oil production technologies; and
- syn-fuel production technologies.

Figure 5.15 shows the results of a study based on the IPAC-AIM[4] technology.

Figure 5.16 shows the CO_2 reduction potential by sector when the simulation is carried out using a cost range of up to \$50/ton of carbon. The figure shows the emission reduction potential by these sectors with costs less than \$50/ton of carbon. Figure 5.17 gives a detailed explanation for the contribution to CO_2 emission reductions. In order to reach a lower emissions future, the energy system has to be changed to align with the targets.

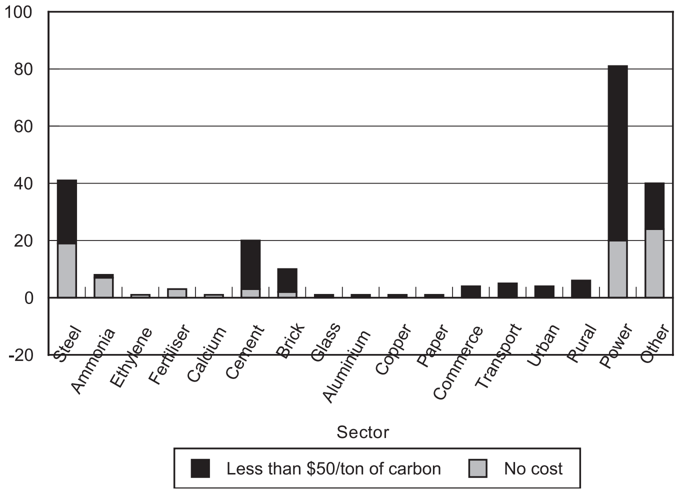
Figure 5.15 Marginal abatement cost curves by sector



Notes: a Average cost for CO_2 abatement (\$/ton of carbon).
b Accumulated CO_2 abatement (million tons of carbon). This is the accumulated CO_2 reduction from the subsidy introduced in 2000 to 2010 compared to the market case.

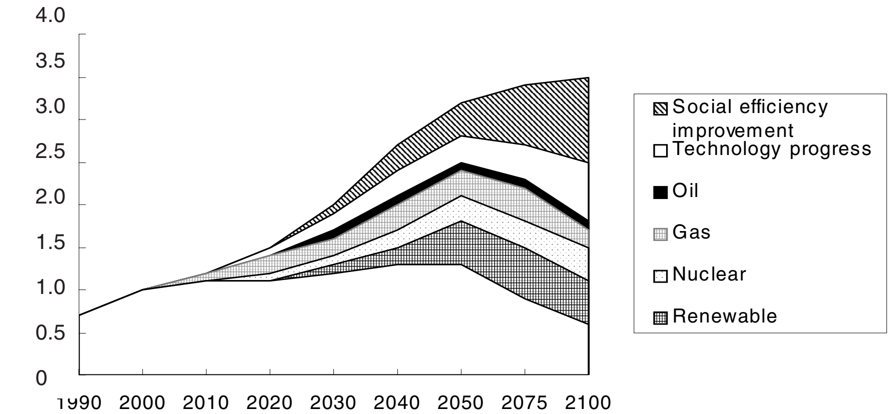
Source: Authors' calculations

Figure 5.16 Emission reduction potential by sector



Source: Authors' calculations.

Figure 5.17 Contribution to CO_2 emission reduction



Note: CO_2 = carbon dioxide.
Source: Authors' calculations.

Conclusion

It is clear that energy development in China is already fully impacted by local environmental issues such as air pollution, water pollution, land damage, and toxic material emissions.

Energy policies have been driven by environmental pressures such as those experienced in developed countries. This trend will continue as further challenges, such as climate change, are expected. In order to reach sustainable development targets, policies for a clean energy future should be well developed. Energy development policies that take into account environmental needs should be consistent with economic development policies such as industry development policy and international trade policy. China's government must follow a consistent and fully integrated approach to these major and long-term challenges.

Notes

1 Pressurised fluidised bed combustion – combined cycle.

2 Integrated coal gasification combined cycle.

3 Circulating fluidised bed combustion.

4 Asian-Pacific Integrated Model.

5 See <http://china.lbl.gov/publications/scenarios_summary_01apr04.pdf>.

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6 Energy Market Reform in the Electricity Power Sector in China

Yong Zhao

Introduction

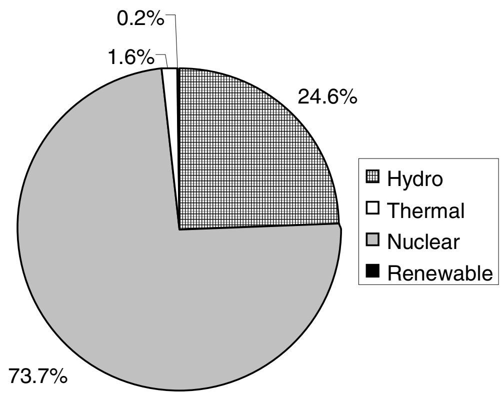
Delivering energy on demand to 1.3 billion people is not a simple task. The physical and institutional infrastructure dedicated to generating and delivering energy in China is complex and has undergone frequent reform. Yet people seeking a thorough knowledge of energy strategies can not overlook this critical issue. This paper reviews the current structure of the electric power sector in China, including the approach to electricity pricing and the ownership structure of the electricity generation and distribution services. It also examines changes that have taken place in the power market and canvasses changes that might be considered in the future.

Status of China's electricity markets in 2004

Generation capacity[1]

By the end of 2004, the total installed capacity of electricity generation was 440.70 gigawatts (GW), 12.6 per cent higher than 2003. Hydropower capacity grew to 108.26 GW, 14.1 per

Figure 6.1 Installed capacity in 2004



Source: National Statistical Bureau (2005).

cent higher than in 2003; thermal power capacity reached 324.90 GW, 12.1 per cent higher than in 2003; and nuclear power capacity increased by 10.6 per cent, amounting to 6.84 GW. The rest, 0.70 GW, was composed of wind power and other renewables.

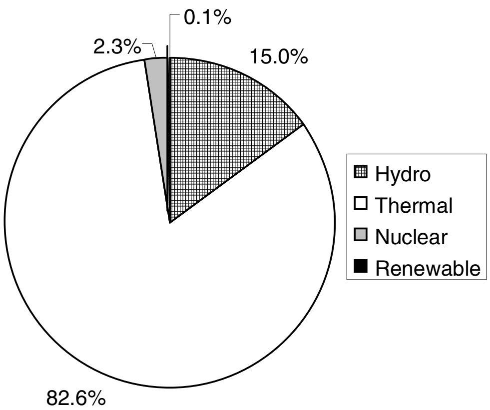
Obviously, thermal power dominated generation capacity, with a share of 73.7 per cent. With capacity growing beyond 100 GW, hydropower retained its share of 24.6 per cent. The shares of nuclear and renewable power were 1.6 per cent and 0.2 per cent respectively (see Figure 6.1).

Annual generation[2]

China's total electricity generation in 2004 was 2,187 terawatt hours (TWh), 14.8 per cent higher than in 2003. Hydropower generation reached 328 TWh, with an annual increment of 16.6 per cent; thermal and nuclear power generated 1,807 TWh and 50 TWh respectively, 14.5 per cent and 14.1 per cent larger than in 2003. Renewable energy produced 1.60 TWh of power, with a remarkable increase of 60.0 per cent from 2003.

Despite installed capacity of non thermal electricity accounting for over 25 per cent of total installed generating capacity in 2004, only 17.4 per cent of consumed electricity was actually generated from non thermal sources. As illustrated in Figure 6.2, thermal power accounted for 82.6 per cent of the total annual electricity generation, compared with 15.0 per cent for hydropower and 2.3 per cent for nuclear power. Renewable energy does not yet play an important role in electricity generation, though its annual growth rate is impressive.

Figure 6.2 Power generation in 2004



Source: National Statistical Bureau (2005).

The discrepancy in the composition of electricity generating *capacity* and the *actual* electricity generation is due to differences in the utilisation hours of different generating units. In 2004, generation units (power plants) were, on average, utilised for 5,460 hours. Thermal units averaged higher than the overall average, at 5,988 hours, while hydropower units were utilised for only 3,373 hours on average. As we know, China suffered from a shortage of electric power from 2002 to 2004 and from dry years in 2003 and 2004. As a result, in 2004 the supply of electricity relied even more than usual on thermal power.

Electricity consumption

In 2004, the total consumption of electricity in China was 2,173.5 TWh (14.9 per cent higher than in 2003) (NSB 2005). Primary, secondary and tertiary industries consumed 61.2 TWh, 1,625.8 TWh and 243.5 TWh respectively, representing increases of 2.7 per cent, 16.4 per cent and 15.2 per cent over their respective values in 2003 while residential consumption of electricity reached 243.0 TWh (8.2 per cent higher than in 2003). The primary, secondary and tertiary industries and the residential sector accounted for 2.8 per cent, 74.8 per cent, 11.2 per cent and 11.2 per cent of total electricity consumption respectively.

Power grid

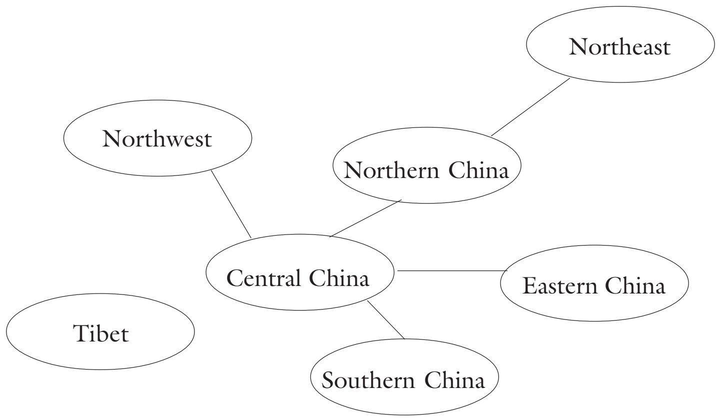
China's mainland energy grid is composed of six regional grids and one provincial grid (Tibet). As shown in Figure 6.3, the six regional grids are interconnected. Connections exist between the Northeast and Northern Grids, Northwest and Central Grids, Northern Grid and Central Grids, Eastern and Central Grids, and the Southern and Central Grids. These six interconnected regional grids form the skeleton of a nationwide interconnected power network. The Central China Grid, where the Three Gorges Hydro Station lies, plays a central and critical role in electricity interconnection all over the nation.

The Southern China Grid Company is responsible for grid management and electricity distribution and transmission in southern China, while the State Grid Company manages the other six grids (including the Tibet grid). Both the Southern China Grid Company and the State Grid Company are state owned.

Ownership

The energy generation industry is considered to be separate from energy transmission and distribution services in China. While transmission and distribution are managed solely by the two state-owned grid companies, energy generation is generally achieved by the private

Figure 6.3 Regional power grids in China



sector. Most of the generation assets in China are owned and run by independent private producers. While around 10 per cent of generation assets are still under the control of the grid companies, 36 per cent are managed and operated by five state-owned independent private producers: the China Huaneng Group, China Datang Group, China Guodian Group, China Huadian Group and China Power Investment Group. The remaining 56 per cent of generation assets are owned by provincial investment companies, private owners and foreign investors.

All the transmission and distribution assets are owned and operated by state-owned grid companies. Rural distribution assets are usually owned by local (county level) governments.

Pricing approaches

Electricity prices are highly complicated in China – perhaps the most complicated anywhere in the world. In the past there were three categories of tariffs: bus bar tariffs,[3] wholesale tariffs and end-use tariffs.

Bus bar tariff regimes

Prior to 2000, the bus bar tariff rate was set by the government pricing department for individual power plants (and even individual energy generating units) according to a 'loan payback' system. This price level was set in order to meet the objective of recovering the costs of an individual energy plant (or unit). The result of this system was that each plant was assigned individual and different bus bar tariffs, effectively making electricity a non-homogeneous product.

The loan payback pricing system was terminated in 2000 and replaced by the 'verified operation lifetime' bus bar tariff mechanism. This new mechanism was an improvement over the loan payback price system because it simplified price schedules in China. Under the verified operation lifetime price system, electricity prices were set at the level of overall industry average cost plus reasonable profit (as determined by the government pricing department), rather than at the level of individual production plant (or production unit) costs (including interest).

While the change to the verified operation lifetime price system simplified China's energy price schedules, the system still relied on the government to determine prices rather than allowing prices to be set by market forces. This residual feature of China's planned economic system was corrected in July 2003 when the State Council approved and issued the 'Arrangement for Electricity Price Reform'. This outlined a market-based pricing mechanism for the generation of electricity. Transmission and distribution tariffs appeared in government documents for the first time. The general idea was to allow the market to determine bus bar tariffs and end-use tariffs while the government would continue to determine the tariffs for transmission and distribution (services currently provided by state monopoly grid companies, as discussed above).

In March 2005, the National Development and Reform Commission (NDRC) and other relevant departments issued 'Electricity Price Management Approaches (Temporary)', for bus bar tariffs, transmission and distribution tariffs and end-user tariffs. Pricing reforms of bus bar tariffs were based on four principles. First, both capacity price and generation price should be categorised. Second, the pricing mechanism should be market oriented: when regional power markets are in their infancy only the generation price will be determined by the market, with capacity price determined by the government; however, when power markets mature, both capacity price and generation price will be formulated in the market. Third, flexible transactions should be permitted. Grid companies (as the single purchaser in the power market) should be allowed to make transactions with power producers with flexible quantities of electricity, either on a contract basis or on a spot market basis; in addition, power producers and users should be able to be flexible in selecting bilateral transaction or spot market transactions. Fourth, the interaction between bus bar tariffs and end user tariffs will act as a mechanism for the government to moderate the market of electricity.

However, the regional power markets of the Northeast Grid and Eastern Grid take different approaches, as shown in Table 6.1.

Table 6.1 Approaches to price setting in the northeast and eastern markets

Approach	Northeast market	Eastern China market
Basis of price setting	Capacity price and generation price	Generation price only
Extent of competition	100 per cent of electricity generation enters the power market for competition	Less than 15 per cent of electricity generation competes in the market, with the remainder being contracted
Mechanism for capacity pricing	Capacity price is categorised by specific investment cost for the generation units	
Frequency of transactions	Transactions are made annually, quarterly and monthly	Transactions are made on a daily basis
Tariff stabilisation	Balance account is set to stabilise end-user tariffs	
Operational integration	The regional grid company, dispatch centre and transaction operator are integrated	The regional grid company, dispatch centre and transaction operator are integrated
Inter-provincial transactions		Inter-provincial transactions are 'black-boxed'

Source: Compiled by authors.

Taking the coal price into account

Given that the overwhelming majority of China's energy production comes from coal, changes in the price of coal have a large impact on the cost of generating energy in China. While the price of coal has risen sharply since 2002, under China's energy pricing systems (discussed above) energy producers are not able to set prices in relation to marginal costs. The result of China's pricing systems during a period of rising input prices (coal prices) was that power producers relying on coal fired units found their profitability rapidly deteriorating. In 2004 alone, the price of steam coal rose by 40 per cent while bus bar tariffs remained at their constant, government-determined rate, causing a major reduction in the profitability of energy production.

In response, the NDRC established a biannual adjustment mechanism called the 'conjunction of electricity tariff and coal price'. The mechanism calls for a change in the bus bar tariff rate whenever coal prices reach a particular threshold *and* the NDRC considers the price revision necessary. When, and to what extent, prices can be adjusted is still determined by the NDRC; however, the adjustment mechanism sets an expectation that prices will be allowed to adjust in response to costs, at least in an imperfect sense. On 1 May 2005 there was an increase in the bus bar tariff averaging 0.025 RMB per kilowatt hour (KWh) as a result of this mechanism.

Residential tariffs regime

End-use tariffs, also called retail tariffs, apply to energy for residential daily life use, non-residential daily life use, commerce, non-industry and general industry, large industry, agricultural production and agricultural drainage and irrigation in poor counties. The structure and level of tariffs are different for different categories. As discussed above, end-use tariffs are still under the control of the government. As stipulated in the Price Law, end-use electricity tariffs can be adjusted only after a public hearing. In the long term, end-use tariffs will be determined on the basis of market choice and competition; there will no longer be any necessity for public hearings.

Institutional reforms

China's energy industry has undergone significant institutional reform under the direction of the State Electric Power Institutional Reform Steering Group, headed at the vice premier level. The key reforms since 1997 (China's first year of surplus electricity supply after decades of shortage) are listed in Table 6.2.

Since 2002, all future reform activities have to be consistent with State Council Document No. 5. Document No. 5 required the segregation of energy generation from the transmission and distribution markets, the establishment of the State Electricity Regulatory Commission, and the construction of a regional power market. It established three objectives

Table 6.2 Institutional reforms in the electric power sector

Year	Reform
1997	State Power Corporation established
1998	Ministry of Electric Power abolished
1998–2002	Power reform experiments undertaken with a fraction of generation bidding for dispatch in six provinces, including Zhejiang Province, Shandong Province, Shanghai City, Jilin Province, Liaoning Province and Heilongjiang Province
2001	Generation and transmission separated in Guangdong Province
2002	State Council issued the Arrangement of Electric Power Institutional Reform (Document No. 5)

for institutional reforms in the power sector in China: to break monopoly, introduce competition, increase efficiency and reduce costs; to upgrade the pricing mechanism, optimise resource allocation, facilitate power development, and promote nation-wide interconnections; and to build a power market system under government regulation in which the government and enterprises are separated; this system should promote fair competition and be open and well-ordered.

Document No. 5 also strengthened the idea that the institutional reforms should be supports for developing the power industry; increasing its reliability; mitigating its environmental impacts; and serving the increasing demand of electricity. It emphasised that reform should occur gradually, in stages.

Initiatives

Segregation of energy generation from transmission and distribution markets

Before the implementation of the institutional reform described in Document No. 5, the power sector was a monopoly: the (former) State Power Corporation was responsible for both generation *and* transmission and distribution of energy. The organisational structure and assets distribution of the State Power Corporation is illustrated in Figure 6.4.

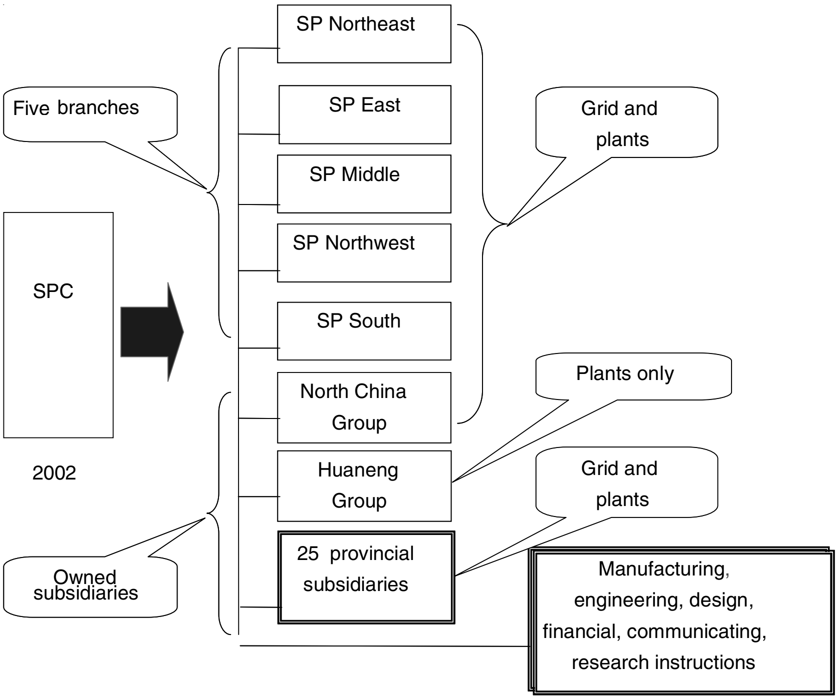
On 29 December 2002, the State Council unbundled the former State Power Corporation. The generation facilities and grid assets were assigned to 11 independent companies, including five generation companies (China Huaneng Group, China Datang Group, China Guodian Group, China Huadian Group and China Power Investment Group); two grid companies (State Grid Corporation and Southern China Grid Company Ltd); two consulting companies (China Electric Power Engineering Consulting Group and China Hydropower Engineering Consulting Group); and two hydro construction companies (China Hydropower Construction Group and China Gezhouba Hydropower Construction Group).

The distribution of the former State Power Corporation's generation and grid assets is illustrated in Figures 6.5 and 6.6.

Establishment of the State Electricity Regulatory Commission

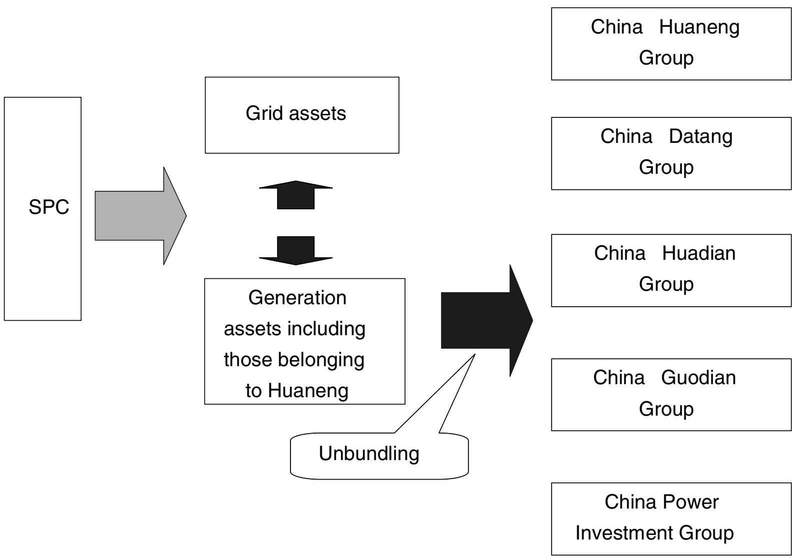
In March 2003 the government established the State Electricity Regulatory Commission (SERC). SERC is designed to be an independent regulator of China's power market. Its main responsibilities are to issue market rules that regulate market operation; to submit suggestions for price adjustments to relevant government pricing departments; to issue and manage

Figure 6.4 Organisational structure of the former State Power Corporation in 2002



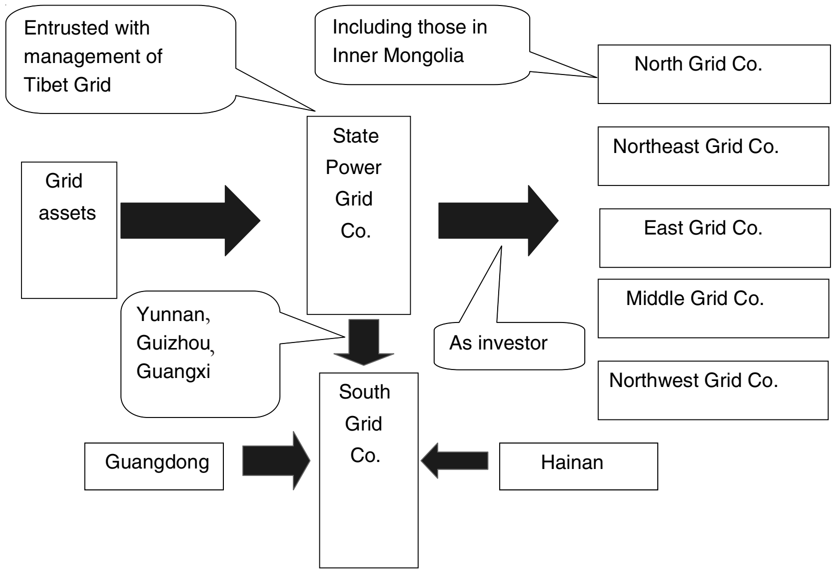
Note: SPC = State Power Corporation.

Figure 6.5 Changes in the ownership of generation assets



Note: SPC = State Power Corporation.

Figure 6.6 Changes in the ownership of grid assets



licences for power businesses and monitor compliance with quality standards; to resolve disputes in the power market; and to monitor the enforcement of social obligation policies.

Although the State Council issued the Electricity Regulatory Code in February 2005, the Electric Power Law enacted in 1996 was not amended. This has raised some doubts about the legal foundation of SERC and its functions. This legal ambiguity could, to a certain extent, explain emerging inconsistencies in the administration of the Chinese power sector by SERC and the NDRC.

Construction of a regional power market

SERC has promoted the construction of regional power markets and competition in energy generation. At the time of writing, two regional power markets had been established and put into operation in the Northeast and Eastern China grids. Two further markets under construction are the Central China power market and the Southern China market (the latter of which was expected to come into being around November in 2005).

Review of reforms

Document No. 5 required five reforms to be completed by 2005:

- the separation of generation from power grid and restructuring generation companies and grid companies;
- the establishment of a bidding system in the power generation sector and a new pricing mechanism;
- the issuing of a standard to convert environmental impacts into monetary value and encourage clean electricity;
- the conducting of experiments on direct supply access for large users; and
- continuing institutional reform in rural electricity.

At the time of writing (as the 4th quarter of 2005 comes), it is time to review the above missions.

Unbundling the generation and grid businesses. The most important achievement of the reform in the electric power sector could be the successful unbundling of generation and grid businesses. This unbundling was achieved with five competitors in the field of generation, along with a number of independent power producers in every grid. There has been keen competition – far beyond expectation – in the construction of new generation plants and units, in grabbing coal resources, and, of course, in decreasing generation costs.

Pricing mechanism. SERC has made ambitious efforts to assist grid companies and relevant government agencies and to establish and promote regional power markets. However the net loss shown in the balance account of the Northeast Power Market places a question mark on the effectiveness of the market structures and mechanisms in place.

Marketisation of environmental externalities. While there has been relatively significant improvement in reducing monopoly structures, separating production and transmission industries and reforming price mechanisms, little has yet been achieved in the monetarisation of the environmental impacts of electricity production or utilisation. The severe shortage in the electricity supply in China that started in 2002 could be considered as one excuse. The State Environmental Protection Administration (SEPA) has made it clear that the environmental impacts of electricity production, transmission and distribution have to be internalised in the decisions about and analysis of power project construction. It is expected that specific incentives and effective mechanisms to promote cleaner electricity will be established.

An experiment on direct supply access for large users of electricity has been conducted in Jilin Province, in northeast China. SERC issued the guideline 'Temporary Approaches for Pilot Direct Purchase of Electricity from Power Producers for Electricity Users' in March 2004. At the time of writing, it was much too early to observe or analyse the performance of this experiment.

Phenomena accompanying reforms

In order to have any insight into the potential for further reform (or to generate lessons for other countries) it is useful to understand the context in which reform has occurred in China. Three key components of China's energy context seem to have been important for reform: shortages of electricity supply, a surge of investment in energy generation, and declining profits in energy generation. Below, I discuss each of these, focusing on their influence on the reform process.

Shortages in the electricity supply

Since 2002, China has been challenged by severe shortages in the electricity supply. Unpredicted steep rises in electricity demand have placed extreme pressure on the energy system, from generation to transmission and distribution. Generation units have had to operate longer than 6,000 hours per annum – sometimes even 7,000 hours. The market pressures caused by this demand surge have been transmitted further upstream, placing pressure on coal production and transportation.

It is estimated that 15–20 GW of power demand went unsupplied in 2003. This figure rose to 30 GW in 2004 and 25 GW in 2005. As a result, interruptions in the power supply became common. Electricity supply services were interrupted in 12 provincial power grids in 2002, (22) in 2003, 24 in 2004 and 21 in 2005.

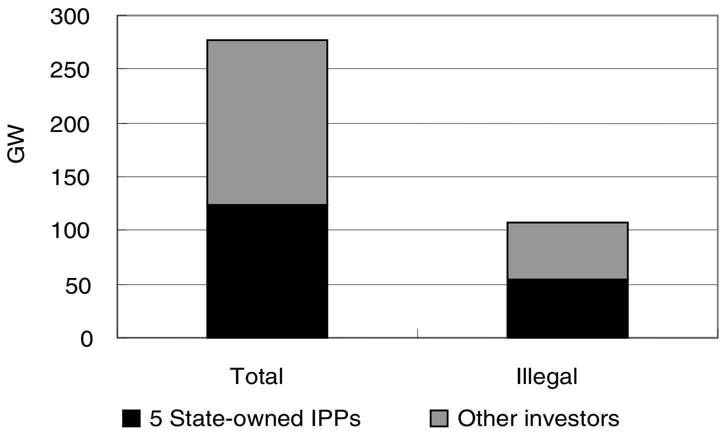
Of course, people can rely on excuses such as higher economic growth than expected, low water flows, extremely high temperatures in summer, the fast growth of heavy industries, and an unbalanced expansion of power grids. However, some experts criticise the timing of the reforms in the electric power sector; they believe that reforms should be undertaken when there is surplus electricity supply, not a deficit in supply.

Surge of investment in power plants

The shortage in the electricity supply has led (rather too late) to huge investment in new energy generation plants and the expansion of existing generation facilities all over the country. According to the NDRC, the total generation capacity of units under construction at the end of 2004 was 280–320 GW, of which around 120 GW was illegal. The five state-owned independent private producers accounted for 100 GW (around 38 per cent) of total construction. They also accounted for about 40 per cent of illegal construction, as shown in Figure 6.7.

The current undersupply of energy and the regular disruption to services clearly require correction through large-scale investment. However, it is possible that the response has

Figure 6.7 Construction in the power sector in 2004



Note: GW = gigawatt; IPP = independent power producer.
Source: NSB (2004).

resulted in over-investment in energy production. Documents issued by the State Council suggest that over-investment in power projects might have four negative impacts on the economy: distortion of electric power planning; waste of resources; accumulation of financial risks; and worsening tension in coal mining and in transportation and equipment manufacturing.

Alternatively, the surge of power construction could be regarded as evidence for the success of the unbundling of the former vertically integrated power system, with realistic pressure resulting from market competition in the generation industry being the direct and primary driver for competition in the construction of new generation units and the expansion of existing units.

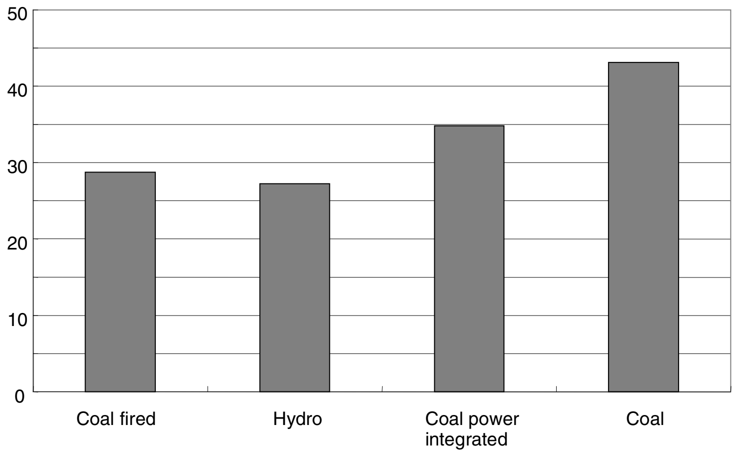
In 2004, around 50 GW of installed capacity came on line, relieving the shortage of electricity supply to a certain extent. At the time of writing it was expected that another 70 GW would be put into operation in 2005. On this assumption, the gap between electricity demand and supply was predicted to be reduced to 10 GW by the end of 2005.

Declining profits of generation companies

More than 80 per cent of electricity generation in China is by domestic coal fired units. Since 2001 the coal price has been rising at much faster than that of bus bar tariffs. This has resulted in the situation discussed in the pricing reform section: generation companies find themselves in a deteriorating financial situation. For example, in 2004 China Huaneng Group, the biggest generation company in China, had to pay an extra RMB 4 billion for fuel because of the rising coal price.

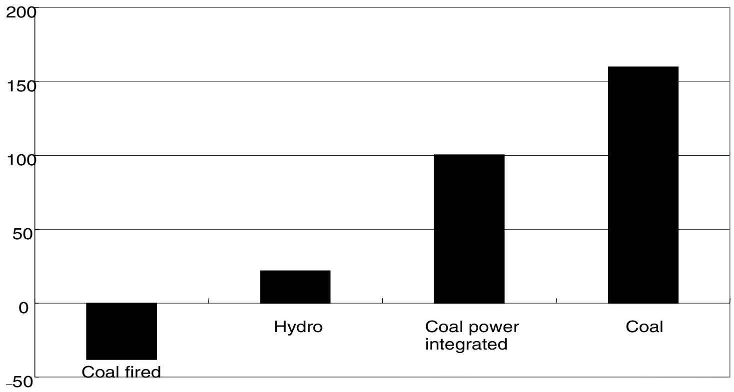
Figures 6.8 and 6.9 compare growth rate of revenue and profits for the first half of 2005 for mainly coal fired generation companies (China Huaneng Group), hydropower companies

Figure 6.8 Revenue of selected power generation companies in China, January to June 2005 (per cent)



Source: NSB (2004).

Figure 6.9 Profits of selected power generation companies in China, January to June 2005 (per cent)



Source: NSB (2004).

(China Yangtze River Power), coal producers (China Coal Group) and integrated coal and power producers (China Shenhua Group).

While there are not large differences in *revenue* growth for different categories of energy companies, the growth rates of *profit* show substantial discrepancies. At one extreme, the profits of coal producers and coal–power integrated producers more than doubled from the previous year; at the other extreme, coal fired generation companies suffered a 40 per cent fall in profit over the same period. In the middle, hydropower companies gained stable and moderate growth in profits, benefiting from better water conditions during the year.

Some may insist that the decrease in the profitability of thermal generation companies is in line with the objectives for the institutional reforms in the Chinese electric power sector defined in Document No. 5. When this is discussed in a broader domain, the whole energy industry, it is not difficult to find evidence for differences in the pace and depth of marketisation in different sectors of the industry. Market-oriented pricing mechanisms for coal, the fuel for thermal electricity generation, together with strictly regulated governmental pricing for retail tariffs for electricity, are shrinking potential profits for generation companies that rely on coal for most of their power generation. This institutional incompatibility between the coal and power sectors implies that there is a transfer of profit from thermal power companies to coal producers.

Possible future reforms

Pricing mechanism

In 'Electricity Price Management Approaches (Temporary)', the NDRC identified the establishment of an interactive mechanism between end-use tariffs and bus bar tariffs as a needed reform. It saw this mechanism as a means for the government to balance electricity supply and demand. Moreover, by manipulating relative prices between coal and electricity bus bar tariffs, the government was attempting to balance profits across both the coal sector and the electricity sector. However, the basis for the above two mechanisms (governmental intervention) is definitely not aligned with the government's stated long-term goal of building a market driven society. The mechanisms could have four main impacts: weaken the market's effect on prices; mislead investors, resulting in either over- or under-investment; result in the embedding of transfer payments; and promote energy-intensive industries and products.

Since the price mechanism lies at the core of institutional reforms in the power sector, improvements have to be made as soon as possible in order to guarantee a sustainable and environmentally friendly electric power industry in China. Three options could be considered. First, the government could formulate a mechanism for bus bar tariffs to internalise environmental costs, thereby providing incentives for the efficient and clean generation of electricity. Second, the government could develop a market-based interactive mechanism between bus bar tariffs and retail tariffs. Third, the government could develop an appropriate structure, mechanism and levels for retail tariffs, abolishing price discrimination and transfer payments, and encouraging the efficient and clean use of electricity.

Unbundling of the dispatch centre and the transaction operator

Currently, China's two established energy markets (in the Northeast and Eastern China grids) integrate dispatch centres and market operators in the regional grid companies. This integration makes the grid companies more dominant in the markets. However, bundling grid services and dispatching services as well as transaction functions in one company injures the market with respect to openness, fairness, transparency and efficiency.

It seems necessary to separate the dispatching function and market operating function from grid companies and to establish independent system operators and independent market operators. Separation of independent system operators and independent market operators from grid companies has proven successful in market practices in North Europe, the United Kingdom and North America.

Coordination among governmental agencies

As discussed above, the unbundling of the energy generation industry from the distribution and delivery industry has been accepted as a successful beginning to the institutional reforms in China's power sector. Progress in the restructuring of management functions is not comparable to that in generation competition. Both vacuum and overlap exist in the management of the electric power industry.

To clarify the interface between NDRC and SERC in the management of the electricity industry, the State Council issued the 'Notification on Functions Shared between NDRC and SERC' in July 2005. Clarifications covered market entrance, tariff management and tariff supervision, as shown in Table 6.3.

Since the electric power sector accounts for more than one-sixth of total state-owned assets, the government agency in charge of state-owned assets, the State-owned Assets Administration Commission (SAAC) cannot be excluded from the institutional network for managing the industry. Further restructuring and clarification of responsibilities and functions is required among government agencies, including NDRC, SERC and SAAC. Table 6.4 shows an alternative structure for the separation of duties between the three principal agencies.

Table 6.3 Responsibilities of the NDRC and SERC as clarified in July 2005

Market entrance	NDRC responsible for review and approval of power construction projects with results copied to SERC SERC responsible for issuance and management of electric power business licences, with results copied to NDRC
Tariff management	NDRC responsible for regulations, policies, nationwide tariff adjustments, retail tariffs, inter-provincial transmission tariffs and distribution tariffs, and non-competitive bus bar tariffs SERC responsible for suggestions on inter-provincial tariffs, ancillary service prices, inter-regional transmission tariffs and distribution tariffs, adjustment on retail tariffs and large user tariffs, and capacity prices NDRC and SERC jointly responsible for cost review approaches for transmission and distribution tariffs, for the price ceiling and for setting the floor for generation competition
Tariff supervision	There is to be a periodic intercommunication mechanism between NDRC and SERC Nationwide electricity tariffs examined jointly by NDRC and SERC SERC responsible for supervising price behaviour among power companies SERC has major influence over capacity price and transmission and distribution tariffs NDRC has major influence over retail tariffs

Note: NDRC = National Development and Reform Commission; SERC = State Electricity Regulatory Commission.

Table 6.4 Recommended functions of NDRC, SERC and SAAC

NDRC (the macro administrative agency)	SERC	SAAC
Development strategy and planning of the electric power industry	Market entrance	Supervision of process and running of state-owned assets in electric power sector
Industrial policies	Supervision of safety, tariffs, cost, investment, services and competition behaviour	Determination of personnel for top management of power companies that belong to SAAC
Market forecasts and investment information	Qualification criteria for top management of power companies	

Note: NDRC = National Development and Reform Commission; SAAC = State-owned Assets Administration Commission; SERC = State Electricity Regulatory Commission.

Conclusions

The electric power sector in China has been growing faster than 10 per cent per year in recent years and is now the second largest power sector in the world, both in total installed capacity and in annual generation. The first industry reforms (improving openness and establishing competition in the generation sector) have proven successful.

However, unique features of social and economic development in China are creating more and more difficulties for both the development of the electric power sector and institutional reform in the sector. First, a large population combined with a rising level of electricity consumption per capita means a huge potential for increased energy demand. Second, lack of primary energy resources per capita compared with the world average increasingly constricts growth in the capacity of supply. Third, the unbalanced distribution of primary energy resources and load centres of electricity means more expensive transmission and distribution. Fourth, a coal dominated primary energy mix requires much more proactive efforts in mitigating pollutants.

Sustainable development in China's electric power industry is expected to support sustainable social development and economic growth. Therefore, successive institutional reforms in the power sector are as necessary as the expansion of the power system.

Notes

1 Generation capacity refers to the maximum amount of electricity a country can produce in a year, measured in gigawatts (GW). It is constrained by the number and size of electricity generating plants which are operational within the country.

2 Annual generation refers to the sum of electricity actually generated in a country in a particular year measured in terawatt hours (TWh). At any given time actual generation is far below capacity generation. Capacity must be sufficient to meet peak demand, resulting in a requirement for more capacity than is the average consumption (and therefore generation).

3 A bus bar is a conductor used to connect two or more electrical circuits. The 'bus-bar tariff' is based on transmission connection costs and marginal costs.

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7 Energy Cooperation in Northeast Asia: Perspectives from Korea[1]

Ji-Chul Ryu

Introduction

The countries in Northeast Asia (South Korea, China and Japan) have experienced robust and dynamic economic growth over several decades. This growth is expected to continue in the future. Accordingly, energy demand is highly likely to increase apace with further economic development, particularly in China and Korea. However, the three countries have only limited indigenous energy resources, so the incremental energy demand will have to be met by imports.

The region has large potential for the development of untapped energy reserves of oil and natural gas in remote areas such as Eastern Siberia, the Sakhalin islands in the Russian Far East and offshore in the East China Sea. Development of such huge energy development projects in Northeast Asia, if accomplished, envisages opportunities for multilateral regional energy cooperation in the region.

However, energy demands in Northeast Asia are expected to increase much faster than growth in the region's supply capability, so energy is a potential bottleneck for sustainable economic growth for the region in the future. Currently, the region is a net importer of energy, so further increases in demand imply a continuous rise in dependence on imports from outside the region, particularly from the Middle East. Keeping the intra-regional supply–demand balance at an optimal level, particularly for oil and natural gas, will be a significant issue in energy cooperation in Northeast Asia.

Regional energy cooperation in Northeast Asia has been impeded historically by some geopolitical factors, including Sino–Japan relations, territorial disputes among the countries in the region, and the current nuclear weapon program in North Korea.

There are three main opportunities for energy cooperation in Northeast Asia:

- to develop energy resources, particularly oil and gas, in the Russian Far East and construct cross-border infrastructure networks such as pipelines for crude oil and natural gas and interconnected energy grids
- to try to create an institutionalised framework for multilateral regional energy cooperation; and
- to resolve the energy poverty problem in North Korea.

This paper will address the above-mentioned issues and prospects related to energy cooperation in Northeast Asia from a Korean perspective.

Opportunities for energy cooperation in Northeast Asia

Energy market and demand growth

Energy demand

Northeast Asia is a large energy consuming region, due to high increases in energy demand in China, Japan and Korea (which rank 2, 4 and 10 in energy demand globally).

Energy consumption per capita varies markedly over the countries in the region, being just 0.9 tons of oil equivalent (toe) in China and 0.7 toe in North Korea – less than one-fourth of the level in South Korea and Japan (greater than 4 toe). The lower energy consumption in China and North Korea implies that Northeast Asia has a large potential for further increase in energy demand in the future.

Northeast Asia is in deficit in terms of energy supply–demand balances. As shown in Table 7.1, China is the only country in the region which is self-sufficient in energy. South Korea and Japan are heavily reliant on imports for energy supply: they depend on overseas sources for more than 80 per cent of their energy (with nuclear energy excluded). Most of their energy comes from outside the region, particularly the Middle East, Australia and Southeast Asian countries.

Given China's large population and its expected further economic growth as well as the industrialised nature of the South Korean and Japanese economies, future energy demand in the region is expected to increase more rapidly than in any other region in the world.

Table 7.1 Energy indicators in Northeast Asia by country, 2003

	South Korea	Japan	China	North Korea
Total primary energy (million toe)	212	505	1,178	16
Energy per capita (toe)	4.3	4.1	0.9	0.7
Energy import dependency (with nuclear excluded) (%)	84	82	0	8
Oil dependency ratio (%)	53	48	28	8

Note: toe = tons of oil equivalent.
Source: KEEI and MCIE (2004).

According to the Asia Pacific Energy Research Center (APERC 2002), the total primary energy demand in Northeast Asia is expect to increase by about 65 per cent during 2000–20, from 1,883 million toe in 1999 to 3,115 million toe in 2020. South Korea is expected to double its energy demand; China is expected to show the largest incremental increase in energy demand (859 million toe) during the forecast period – from 1,088 million toe in 1999 to 1,947 million toe in 2020 (Table 7.2).

Oil demand and imports

Northeast Asia is a net oil importer. As oil demand increases in countries in the region, oil imports are expected to increase significantly. In particular, China is expected to contribute 73 per cent of total incremental oil imports in the region by 2020; its share in total oil imports in Northeast Asia is expected to increase from 10 per cent in 1999 to 60 per cent in 2020 (Table 7.3).

Energy security

Northeast Asia's aspirations for sustainable economic growth cannot be accomplished without effective security of energy supplies. Economic growth will bring about increases in demand for energy and needs to be supported by a stable supply of energy resources (oil, gas and electricity).

Regional cooperation in the development and reservation of indigenous energy resources (especially oil and natural gas) in Northeast Asia will contribute to greater self-sufficiency in energy in the region as a whole and thus to reduced dependence on imports, particularly from the Middle East.

Table 7.2 Energy demand outlook in Northeast Asia (million toe)

	1980	1999	2020	Change p.a. 1980–99 (%)	Change p.a. 1999–2020 (%)
South Korea	44	183	362	8.2	3.3
Japan	346	515	624	2.1	0.9
China	593	1,088	1,947	3.2	2.8
Northeast Asia total	1,017	1,883	3,115	3.3	2.4

Note: toe = tons of oil equivalent.
Source: APERC (2002).

Table 7.3 Outlook for oil demand and imports in Northeast Asia (million toe)

	1999		2020		Change p.a. 1999–2000 (%)	Contribution (%)
	Demand (million toe)	Import share (%)	Demand (million toe)	Import share (%)		
Demand						
China	204.3	21.7	497.2	69.5	4.3	72.6
Other countries in Northeast Asia	415.8	99.7	526.4	99.9	1.1	27.4
Total	620.1	74.0	1,023.6	85.1	2.4	–
Imports						
China	44.3		345.4		10.3	73.0
Other countries in Northeast Asia	414.6			525.9	1.1	27.0
Total imports	458.9			871.3	3.1	–

Note: – = not applicable; toe = tons of oil equivalent.
Source: APERC (2002); APEC (2002).

However, the lead times involved in energy projects are long, and the capital requirements for implementing projects and necessary infrastructure are enormous. In particular, the energy sectors will require large amounts of capital to develop and upgrade energy facilities and infrastructure, to develop natural gas fields and pipelines, and to explore and extract energy resources. There is a need for urgent action to avoid bottlenecks in this development.

Demand may exceed the capability of a single country. There will be a need for regional and/or international cooperation to secure energy sources for the longer term and to finance the large-scale energy projects that will be required for sustained economic growth in the region.

Regional energy and infrastructure development

The Russian Far East is blessed with abundant natural resource reserves (including oil and gas) that are yet to be fully tapped. Countries in Northeast Asia have shown increasing interest in developing the huge untapped energy resource reserves in remote areas and promoting projects to construct cross-border energy infrastructure networks. This includes, for example, the development of oil and natural gas resources and the construction of energy network systems for cross-border pipelines and power grids.

Natural gas development

Eastern Siberia is one of the largest unexplored hydrocarbon, oil and natural gas bearing areas left on earth. The area is a potentially large source of natural gas for Korea, China and Japan. Russia could supply Korea with up to 10 billion cubic metres of natural gas per year via a trunk pipeline. Development plans for natural gas in Northeast Asia include a project for building a gas export line from gas fields in Eastern Siberia (Irkutsk, Yakut, Sakhalin Islands) to Korea and China.

Development of the Eastern Siberian energy resources and construction of the intra-regional gas pipeline network from the Russian Far East to Korea, China and Japan will give countries in the region the opportunity to benefit from diversification of energy sources (from coal and nuclear power) and to reduce the environmental impacts of their energy systems. Eventually, the project aims to contribute to the creation of an integrated regional energy system in Northeast Asia.

However, there are major political and economic obstacles to implementing this ambitious plan. These are due mainly to political uncertainty in Russia, project financing risk, and security issues on the Korean peninsula. Unless North Korea and South Korea resolve their difficulties, one of the most difficult problems is likely to be routing the pipeline network from Siberia to South Korea through North Korea. Table 7.4 summarises the proposals and issues involved in two important proposed projects: the East Siberia gas pipeline and the oil/gas fields development in East Siberia and Sakhalin.

Regional power interconnection

Cross-border power interconnection grids

Currently, there is no cross-border power interconnection system in Northeast Asia. Each country in the region operates their own power transmission system, being separated from and independent of neighbouring countries. However, a cross-border power interconnection system in the region could produce economic gains/benefits for countries in the region through factors such as load diversity between countries, lower capacity additions, reduced spinning reserve requirements, more efficient dispatch, and more reliable system operation.

Power interconnection is one of the most efficient ways to overcome the difficulties electric power industries are facing – for example, enormous investment costs and concerns about environmental pollution. Feasible projects for cross-border power interconnection in Northeast Asia under discussion include construction of transmission lines between Russia, North Korea and South Korea. Russia is known to have a large potential for hydropower development for exports in Eastern Siberia. Table 7.5 summarises the steps being taken to establish a cross-border power interconnection system.

Table 7.4 Petroleum sector cooperation

Project	Action agenda	Factors to be considered
(a) East Siberia Gas Pipeline Project		
1st stage (2006–08) • Construct a gas pipeline in the Sakhalin–Khabarovsk section • Build a trunk line and supply gas in the Irkutsk area	Preliminary stage • Korea and Russia will need to reach and sign the inter-governmental gas supply agreement • The Russian government should provide a detailed plan for construction of the UGSS and for the development of gas fields in the East Siberia and Sakhalin regions	• Three parties, BP-TNK, CNPC, and KOGAS, have promoted the Irkutsk project. However, the Russian government has prepared a different plan for construction of the pipeline and for development of gas fields in the East Siberia region. • Before South Korea and Russia reach inter-governmental agreement on the gas supply, both countries have to find a solution for the Irkutsk project, which is currently at a stalemate
2nd stage (2008–10) • Development of Chayandinsk gas field • Construct a branch line for supplying gas to China at Blagoveshchensk • Connect a gas trunk line between Irkutsk and Tarshet • Connect the trunk line between Khabarovsk and Vladivostok and supply natural gas to South Korea	Initial stage • The parties should secure the economics of importing pipeline natural gas, commit the pipeline route for delivering gas, establish ownership of the pipeline, agree on the importing volume and settle prices	• Gazprom insists that gas from the Kovykta fields is supplied for domestic uses. It expects the Sakhalin project to have enough gas to meet Asian demand until 2015; it could produce 20 bcm of gas a year starting in 2010 • The price of pipeline gas should be competitive with that of current imported LNG. If the East Siberia pipeline is to materialise, both countries have to make an effort to set reasonable prices
3rd stage (2011–13) • Develop fields in the Krasnoyarsk region and connect the line to the Tarshet region	Project stage • Korean domestic companies will participate in pipeline construction by forming a consortium. Korea can diversify energy import sources by importing natural gas from Russia	
4th stage (2014–20) • Connect gas fields between Irkutsk and Chayandinsk • Connect the gas trunk line in the Blagoveshchensk and Khabarovsk section (complete the UGSS)		
(b) Oil/gas fields development in East Siberia and Sakhalin		
• Participate in the development of oil and gas fields in Sakhalin reserve by acquiring equities: Sakhalin projects, which are at a relatively early stage of development, especially Sakhalin III-V, can provide opportunities for neighbouring countries to make economic gains by joint development and production.	• Secure a competitive price for LNG from Sakhalin. An invitation of tender for a new LNG deal is needed to reduce the import price • Develop strategic plans for energy projects in Sakhalin • Conduct feasibility studies (energy projects are high risk at the initial stage), form an international consortium to join the projects, and agree to contracts to avoid risks underlying the exploration and production stage	•Korea has a contract for the supply of LNG from the Sakhalin II project (about 1.5–2.0 million tons per year) to meet increased natural gas demand and to replace Arun III, which will expire in 2007. Sakhalin II is the first bilateral energy project between Korea and Russia • Although both countries have discussed energy cooperation or the last 15 years, including the joint development of the Sakha gas field, nothing has been realised yet

Notes: bcm = billion cubic metres; LNG = liquified natural gas; UGSS = Unified Gas Supply System (of Russia).

Table 7.5 Cross-border power interconnection grids

Project	Action agenda	Factors to be considered
• Russia proposes a two-step power interconnection system: first, connecting power between Vladivostok and Chung-jin in North Korea; and, second, building a power line between Russia and South Korea • Russia and North Korea have already agreed to the first step and are constructing a 380-km transmission line that will provide a power supply of 500 MW from 2006· • If the first step is economically feasible, the second step will be to build transmission line from Russia to South Korea with a capacity of 2,000 MW	Preliminary stage • Conduct economic, technical and environmental feasibility studies on the interconnection of power in the region Initial stage • Secure the technology to prosecute projects, revise legislation applying to power trade and plan a financing scheme Project stage • Connect the power system and begin power trade in the region	• Before implementing power interconnection in the region, resolve issues such as investment costs, proprietary rights, operating rights, differences between regional groups or countries in the electrical power structure and taxation systems

Notes: km = kilometre; MW = megawatt.

Petroleum sector cooperation

Feasible regional cooperative projects for the oil sector in Northeast Asia include the establishment of crude oil pipeline networks; joint strategic oil stockpiling for oil importing countries (Korea, Japan and China); a free trade agreement for oil products; sharing of refinery/upgrading facilities, and strategic cooperation for sea-lane transportation security for crude oil.

By promoting cooperative projects, oil importing countries in the region will benefit from greater energy security, reducing investment requirements and improving regional oil market efficiency. Table 7.6 summarises the steps being taken to achieve these goals.

Multilateral energy cooperation framework

Currently, there are no concrete formal or institutionalised frameworks for multilateral energy cooperation in Northeast Asia. In the current political climate, even preparatory signals for regional cooperation are yet to mature. Most energy relations in the region are undertaken bilaterally, involving specific projects or deals.

However, there is a growing interest among the countries in the region in creating a useful institutional scheme to initiate multilateral intra-regional energy cooperation in the pursuit of common objectives of energy policy. This may take the form of joint development of supply sources, integration of energy infrastructures, energy conservation, etc. An institutionalised framework for risk mitigation could also help facilitate large-scale energy investment and trade in the region.

Implementation principles

Any form of regional agreement for cooperation on energy issues will need to adhere to three basic implementation principles. First, they will need to take a market-oriented and comprehensive approach, pursing common benefits through market mechanisms. Second, they will need to take a broad approach, simultaneously addressing other issues, such as environmental impact and price stability. Third, they will need to pursue open regionalism by task sharing and by cooperation with international organisations and countries outside the region and by encouraging their participation.

Multilateral regional energy cooperation in Northeast Asia

There are five main ways in which multilateral regional energy cooperation can be advanced in Northeast Asia.

Table 7.6 Petroleum sector cooperation

Project	Action agenda	Factors to be considered
(a) East Siberia oil pipeline • In 2004, Russia finally decided the route for the East Siberia oil pipeline • The route of the pipeline will be from Tayshet located in the northeast and Angarsk via Baikal Lake northern area and the China–Russia border (Skovorodino) along the Trans Siberia Railroad, finally reaching Perevoznaya, bounded by the Pacific Ocean • With the development of oil resources and export oil, the Russia government expects its economy to grow more steadily than before and expects the East Siberia/Far East Russia region, which is relatively undeveloped, to have change to accommodate the rehabilitation of the local economy • According to Transneft, which will operate the pipelines, the construction of pipelines will accelerate the development of additional oil resources in the region, so securing oil reserves should not be the first consideration. The project will take 5 years to complete, at which point annual supply will be about 80 million tons. • About 50 million tons of oil a year will be exported via Perevoznaya port to the Pacific market, including Japan, South Korea and the United States; about 30 million tonnes of oil per year will be supplied to China at Skovorodino through the construction of an extra pipeline • Reserves near Tumen will provide oil for the northeast pipeline, with a transportation capacity of 50 million tons a year; if necessary, more oil will be supplied through additional exploration of East Siberia in the Far East	Preliminary stage • Conduct feasibility studies for the economics of pipeline construction by establishing a study group that includes domestic companies such as KNOC, POSCO, HYSCO, and KOEXIM	• Large capital investment is needed to construct the pipeline and to develop the East Siberian oil resource. The Russians estimate that the project will require capital of more than $10 billion cooperation • There will be a need for cooperation between governments and between governments and companies on the participation process
(b) Joint oil stockpiling • Korea can be an logistic hub for oil in Northeast Asia • Extra tank capacity can be rented by foreign oil companies that seek to expand oil exports in the region	Preliminary stage • Conduct comprehensive studies on the possibility of international joint oil stockpiling and the provision of logistic facilities • Conduct pilot projects with foreign oil trading companies • Complete the construction of additional facilities Project stage •Ratify and revise domestic laws and regulations on utilising stockpile facilities and create trading companies for renting facilities	

First, there is a need for countries in the region to achieve consensus on what is required. They need at least to reach a consensus on promoting regional energy cooperation with common efforts at the level of government and the private sector. Countries in the region must be encouraged to participate in this endeavour. There is a strong need to actively induce China and Japan to participate in joint efforts to create a regional multilateral energy cooperation framework.

Second, countries in the region should implement 'soft' bilateral or cooperative projects that are expected to be feasible. For example, countries could cooperate in liquified natural gas (LNG) or crude oil trade.

Third, multilateral cooperation should follow these initial steps. Countries involved in initial bilateral or cooperative projects could be encouraged to pursue multilateral approaches. Multilateral international organisations such as the World Bank, the International Finance Corporation and the United Nations Development Programme and countries outside the region such as the United States and the European Union countries could be invited to participate in regional energy cooperative projects and activities.

Fourth, the institutionalisation of an energy cooperation framework could be advanced by establishing an overall coordinating agency responsible for regional projects. This could be achieved by expanding and/or integrating individual coordination systems for each project into a single entity dealing with all project participants. In addition, there could be arrangements for inter-governmental policy cooperation – for example, through meetings of senior energy officials, energy ministerial meetings, and leaders' meetings with a focus on energy.

Finally, countries could agree to the creation of a regional common market for energy. They could facilitate regional energy investment and trade by expanding intra-regional trade in natural gas and electricity and promoting a regional free market. A regional free energy market for the electricity and gas sectors would be beneficial in increasing price competitiveness and in turn improving the international competitiveness of energy-intensive industries such as the iron, steel and petrochemical industries and other manufacturing industries. The creation of a regional common energy market in Northeast Asia could occur in parallel with the creation of a regional economic cooperative body. A regional common energy market would act as a basis for the economic and social integration of economic blocs in Northeast Asia.

Regional senior officers meeting on energy

Regional energy cooperation needs significant leadership from the top political levels. Establishing a regular senior officers meeting (SOM) on energy is the most effective way of ensuring that political will is generated and sustained across the region.

Without the political commitment of senior regional energy officers, questions such as free energy transportation and trade across the region and the establishment of regional regulations for promoting regional energy investment will not overcome the political difficulties in Northeast Asia.

Within the framework of a regular SOM, working groups should be established to discuss the details of issues such as energy planning and policies, electric power development and interconnection, inter-state transit of fossil fuel, and energy efficiency. Creating this type of regional cooperative institution will be a major advance for energy issues in Northeast Asia.

The creation of a SOM could be undertaken in three steps. First, task force meetings should be held for reaching consensus and discussing what mechanisms might be involved in SOMs. Next, SOMs would be held on a regular basis; a secretariat could be established to organise the SOM meetings and working groups. At this stage, SOM meetings could be hosted by countries that are interested in multilateral energy dialogues in the region. Next, the scope of the SOMs would be expanded by engaging new members such as China and Japan, and by initiating feasible energy projects and joint energy related research. In the long term, SOMs will lead to energy summit meetings and the creation of a regional energy charter in Northeast Asia.

Research

Given the political sensitivity both in the region and relating to energy issues, a useful first step in achieving regional energy cooperation in Northeast Asia would be to establish regional networks for research and information and expertise exchange among the countries involved. Aside from the direct benefits of knowledge sharing, shared research activity and information sharing can be useful in encouraging other forms of cooperation. It could also contribute to the promotion of intra-regional energy investment and trade as well as the development of measures to mitigate environmental problems.

Information sharing and joint research activities will be particularly beneficial for the non-market economies, Russia, China and North Korea, which lack the information and expertise needed to work jointly with neighbouring countries. There are four areas of research where joint projects could be useful in contributing to regional cooperation. First, countries could establish a basis for research (e.g. research on energy policy, market structure and regulations in each country; research on the design and development of a common energy database for Northeast Asia; and research on the development of an integrated methodology or model for energy–environment–trade analysis and forecasting. Second, countries could undertake policy research (e.g. on political and economic systems or energy investment policies in each country, or on the creation of a regional multilateral energy cooperation framework). Third, countries could conduct research on project development (e.g. to improve the efficiency of the energy system in Northeast Asia; to construct cross-border energy infrastructure or networks and related project plans; or to develop joint measures for energy–environment projects on a regional basis. Fourth, countries could cooperate in information exchange (e.g. through the establishment and operation of a regional energy expert forum and policymaker network; through expert training and education; and through information exchange and mechanisms for the common use of information).

Energy poverty in North Korea

Over the last decade North Korea has suffered serious shortages of energy which have jeopardised its economy. The downturn of the energy sector is primarily a result of the four factors: a significant cut in the subsidised oil supply from the former Soviet Union and China since the late 1980s; failure to maintain and modernise energy infrastructure; natural disasters; and inefficient energy production.

Given the lack of capital and technology to rehabilitate its energy system, North Korea is desperately in need of international cooperation with other countries, particularly South Korea, Russia, China, Japan, the United States, Australia and the European Union, and with relevant international organisations.

If North Korea is to fundamentally resolve the energy crisis, it should abandon its long-pursued economic policy of self-reliance (*juche*) and open the energy system to commercial energy supplies from overseas; establish a market mechanism for energy and create an energy market by introducing energy pricing and tax systems and reforming energy legal structures; promote active cooperation with South Korea and other countries for rehabilitation of the existing energy facilities as well as for expansion of the energy system by de-coupling energy issues from politics and accommodating foreign investment; adopt cost-effective energy options in the short term, particularly by increasing the role of petroleum in the energy mix in parallel with pursuing new and renewable energy and natural gas for the medium to long term; and strengthen the capability for energy policymaking by improving energy statistics and modelling infrastructure and by training energy experts and scientists

To promote international energy cooperation, North Korea should take three preliminary steps. First, it should accept demands from the international community on military and security concerns transparently, and actively participate in international energy cooperation activities in pursuit of the membership of the International Monetary Fund, other international financing organisations, and multilateral regional energy cooperation bodies in Northeast Asia. Second, it should closely consult with South Korea in reconstructing the energy system, so that the energy systems of both Koreas can be integrated into a mutually compatible single system in the future. Third, it should enhance capacity building for introducing a market mechanism in the energy sector by promoting international cooperation in the areas of training and educating energy experts, jointly undertaking energy project feasibility studies, and policymaking capability.

North Korea and neighbouring countries could undertake the following energy cooperation projects:

- humanitarian aid for the supply of energy products for civilian energy use – for example, anthracite coal, LPG, kerosene, diesel, and heavy fuel oil for power generation
- renovation/reconstruction of existing energy production facilities (coal mines, refineries, power generation systems, and transportation/storage systems)
- technical, financial and expert assistance
- revision of legal/market rule structures to establish market mechanisms
- power interconnection with South Korea and the Russian Far East
- natural gas pipeline project (Sakhalin and Irkutsk projects)
- provision of training/education programs for energy planning/implementation
- resumption of the construction of two light water reactors by the Korean Peninsula Energy Development Organization.

Conclusions

In 2002, South Korea ranked 10th in the world in terms of total energy consumption, 6th in oil consumption, 4th in oil imports and second in LNG imports. Despite its high energy import dependence (97 per cent), South Korea's performance in achieving energy security (for example, through overseas oil development, renewable energy development, energy conservation and efficiency improvement) is weak.

South Korea's total energy demand is expected to increase by 3.1 per cent per annum by 2010 and by 2.4 per cent by 2020, when it is expected to reach 311.8 million toe. Demand for natural gas is expected to increase more rapidly than any other energy source, by 5.4 per cent per annum.

South Korea faces energy-related problems such as supply security, price stability and environmental conservation; it needs to take stronger effective measures to tackle these challenges. As global environment protection efforts strengthen, Korea needs to improve its energy demand–supply structure to achieve a more environmentally friendly system.

Tackling these challenges will require energy cooperation with the countries in Northeast Asia. In particular, the expected increase in China's oil imports from the Middle

East will be a significant factor for South Korea's energy security capability. On the other hand, regional energy cooperation in Northeast Asia will contribute to the resolution of energy poverty problems in North Korea and thus improve political and economic relations between the two Koreas.

By initiating and promoting bilateral energy cooperation, South Korea can play a leading role in encouraging China, Japan and North Korea to participate in regional energy cooperation initiatives in Northeast Asia. With the integration of onshore and offshore energy systems, Korea will have a bridging role in the creation of an integrated energy system in the region and will be a centre for energy logistics and trade. South Korea has the capacity to lead energy cooperation in the region. For example, KOGAS is the largest LNG importer in the world. In addition, South Korea can play a leading role in initiating joint research efforts by the countries in the region, by supporting and strengthening related research activities.

Notes

1 This paper is based on Ryu (2003) and Park and Ryu (2005).

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8 The Energy Outlook for Northeast Asia: Japanese Perspectives

Kensuke Kanekiyo

Introduction

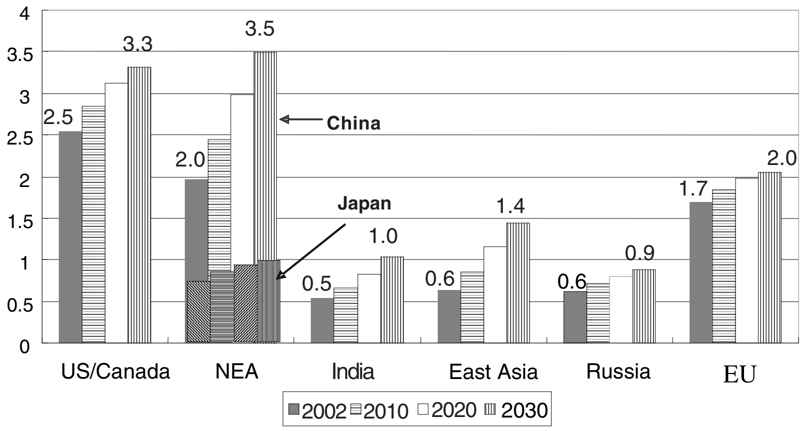
In the past two years, we have been experiencing worldwide resource inflation and shortages. Prices of energy and raw materials are soaring rapidly. Power shortages in industrial regions of China are serious and energy might become a serious hindrance to development. Energy cooperation among Northeast Asian countries is essential for the region's sustainable development. In this paper, I review the energy situation of Northeast Asia and discuss one possible direction for energy cooperation among countries in the region.

Asia in the world

Today, Northeast Asia ranks as one of the three major energy markets of the world, together with North America and Europe. The sub-region consumes over 2 billion tons of oil equivalent (toe) of energy, which accounts for more than 20 per cent of the world energy consumption (Figure 8.1). The recent trend has been driven by the high economic growth of China. China's energy consumption recorded a jump of 15.1 per cent in 2004, compared with 2.8 per cent in the rest of the world; the corresponding figures for oil consumption were 15.5 per cent for China and 2.1 per cent for the rest of the world (Table 8.1). This trend continued in 2005, though China's oil imports were being curbed substantially.

According to the International Energy Agency (IEA 2004), energy consumption in Northeast Asia will continue to grow rapidly and will exceed that of North America sometime in the 2020s (Figure 8.2). Looking to future energy demand, Japan will level off moderately as its economy has reached a mature stage and its population will start decreasing within several years. South Korea recorded a substantial increase in energy consumption in the 1990s but is showing signs of moderating in the coming decades. Its economy will be shifting to a hi-tech, less energy-intensive structure while energy consumption in the residential and commercial sectors will be maturing. In contrast, China will continue its rapid increase in energy consumption, driven by high economic growth. With vast territory and a big population, China's growth will take time and will consume huge quantities of energy for a prolonged period.

Figure 8.1 World energy outlook (billion toe)



Note: NEA = Northeast Asia; toe = tons of oil equivalent.
Source: IEA (2004).

Table 8.1 Growth in world energy and oil consumption (2004)

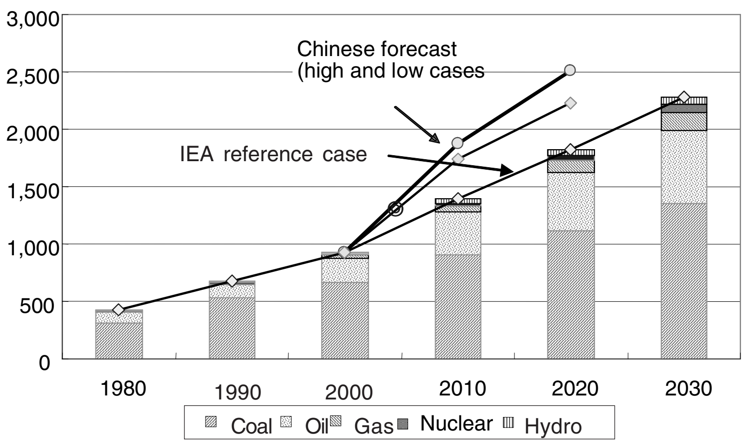
Energy	Consumption (Btoe)	Year on year growth (%)
Total		
China	14.1	15.1
India	3.8	7.2
Other Asia	17.6	4.4
US, Europe, others	66.8	2.1
World	102.2	4.3
Oil		
China	3.2	15.5
India	1.2	5.5
Other Asia	5.1	4.7
US, Europe, others	28.2	1.9
World	37.7	3.4

Note: btoe= billion tons of oil equivalent.
Source: BP (2005).

The IEA's projection substantially undershoots the actual recent energy trend. China recorded consumption of 1.38 billion toe in 2004, compared to the IEA's projection of 1.39 billion toe for 2010 (IEA 2004). It is apparent that China's energy consumption will grow faster than the IEA's projection (Figure 8.2). Many Chinese research institutes forecast that consumption may reach 2.0–2.5 billion toe by 2020; however even this could be realised only with enormous efforts to conserve and rationalise energy. If energy consumption continued in the current pattern, China's energy consumption would exceed 3 billion toe by 2020 (Figure 8.2).

Japan and Korea depend almost entirely on imported energy, with oil and gas playing major roles. In contrast, coal dominates in China (Table 8.2). With plenty of domestic coal resources, China's import dependence is only 13 per cent. China depends on oil for only 25 per cent of its energy consumption; however, its oil imports are increasing rapidly. China's oil consumption is increasing rapidly, but its production is levelling off. Its oil imports will increase faster than the increase in consumption, and the absolute incremental quantity will also be huge. During the oil crisis of the 1970s, Japan successfully diverted oil use in its power and industry sectors to natural gas and nuclear power. However, this cannot be expected to occur for China, since oil is scarcely used in these sectors there. In this environment, oil security is a very important policy objective for the region. Ensuring that economic growth can continue without unsustainable growth in oil demand is a critical priority. In the past decades, China has dramatically improved its energy efficiency. China's energy consumption per unit GDP has decreased to one-third of that of the 1970s. But it is still three times worse than that of the United States and nine times worse than that of Japan per GDP in constant US dollars (Figure 8.3).

Figure 8.2 Energy outlook of China (Mtoe)



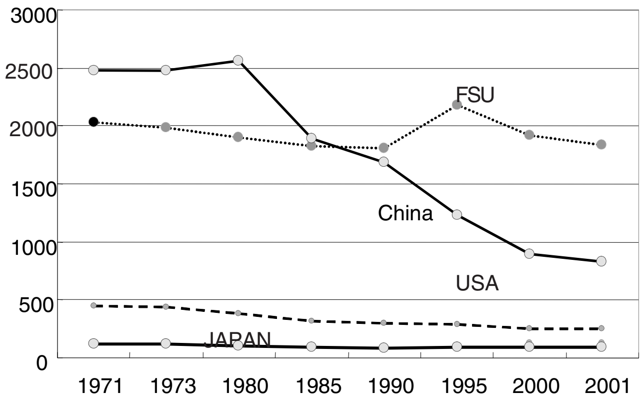
Note: IEA= International Energy Agency; Mtoe = million tons of oil equivalent.
Source: IEA (2004).

Table 8.2 Structure of energy use in Northeast Asia

	Total (Mtoe)	Oil (%)	Coal (%)	Gas (%)	Other (%)
Japan	515	47	24	13	16
Korea	217	48	24	13	15
China	1,410	23	68	3	6
Total	2,142	31	53	6	10

Notes: Mtoe = million tons of oil equivalent.
Source: BP (2005).

Figure 8.3 Energy efficiency of selected countries, 1971–2001 (toe per $ million of GDP)



Note: FSU= Former Soviet Union.
Source: IEA (2004); World Bank (2005).

China's apparent energy efficiency may have been exaggerated by the monetary terms used in the calculation. However, industrial energy consumption per unit is still considerably higher than the international standard when physical units are used for the comparison. For example, the rate of energy consumption at steel mills in China is 50 per cent higher than that of Japan. Small and inefficient plants scattered over rural towns are problematic, but integrating them into world-class plants would affect rural economies through negative effects such as job security, income source and modernisation. It is not as easy to improve these as the theory implies. Transport is another factor to be taken into account in curbing energy consumption, because China is a vast continental country.

Oil outlook for Northeast Asia

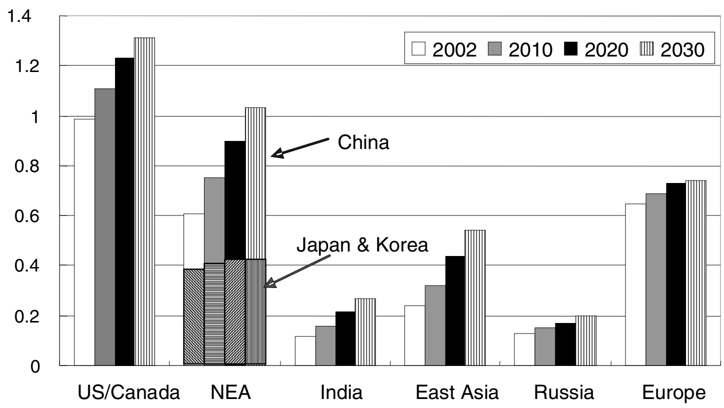
Oil demand and supply

According to the IEA (2004), oil consumption in Northeast Asia will continue to increase rapidly, exceeding that of Europe and approaching that of North America. China's oil consumption is expected to increase rapidly, while that of Japan and Korea will level off (Figure 8.4).

One serious concern is that the region depends upon the Middle East for over three-quarters of crude oil imports. In 2004, Japan was dependent on the Middle East for 89 per cent of its crude oil needs, Korea for 78 per cent, China for 45 per cent and total Northeast Asia for 74 per cent . To accommodate large import increases in the future, it is inevitable that countries in the region will become even more dependent on the Middle East. Given the unstable situation in the Middle East, this is a point of great vulnerability for the region.

Despite the above trends, in 2004 China's imports of Middle East crude decreased their share to 45.4 per cent from 50.9 per cent in 2003 (although the quantity of Middle East crude

Figure 8.4 World oil outlook (billion tons)

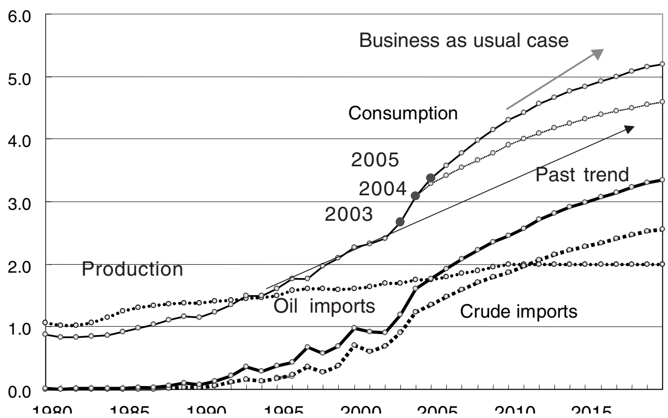


Note: NEA = Northeast Asia.
Source: IEA (2004).

imports increased by 20 per cent). This was due to a sharp increase in the amounts of lighter crude imported from the Atlantic basin (66 per cent). The share of African crude increased from 24.3 per cent to 28.7 per cent. This was caused by lack of refining capacity in China – in particular cracking and desulphurisation facilities – to catch up rapid demand growth.[1] Another important factor is that China plans to improve its motor fuel quality to Euro 4 level by 2010. This requires construction of large secondary facilities such as those mentioned above. If investment in such facilities is not made in time, the same tendency to prefer crude oil will continue.

I turn to the petroleum outlook for China. China's oil consumption exceeded that of Japan in 2003, to make it the world's second largest oil consuming country after the United States. It jumped another 15 per cent in 2004. According to the IEA, Chinese oil demand is forecast to keep growing, to 503 million tons by 2020; however, as shown in Figure 8.5, the current trend indicates that by 2020 China will reach a demand of 600 million tons under a business as usual scenario. We should note that although the Chinese government maintains its target of quadrupling GDP by 2020 (implying 7.2 per cent growth on average for 20 years), the IEA assumes GDP growth of just 6.4 per cent from 2002 to 2010 and 4.9 per cent for the next decade.[2] Further, the IEA's alternative policy scenario suggests that by enhancing energy conservation and introducing alternative energies, oil demand could be curbed by 10 per cent (down to 464 million tons). Given China's sustained rapid economic growth, it is not clear which scenario (the Chinese government's or the IEA's) is more likely.

Figure 8.5 Petroleum outlook for China (100 million tons)



Source: Author's estimations; see <http://eneken.ieej.or.jp/en/data/pdf/290.pdf>.

However, which one proves closer to reality will have significant ramifications for China's energy and petroleum demand.

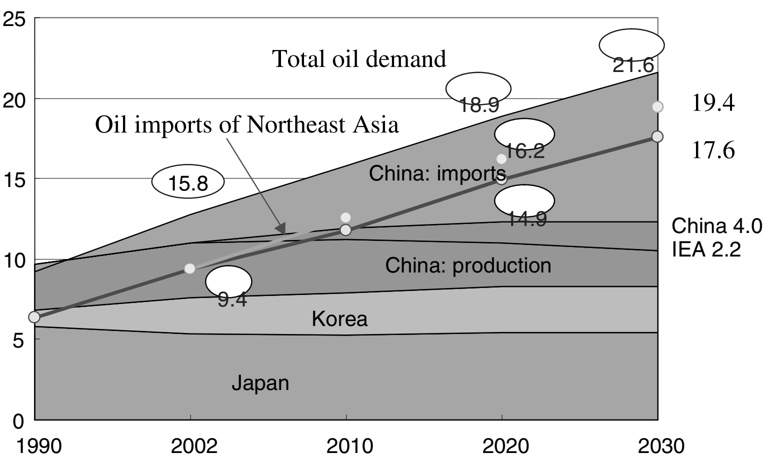
In China, major oil fields like Daqing are maturing. Taking an optimistic view, domestic oil production may be levelling off; the IEA estimates that it will decline to 140 million tons by 2020. Considering recent high oil prices, we may comfortably assume the optimistic scenario. Then, China's oil imports may more than double in the next two decades. If the IEA's alternative scenario is possible, this scenario will not be substantially affected.

Figure 8.6 summarises the petroleum outlook for Northeast Asia. Oil consumption in the region will reach almost 20 million barrels per day by 2020. Net oil imports will exceed 15 million barrels per day, increasing by 5 million barrels per day from now. That is, something like another Japan (the world's second largest oil importing country) is emerging in the region. The majority of this increase in oil imports comes from China. Dependence on the Middle East will inevitably go up, as the Middle East could be the last area with substantial potential for incremental supply.

Oil price issues

Given this background picture of supply and demand, Northeast Asia faces two major problems regarding international crude oil prices in the market. They are the Asian premium for the price paid for Middle East crude and the expanding spread between light and heavy crude.

Figure 8.6 Petroleum outlook for Northeast Asia (million barrels a day)



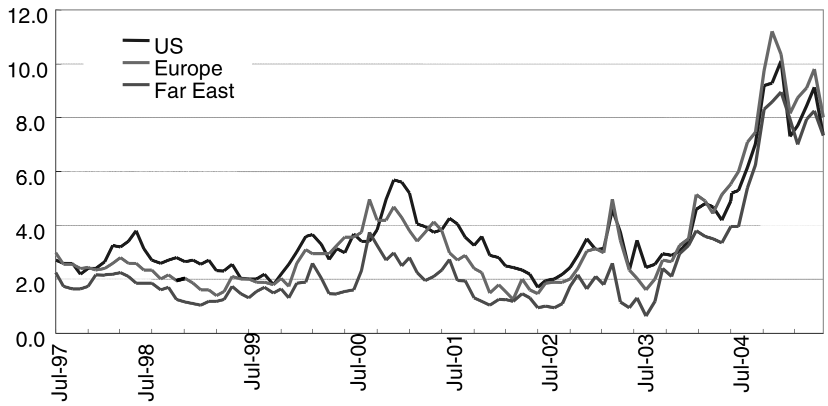
Note: IEA = International Energy Agency
Source: Author's estimations; see <http://eneken.ieej.or.jp/en/data/pdf/290.pdf>.

Historically, Middle East crude oils have been priced about $1 per barrel higher for Asia[3]. However, since the Middle East is the only reliable source of supply for the mega quantities demanded, the upward price pressure on Asia-bound crude oil is expected to continue. This certainly will not ease while China and India continue increasing imports in response to their rapid economic growth. An effective cure for the Asian premium price will require new supply sources other than the Middle East.

In addition, the light–heavy spread of Middle East crude oils jumped tremendously in 2004 as shown in Figure 8.7. The technical cost differential for light and heavy crude oils may be in the range of $2–4 per barrel; this is the figure that was represented in the market trend band historically. The oil product demand pattern is shifting globally to lighter transportation fuels such as motor gasoline, jet fuel and diesel gas oil. The abnormal light–heavy spread pattern suggests lack of sufficient cracking and desulphurisation facilities to meet this demand pattern. In 2004, China and the United States were scrambling for lighter crude oils in the Atlantic basin, as both of them are short of secondary facilities downstream. This competition was magnified in the market by speculative funds.

In summary, the above phenomena indicate lack of effective investment in either upstream or downstream facilities in the global oil supply chain.

Figure 8.7 Spread of Arabian extra light and Arabian heavy (fob by loading month, $/bbl)



Note: bbl = barrel; fob = free on board.
Source: Middle East Economic Survey; see <www.mees.com>.

Natural gas outlook for North East Asia

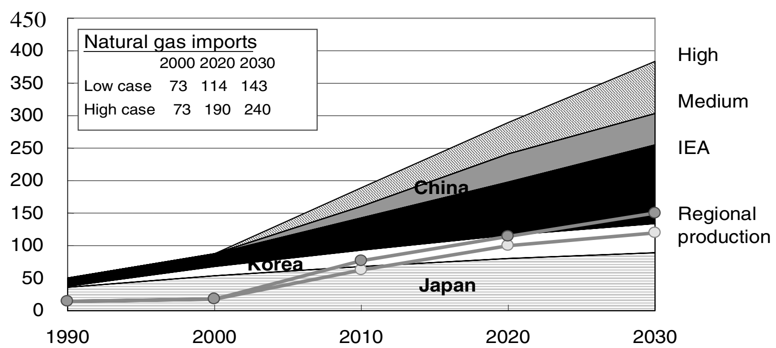
As with oil, the region's natural gas demand is expected to grow fast, particularly in China (Figure 8.8). In Northeast Asia, Japan and Korea have established nationwide gas use based on liquified natural gas (LNG). These markets are already nearing maturity and future growth is forecast to become moderate.

Until recently natural gas use in China was restricted to a few gas producing provinces like Sichuan. The first long-distance trunk line, from Shaanxi to Beijing, was completed in 1997. The great project 'West–East Gas Pipeline', connecting the interior Tarim basin to Shanghai, started transmission in 2004. Its capacity is 12 billion cubic metres per annum, with a plan to upgrade to 17 billion cubic metres. This pipeline has begun to open up a new era of nationwide gas use in China.

China's national gas market is in its early stages. The IEA (2004) takes a very conservative view of gas market development, but it is now generally expected that Chinese gas use will increase increasingly rapidly. Gas turbines are expected to be a very effective measure for coping with power shortages in peak hours – shortages which have seriously affected the development centres of China since 2003.

Gas is also cleaner than other forms of energy. This is especially important in China given the country's very large greenhouse gas emissions. For these reasons, the central

Figure 8.8 Natural gas demand of Northeast Asia, 1990–2030 (million tons per annum of LNG equivalent)



Note: IEA= International Energy Agency; LNG = liquified natural gas.
Source: Author's estimations; see <http://eneken.ieej.or.jp/en/data/pdf/290.pdf>.

government promotes the introduction of natural gas (pending any controversial price negotiations). Since the opening of the west–east pipeline, the majority of the gas supply is transmitted to eastern provinces, with provinces upstream of the pipeline moving quickly to adopt natural gas. Given the absorption of gas in upstream provinces, Shanghai (the destination of the pipeline) suddenly found itself unable to receive the originally allocated quantity of indigenous gas and is now scrambling for an LNG import plan. Although an expansion plan for the west–east gas pipeline is being advanced, upstream gas field development is also necessary. Under these circumstances, in addition to the aggressive development of domestic gas supply plans, almost 20 LNG import projects have been instigated nationwide. Should China's gas market develop as expected above, the region's gas use would double by 2020.

Opportunities for regional cooperation: the 'three S's of energy'

The Northeast Asian energy market is expanding fast and (as described above) is expected to become the world's largest energy consumption centre in the 2020s. At the same time, it is the development centre driving the world economy. Interdependence of the regional economies is progressing quickly. The mutual trade in Northeast Asia exceeds 25 per cent of the total imports/exports of each country. Japan and Korea have heavily invested in China, and the economic/industrial mosaic of the region is tightly constructed today.

The region faces several serious challenges in the field of energy and the environment – for example, rising dependence on the Middle East, unstable and unfair oil pricing and the security of sea lanes on the supply side, and low energy efficiency and environmental pollution on the demand side. These problems are generally international in nature. To solve, or at least alleviate, them will require a concerted regional effort; the problems are too great for an individual country to cope with independently. Countermeasures will require major efforts beyond national borders.

There are three main areas in which opportunities for such regional cooperation are evident: security, stability and sustainability of energy. We can call these the 'three S's of energy'.

Energy security

Regional cooperation on energy security should take account of short-term turbulence and long-term supply.

Short-term turbulence

In the past year there have been two important multilateral initiatives for improving preparedness for short-term disruptions. One is the Joint Oil Data Initiative (JODI), covering 94 countries; it is being promoted by a collaboration of six international institutions.[4] This system compiles and reports monthly data on oil production, consumption and inventory on the 20th day of the next month, covering over 90 per cent of the world's oil movement. The second initiative is the Real Time Emergency Information Sharing System (RTEISS) among APEC countries. This is a real-time communication system among government officers, to share and exchange information and intentions. The Institute of Energy Economics, Japan is working as a secretariat for both systems.

The use of energy reserves, or stockpiling, is a technique used to counter short-term turbulence. Japan currently has reserves equivalent to 173 days of Japanese consumption and Korea has 67 days of reserves. Recently China began to construct four energy reserve terminals, with an initial target of 20 days import quantity equivalent. The first batch of 16 tanks at the Zhenhai terminal was completed in August 2005. By 2008, 52 oil storage tanks will be completed at the four terminals under the above program; China plans to upgrade to 30 days by 2010. Although China is considering increasing the oil stockpile up to 90 days import equivalent in the long run, the program began only recently and the current size is still minimal. Establishing a shared regional energy reserve is yet to be discussed internationally.

Protection of sea routes is another issue which is of regional importance. There are currently security issues at choke points in sea lanes, such as piracy in the Malacca Strait. Since huge amounts of oil are transported through sea routes, the safety of oil tankers and oil spill responses are very important issues common to the region.

Energy stability

Major energy stability issues are stability of the market and oil/gas pricing. Although Northeast Asia is already a world-class energy market, its reality is not well reflected in oil pricing in the international market. There are three main concerns. First, even for term contracts, the pricing of crude oils for Asia depends on scarcely traded Dubai and Oman supplies. The scarcity makes the pricing quite vulnerable to slight incidents or speculation. Second, Middle East crude oil is priced in Asia at a slightly higher price than elsewhere in the world (the 'Asian premium'). Third, the expanding differentiation between light and heavy crude oil can be exaggerated by speculation.

There are two ways in which these issues can be dealt with. The first is to compile and make available accurate information on the market as quickly as possible through JODI; to encourage close communication among policymakers through RTEISS; and to facilitate the frequent exchange of views on the future outlook. These measures will help avoid obsession and upset in the market. Secondly, to realise rational pricing it is desirable to create a new price marker for the Asian market. Russian crude ex Perevoznaya, a Pacific coast port, may provide a good marker: as with Sakhalin 2 crude sales, to apply a new pricing system to align with those of Japan. To make prices more stable, it would be desirable to promote in the region international product trade that would provide an international price index. To this end, Northeast Asia should cooperate to create a proper and mature Asian oil and gas market, ideally similar to that in Europe.

In creating a mature petroleum market, it will be necessary to make the downstream sector more flexible. This may require alignment of product quality standards and reinforcement of physical capability through expansion and upgrading of refining and storage capacity. Upgrading of product quality should be promoted for more effective and environmentally friendly use. To this end, utilisation of spare capacities of refining and upgrading facilities in Japan and Korea should be promoted. Rationalisation of the regional and domestic transportation and trade systems are other important factors in the creation of a mature international market and the enhancement of regional energy security.

Long-term supply

Sustainability is the most important factor in assuring the development of the region. To this end, Northeast Asia needs to strengthen its energy supply base and rationalise energy consumption. These measures require a long lead time from planning to operation; however, no material dialogue has so far begun. There are two important ways to assure energy sustainability.

One is to reinforce the supply of energy sources. Introducing Russian resources to Northeast Asia will be one powerful option, which may be realised by constructing an oil and gas trunk pipeline and promoting upstream exploration and development. Oil and gas exploration and prospecting should also be promoted in other areas of the region, which may require settling territorial disputes. The introduction of natural gas and power and the creation of a mature market will require the construction and modernisation of delivery networks.

The second is energy conservation, or increased energy efficiency. Part of conserving energy consumption will require the further marketisation of the energy industry, including consumer level tariff systems. The second crucial part of increasing China's energy efficiency must lie in technology transfers, especially clean coal technology,. The Clean Development Mechanism and Emission Trading System (a multilateral approach) can help facilitate this technology transfer, but government incentives (unilateral) as well as bilateral and regional partnerships are also required.

There are a number of possible projects which the countries of Northeast Asia could successfully partner on.

Potential regional energy projects

Potential regional energy projects in Northeast Asia are shown in Table 8.3. Coal, oil, gas and hydropower in Eastern Russia have ample potential, but transporting them to the market requires gigantic projects. A Siberian oil pipeline may be the most feasible solution, as explained later. However, it is important to note that, in developing oil resources, we should consider the disposal of associated natural gas. We cannot only pick ripened fruits.

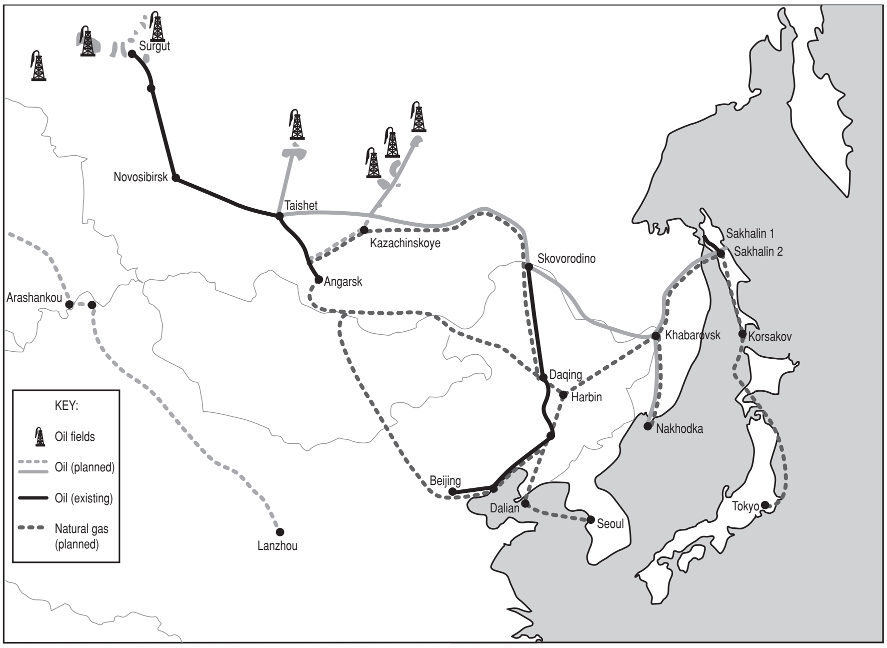
Figure 8.9 shows potential energy supply routes from Russia to the Northeast Asian markets. The oil and gas provinces are West and East Siberia and Sakhalin. Coal is also present in East Siberia. The mountainous area along the Amur River provides rich hydropower potential. But these sources are remote from markets and need to cross international borders. Additionally North Korea is located in a highly strategic geopolitical position for South Korea and Japan. International transit arrangements must be put in place before a transmission route can pass through this area.

Table 8.3 Characteristics of potential energy projects in Northeast Asia

	Upstream	Transportation	Market
Coal	Rich resource Abundant low-quality coal	Railway and shipping port congestion	Japan and Korea: Available China: Heavy use causing serious pollution
Oil	Potentially rich, but yet to be confirmed	Pipeline project is huge but relatively cheap	Readily available
Natural gas	Rich potential	Pipeline project is huge and costly	Japan and Korea: Maturing China: Yet to develop
Hydropower	Rich potential	Transmission is very costly	Japan and Korea: Matured China: Main market is remote

Source: Compiled by authors.

Figure 8.9 Potential energy flow from Eastern Russia



Source: Adapted from <http://eneken.ieej.or.jp/en/data/pdf/290.pdf>.

Siberian oil pipeline

On 31 December 2004, the Russian government announced its official decision to construct the Pacific oil pipeline from Taishet to Perevoznaya Bay, located along the Pacific coast west of Vladivostok. The total length of the oil pipeline will be 4,188 kilometres (km) and there will be 11 pumping stations. The initial capacity will be 1.6 million barrels per day. At the Pacific coast terminal, 4.3 million kilolitres of oil storage and shipping facilities will be constructed with one single buoy mooring (SBM) to accommodate 300,000 deadweight tonne (dwt) tankers and two SBMs for 150,000 dwt tankers. Ten regional governments in east Russia have already agreed to the construction. Potential environmental impacts are being assessed in a coordinated fashion; at the time of writing the Ministry of Energy and Industry was waiting for the Russian government to give final instructions to implement the plan submitted in the spring of 2005.

The pipeline will be constructed in two phases. Phase 1, from Taishet to Skovorodino, will be complete by 2008. From Skovorodino, oil will be initially transported by rail to the shipping terminal (pending completion of phase 2 of the pipeline). The shipping terminal at

Perevoznaya will also be constructed in phase 1. Additional locomotives for rail transport have already been ordered. China plans to construct a branch line from Skovorodino to Daqing, which will carry oil finally to Dalian. Phase 2 will be completed, at the earliest, around 2010. At the time of writing there was a report that the location of the shipping port might be changed from Perevoznaya to Kozmino Bay near Nakhodka because of environmental concerns. This may change the design of the export terminal.

At the time of writing total investment was expected to be in the range of US$11–14 billion (Table 8.4). The first estimate given by Transneft in 2002 was $6.5 billion, including a branch line to China. The budget has subsequently been doubled, possibly due to technical and environmental requirements in coping with permafrost, the worldwide inflation in oil, material prices, service fees and so on. The earlier estimate was comparable to the investment made in China's West–East Gas Pipeline (covering 4,000 km).

Rail transport is costly and troublesome for world-class oil trade. Japan is therefore anxious about the situation as the phase 1 plan seems to serve only China. Only 24 million tons of West Siberian oil is allocated and some Russian sources say that the phase 2 construction will begin only when development of the east Siberian fields is confirmed. In its negotiations on institutional loans, the Japanese government has expressed a strong desire for the simultaneous construction of the whole pipeline to the Pacific coast.

Economics of pipelines

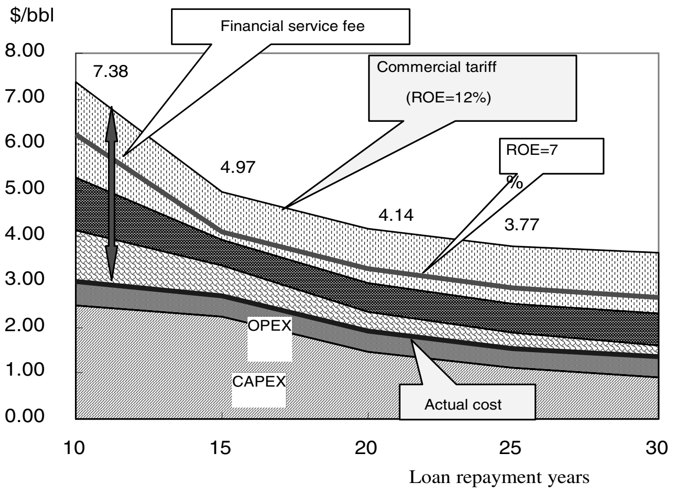
Pipelines are very capital-intensive projects with prolonged repayment periods. As shown in Figure 8.10, project economics depend heavily on the loan repayment period; commercial

Table 8.4 Siberian oil pipeline plan

Destination	Distance	Annual hydropower capacity	Construction cost
Taishet	1,800 km from West Siberia		
Perevoznaya or Kozmino (export)	4,188 km from Taishet	Export: 50 M Local: 10 M	$10–14 billion
China: Daqing(further to Dalian)	900 km from Skovorodino (+1,000 km to Dalian)	10–20 M	$1–2 billion

Note: MTPA = million tons per annum.
Source: Compiled by authors.

Figure 8.10 Pipeline economics



Note: bbl = barrel of oil; CAPEX = capital expenditure; OPEX = operational expenditure; ROE = return on equity.
Source: Author's estimations; see <http://eneken.ieej.or.jp/en/data/pdf/290.pdf>.

projects require financial service fees of 1.5 to 3 times the technical cost (CAPEX plus OPEX); and the price risk barrier for commercial viability is 2.5 to 4 times the actual cost.

It should be noted that figures in project cost–benefit analyses are not necessarily entirely reliable since there is considerable room for improving the appearance of the project's economics by arbitrarily changing assumptions for loan repayment periods, interest rates, tax rates and so on. In dealing with pipeline economics at an early stage, we should focus not on upgrading the cost estimation but on considering an appropriate financial structure.

According to Russian information, Transneft has proposed an estimated pipeline tariff of $6.7 per barrel, which is slightly greater than the BTC pipeline. This would involve a 10–15-year repayment period, which is reasonable given the currently available institutional finance. However, Figure 8.10 suggests that there are many measures which could lower the project threshold, such as provision of long-term credit, tax exemptions and subsidies. One important note is that the various social benefits expected from such pipeline projects could not be incorporated into the investment economics of the private sector. There is therefore a case for the government to provide some assistance.

Using the assumptions made in the above paragraph, the commercial pipeline tariff is below $5 per barrel for oil and around $2 per million British thermal units (BTU) for natural gas as summarised in Table 8.5. These figures are more than double those of conventional ocean transportation costs, but technical costs represent only half the total cost. Imported prices may be in the range of $50 per barrel for crude oil and $6 per million BTU for natural gas. Facing these end-user prices, commercial pipeline tariffs account for only 10 per cent of the final price for oil, but 30–40 per cent for natural gas.

The international natural gas price has soared rapidly in recent years, significantly reducing the proportion of the final price attributed to transportation costs. This has made some projects involving remote 'stranded gas'[5] financially viable however. High gas prices are required to justify a gigantic project. The following thresholds may provide an indication of feasibility:

- The wellhead gas price may be $0.5–1.5 per million BTU depending on size, location and other characteristics of the gas fields. Smaller gas fields in Southeast Asia are on the higher side of this estimate.
- The delivered gas price for LNG projects and long-distance pipelines such as the one from inner Siberia may be $3.5–4.5.
- If gas delivered to the coast needs to be liquefied for further shipping, the cost may be $4.5–5.5.

Table 8.5 Oil and gas pipeline costs: tariff, actual and market prices

Project period	Pipeline tariff (ROE=12%)	Actual cost	Market price	B/A	A/C	B/C
	A	B	C			
Oil (1.6MBD)	$/bbl	$/bbl	$/bbl	%	%	%
15 years	4.97	2.70	CIF 50.0	54	10	5
25 years	3.77	1.55		41	8	3
Natural gas (20 BCM/y)	$/MBTU	$/MBTU	$/MBTU	%	%	%
15 years	2.37	1.20	At city gate 6.00	51	40	20
25 years	1.79	0.69		39	30	12

Note: bbl = barrel; BCM = billion cubic metres; CIF = cost, insurance, freight; MBD = million barrels per day; MBTU = million British thermal units.
Source: Author's estimations; see <http://eneken.ieej.or.jp/en/data/pdf/290.pdf>.

Recently, the price of LNG surpassed all these thresholds. Here, we should note that the crude oil price (nearly $70 per barrel) prevailing in the market is equal to $12 per million BTU in heat value equivalent. The LNG price delivered to Asia is still much lower than this. If the gas price trend in Asia continues further toward the values seen in American markets, we can expect most of the remote stranded gases to be liberated from cost constraints.

However, when we talk about remote interior gas, there will be another discussion on the competition of piped natural gas (PNG) against seaborne LNG. To implement a large project, large amounts of demand and supply have to be aligned comfortably to assure project credibility. In the early stage of market development, PNG can pick up markets only along the pipeline route, while LNG can collect any market within a cost-effective shipping distance. Thus, since the global gas price has soared to a level where shipping costs are marginalised, LNG has become a global commodity. In addition, a pipeline project needs to resolve transit issues with the provinces and nations it crosses. Many international pipeline projects are faced with this problem. Overall, the market development of LNG is more flexible than that of PNG. We have seen a typical example of this in the project development of Sakhalin 1 and Sakhalin 2. At any rate, the remote interior gas from Siberia has to be delivered by pipeline to the market or to the seashore for further shipment as PNG or LNG.

While LNG has flexibility in serving different markets, it requires a costly liquefaction process. Compared with seaborne LNG, PNG can be used strategically to promote the development of regions along its route. Once a certain pipeline network has been developed, like in the United States and Europe, a pipeline may be substantially more beneficial for society than LNG. Seaborne LNG can be sold to any market in the world which offers the highest price – for example, the US market – but PNG is restricted to the markets connected by the pipeline system. PNG therefore offers a more stable and less uncertain long-term energy supply than LNG does. The costs and benefits of PNG and LNG must be assessed carefully when we discuss the development of regional energy systems.

As observed above, there are various hurdles to be overcome in implementing pipeline projects. Table 8.6 shows the major factors that influence whether an oil or gas pipeline is feasible.

As Table 8.6 shows, the only real problem in the case of oil is the gigantic project size involved. However, this may be overcome if institutional finance is available. Russia and Japan are negotiating conditions under which such funds would be provided for construction of the Siberian oil pipeline. In the case of natural gas, on the other hand, all the issues listed in Table 8.6 are substantial and are not easy to solve. Finding a way to develop natural gas supplies may take more time in this case.

Table 8.6 Factors influencing the feasibility of oil or gas pipelines

Factor	Oil	Gas
Price	Commercial pipeline tariffs are about 10 per cent of the market price	Commercial pipeline tariffs amount to 30–40 per cent of the end user gas price
Tariffs	Commercial pipeline tariffs are substantially lower than rail transport costs (over $10 per barrel)	The existing natural gas market is tightly guarded by long-term LNG contracts, though some contracts are coming nearer to expiration/extension
Market	The contract term is shorter and more flexible for crude oil than for gas, and Northeast Asia provides a large enough international market for trade	Piped natural gas is inferior to LNG in market development, as the former is restricted to delivery along the pipeline route, while the latter can be delivered to almost any sea port
Distance	The long-distance pipeline is too large and lacks the economic profitability required to attract private sector investment	The long-distance pipeline is too large and lacks the economic profitability required to attract private sector investment

Source: Compiled by authors.

Conclusion and recommendation

While Northeast Asia is already a world-class energy market, and is growing fast, the region is vulnerable to short-term disturbances as well as to potentially uncertain long-term developments in the region. Northeast Asia faces considerable risks in relation to energy security, stability and sustainability. Yet cooperation to form combined policies addressing those risks has not been forthcoming. Specifically relevant to long-term sustainability are the challenges of being located far from primary energy supply sources and the low energy efficiency currently prevailing in China.

Global actions are already being taken to strengthen energy security, reinforcing preparedness against emergencies. However, Northeast Asia still lacks any dialogue on issues and projects specific to the region. To improve this situation there should be:

- a joint response program on supply disruption;
- the creation of a region-wide energy market;
- investment in energy resources, transportation and market infrastructure, and an expansion or upgrading of energy processing facilities; and
- technology transfer and joint technology development, including socioeconomic systems.

A world-class market needs world-class policy. Developing and mobilising Russian resources will involve gigantic projects. This in turn will require a proper regulatory framework and suitable support promoting cross-border investment, trade and technology cooperation. Governments of the region will need to make concerted efforts to implement these initiatives.

All in all, we need regional cooperation, such as a Northeast Asia Energy Partnership, to coordinate projects of gigantic size and international intricacy in order to realise stable and sustainable energy supplies. Such action should focus on collaboration, not aid, and it should be based on the principle of equitable contribution for equitable benefit.

To facilitate a regional dialogue, we need to create implementing bodies at the government level as well as among private players. Initially, there may be a need for non-binding dialogue to identify the priority agenda. The first collaborative job may be joint studies on the regional energy outlook, not just an exchange of individual views. This looks like a detour, but it is necessary to provide the basis and authority for the job to follow.

Having established a road map for cooperation, the next step is to create an organisation for regional partnership. Agreements at this stage should be legally binding, if 'softly', to assure enforcement by each country.

This process may take time, but may be upgraded gradually, step by step, confirming that all members recognise the need for such actions. Then human wisdom will find the desirable path to assure sustainable development of the region at some time in the not too distant future.

Notes

1 This tendency is continuing. During the first half of 2005, Middle East crude imports regained their share, at 49.2 per cent, while the African crude import share further increased to 30.3 per cent. In contrast, Southeast Asian crude imports recorded a sharp decrease of 37.3 per cent in the same period.

2 For this forecast to be accurate given China's high recorded growth to 2005 (exceeding 9 per cent per annum on average), China would need a much lower growth rate (around 4.9 per cent) for the years 2006–09. This seems highly unlikely.

3 This relationship was reversed in 2004, possibly due to the current abnormal global appetite for Arabian extra light, as explained below.

4 They are the Asia-Pacific Economic Cooperation (APEC) forum; Eurostat; the Organisation for Economic Co-operation and Development (OECD); the IEA; the Organizacion Lattinoamericana de Energia (OLADE); the Organization of the Petroleum Exporting Countries (OPEC); and the United Nations Statistics Division.

5 Gas that has been too far from the market to be commercially viable.

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