Balancing Development, Energy and Climate Priorities in China

Current Status and the Way Ahead

September 2007

Kejun Jiang
Xiulian Hu
Xianli Zhu
Amit Garg
Kirsten Halsnaes
Qiang Liu

UNEP

UNEP RISØ CENTRE
ENERGY, CLIMATE AND SUSTAINABLE DEVELOPMENT

Balancing Development, Energy and Climate Priorities in China

Current Status and the Way Ahead

Kejun Jiang
Xiulian Hu
Qiang Liu
Authors (Chapters 6-8)

Xianli Zhu
Author (Chapters 2-5)

Amit Garg
Kirsten Halsnaes
Report Editors,
Authors (Chapters 1 & 9)

September 2007

UNEP

UNEP RISØ CENTRE
ENERGY, CLIMATE AND SUSTAINABLE DEVELOPMENT

Balancing Development, Energy and Climate Priorities in China:
Current Status and the Way Ahead

UNEP Risø Centre
on Energy, Climate and Sustainable Development
Risø National Laboratory
Technical University of Denmark - DTU, Roskilde, Denmark

ISBN: 978-87-550-3628-4

Publisher: Magnum Custom Publishing (A Division of Magnum Books Pvt Ltd)
New Delhi, India; website: www.magnumbooks.org

September 2007

When citing this report the following citation should be used:
Kejun J, Xiulian Hu, Xianli Zhu, Garg A, Halsnaes K and Qiang L, 2007. *Balancing Energy, Development and Climate Priorities in China: Current Status and the Way Ahead*. UNEP Risoe Centre on Energy, Climate and Sustainable Development, Roskilde, Denmark. ISBN: 978-87-550-3628-4. September 2007

Preface

This report is the China Country Report of the *Projecting future energy demand: Balancing development, energy and climate priorities in large developing economies* Project that has been managed by the UNEP Risø Centre on behalf of UNEP's Division of Technology, Industry, and Economics (DTIE). This project is a partnership between the International Energy Agency (IEA) and UNEP to broaden the knowledge base on energy demand policies in the large developing economies of China, India, Brazil and South Africa. The twin goals are to strengthen planning in these countries, and improve the quality and usefulness of the IEA World Energy Outlook 2006 through a better understanding of the environmental, social and economic drivers that influence energy demand.

The project is implemented through cooperation between the UNEP Risø Centre and centers of excellence in Brazil, China, India and South Africa. The project is sponsored by UNEP and carried out in close coordination with the International Energy Agency's (IEA) Economic Analysis Division and provided inputs to the World Energy Outlook 2006 report. The present report has also benefited immensely from this collaboration and we thank all the concerned researchers for their inputs.

Energy, and Climate Project has through country case studies, sustainable development indicators (SDI) and cross-country comparisons explored how a broad range of economic, social and environmental policy objectives can be combined in a way whereas local as well as international concerns can be met simultaneously.

Under this project, four country studies have been carried out, on China, India, Brazil, and South Africa. The country studies address energy sector issues, and alternative scenarios that align national development priorities with energy sector policies. The projects examine in greater detail how domestic energy sector policies can be evaluated using specific sustainable development indicators and existing analytical approaches and tools relevant to the countries. It is aimed at identifying promising energy policy options and technology innovation approaches that are consistent with their national sustainable development objectives, and which reduces greenhouse gas emissions or keep these at a relatively low level.

The focus of this report is on the energy sector policies that mainstream climate interests within development choices. The country study results for future energy and environment projections that are included in this report are backed by intensive economy-energy-environment modeling by Energy Research Institute of China National Development and Reform Commission, wherein general scenario analysis of the energy sector explores some policies in more depth.

The report includes a short introduction to the project and its approach. This is followed by our Chinese energy, development and climate change analysis which is followed by an assessment of cross-country results that gives a range of key indicators of the relationship between economic growth, energy, and local and global pollutants.

A key lesson from our assessment is that climate agreements can deliver more if they view the climate problem from the development lens. Climate-centric instruments are inferior to those which first support endogenous climate-friendly actions and then induce exclusive climate-centric actions. The benefits of aligning development and climate actions, especially in the energy sector are not exclusive to developing countries, though their welfare gains are more apparent. The alignment should be embraced by developed countries too, so as to modify their unsustainable energy consumption and emissions pathways that are the primary cause of climate change.

The country study results presented in chapters 6-8 are “owned” by the ERI team, while URC has contributed with chapters 1–5, cross-country comparison and editorial support. The report has benefited immensely from joint modeling work, discussions and insights on the theme between ERI, over the years, with Japanese, US and European colleagues. We are especially thankful to the NIES, Japan researchers for providing access to AIM Strategic Database and close interactive discussions on modeling with AIM Team members. This report has also benefited from our discussions with other project partners and eminent researchers Dr Fatih Birol and Dr Laura Cozzi of IEA, Prof Emilio La Rovere of Brazil, Prof P.R. Shukla of India, and Dr Harald Winkler of South Africa. We are thankful to them. The report also draws from the work of numerous Chinese co-researchers with whom some of the authors had the privilege to work. Last but not the least, the coordination, encouragement and project facilitation extended by Dr Mark Radka (Head of UNEP Energy, UNEP DTIE, Paris), Dr John Christensen (Head of URC) and Daniel Puig are acknowledged.

We are sure that this report would be of interest to various domestic and international audiences including policymakers, researchers and scientists.

Authors

Contents

TABLES

FIGURES

Part I

Overview and Methodological Issues

CHAPTER – 1

Sustainable Development as a Framework for Assessing Energy and Climate Change Policies

The project introduces a conceptual framework that can be used for integrated assessments of sustainable development (SD), energy and climate policy objectives. The approach is here to use a number of key SD indicators[1] that reflect economic, social, and environmental dimensions of sustainable development, and to use these to examine specific clean energy policies.

The sustainable development agenda of a country could be very wide and the literature includes hundreds of different definitions. It is beyond the scope of this project to go into an assessment of the theoretical literature about sustainable development, rather the approach taken here is pragmatic and the focus is to consider how current development trends in the energy system can be made more sustainable.

The perspective taken is that climate policy goals are not a major priority area in developing countries since other development goals including poverty alleviation, energy provision etc., are more important immediate concerns. However, many general development policies have large side-impacts on climate change, and in order to capture these, we have outlined a framework for how SD dimensions, energy and climate can be assessed jointly.

The starting point for the methodological approach is that an assessment of human well-being aspects of energy provision can be structured around an evaluation of specific policy cases in relation to a number of focal indicators that reflect key SD dimensions. One way to organize such an analysis is to formulate a general objective function for policy evaluation that includes arguments in terms of well-being indices. These for example can reflect areas like:

---

[1] An SD indicator in this context is used as a sort of measurement point for a quantitative assessment of the impacts of implementing specific policies with regard to areas that are considered to be key national focal points for addressing sustainable development. See also a more elaborate discussion about the use of SD indicators in Halsnæs and Markandya, Chapter 5, 2002

- Costs, benefits and other general economic impacts.
- Total income generation and income distribution.
- Energy provision and distribution.
- Environmental impacts
- Health impacts of energy use and access to health services.
- Education.
- Local participation in policy implementation.

1.1 Sustainable Development Indicators

A number of quantitative or qualitative indicators that reflect these human well-being dimensions have been defined and applied to the assessment of development, energy and climate policies. Obviously, it is most easy to apply well-being indicators to the evaluation of sector or household level policy options rather than at macroeconomic level. This is the case, because the well-being issues addressed here include various elements that directly reflect the freedom and rights of individuals and households. A meaning full representation of these therefore requires rather detailed information that is most easy to cover in micro-oriented or sectoral studies.

The following Table 1 provides an overview of how economic, environmental and social sustainability dimensions related to energy and climate change can be covered by specific indicators. These indicators are defined in a way, where they can be linked to specific quantitative measurement standards and modelling output.

The approach of the Development, Energy and Climate project in addition to the suggested SD indicators also includes recommendations about how institutional elements of studies can reflect specific aspects of inter- and intra-generational issues of SD. Some of the major assumptions are here that studies should reflect social costs, where i.e., externality costs of pollutants are integrated, and that the

Table 1: Examples of indicators that can be used to address economic, environmental and social sustainability dimensions seen from an energy sector perspective

SD Dimension	SD Indicator
Economic	
Cost Effectiveness	Net costs, Financial flows
Growth	Income generation
Employment	No of people and man-hours
Investments	Energy investments
Energy Sector	Energy consumption, Access and costs
Environmental	
Climate change	GHG emissions
Air pollution	Local air pollution, particulates, Environmental health benefits
Water	Discharges to water
Soil	Exposure to pollutants
Waste	Waste discharge
Exhaustible resources	Fossil fuels
Biodiversity	Specific species
Social	
Local participation	Direct participation of local companies or people in policy implementation
Equity	Distribution of costs and benefits, income distribution
	Energy consumptions and costs to different income groups
Poverty alleviation	Income or capabilities created for poor people
Education	Literacy rates, primary and secondary education, training
Health	Life expectancy, Infant mortality, Major diseases, Nutrition, Burden of Disease (BoD)

social discount rate is recommended for assessments over long time horizons[2].

It has been suggested for practical reasons to focus on a more limited range of indicators in the studies, and the countries were asked to develop an overview table in the format like

[2] See IPCC, 2001 and 1995.

Table 2: Overview of definitions and measurement standards for key SD dimensions

	SD Theme	Indicator	Measurement standard
Economic dimension	Investment and Costs	Total capital cost	Financial cost
	Employment	Labour employed	No of man hours skilled and unskilled
	Energy	Energy access and affordability	Energy supply to households and industry (quantity and share) and energy costs relative to income
Social dimension	Poverty alleviation	Income generation	Income to poor households
	Health improvements	Health services	Income generation No. of people with access to health clinic
Environmental dimension	Air quality	Air pollution	Emissions of SO_2, NO_x and particulates
	Climate change	CC impacts and GHG emissions	Loss of crops, land etc. GHG emissions

shown in Table 2. It was here suggested to focus on a limited set of SD dimensions including investments, costs, employment, and energy access and affordability in the economic dimension; poverty alleviation and health in the social dimension; and air quality and climate change in the environmental dimension.

1.2 Energy and Sustainable Development

It is worth recognizing that the well-being indicators that are suggested in Table 1.1 include many of the dimensions that were covered in the Millennium Development Goals (MDGs) that were adopted by the World Summit on Sustainable Development in Johannesburg in August 2003 (UNDP, 2003). Some of the major MDGs are to decrease poverty, to reduce hunger and to improve education and health. Environmental issues are only directly referred to in the MDGs in relation to air pollution impacts on health and to the degradation of natural resources. Energy obviously is indirectly linked to all these environmental issues. However, there are several other strong linkages between the top priorities of the MDGs as for example poverty alleviation and energy issues and the same is the case with the MDGs related to water and food supply. Supply of high quality and clean energy offers income generation opportunities for business as well as for households and may allow time for educational activities. At the same time access to clean energy improves health conditions and energy is needed for health clinics and educational activities.

The UN Millennium Task Force has conducted in-depth studies on the requirements for achieving the different goals, and part of this work is a specific assessment of energy services for the poor (Modi et al., 2004). The energy task force group concluded on the basis of the Modi study that a number of energy targets were a prerequisite for achieving MDGs including introduction of modern fuels to substitute traditional biomass use, access to modern an reliable energy sources for the poor, electricity for education, health, communication, mechanical power, and transportation.

Many studies of development and energy linkages assume that energy is a key component in development without a further examination of—in which way and in which configurations energy most effectively supports development. This is a limitation since investments in energy provision compete with other investments of scarce resources, and energy consumption has several externalities including local and global pollution, which negatively affects human well-being. Furthermore energy investments tend to create lock-in to technology trajectories, which can make it very expensive to change track later if there is a need for managing externalities or other concerns.

Energy has a key role in economic development through its role as a production input, and as a direct component in human well-being. Toman and Jemelkova (2002) in an overview paper provide a number of key arguments for how and in which way energy plays a role in development. They note that "there are several ways in which increased availability or quality of energy could augment the productivity and thus the effective supply of physical and/or human capital services. The transmission mechanisms are likely to differ across the stages of development… for more advanced industrialized countries, increased energy availability and flexibility can facilitate the use of modern machinery and techniques that expand the effective capital-labour ratio as well as increase the productivity of workers. Whereas supply-side energy changes in less advanced countries economize on household labour, here energy availability can augment the productivity of industrial labour in the formal and informal sectors."

The general conclusion that arrives both at macro level and at household level about the relationship between economic development and energy consumption is that increased energy availability disproportionately could affect economic development. Toman and Jemelkova (2002) identify the following factors behind this as:

- Reallocation of household time (especially by the woman) from energy provision to improved education and income generation and greater specialization of economic functions.
- Economics of scale in more industrial-type energy provision.
- Greater flexibility in time allocation through the day and evening.
- Enhanced productivity of education efforts.
- Greater ability to use a more efficient capital stock and take advantage of new technologies.
- Lower transportation and communication costs.
- Health related benefits: reduced smoke exposure, clean water, and improved health clinics through electricity supply.

In addition to energy's potential for supporting economic growth disproportionately, there can also be a tendency to see decreasing energy/GDP intensity with economic development, as a consequence of increasing energy efficiency with the introduction of new energy technologies.

The conclusions by Toman and Jemelkova regarding industrialized countries are based on detailed empirical analysis from the US on the role of energy in industrialization processes including work by Schurr et al. (1982) that identifies more flexible energy forms (like electricity) and higher energy conversion efficiency as major factors in productivity increases for non-energy production factors. A consequence of this is that energy/GDP intensities tend to increase or to be stable in earlier phases of industrialization, while they later tend to decrease. This suggests that economic development, energy consumption, and in some cases[3] pollution can be decoupled from economic development. This tendency is subsequently illustrated with data for some industrialized and developing countries in this project.

In less advanced countries larger and cleaner energy provision can support human well-being through several channels including increasing opportunities for income generation activities and a number of benefits in relation to education, health, decreased time for household chores, and increased leisure time. The magnitude of these benefits has been assessed in detailed studies for a number of developing countries, and some results will be presented subsequently.

[3]The local and global pollution associated with increasing energy consumption depend on the structure of energy supply, whether this goes in a more pollution intensive direction or if cleaner fuels are introduced.

1.3 The Sustainable Development Concept

SD and environmental linkages can be understood in many different ways dependent on the underlying paradigm of development (Halsnæs and Verhagen, 2006). Some of the controversies that have been going on in the theoretical debate about sustainable development have been between economists and ecologists. Economists have tended to focus on economic growth patterns and substitutability between man-made and natural capital, while ecologists have emphasized limits to growth and constraints. Recent work by a group of leading economists and ecologists has done an attempt to "merge" the two disciplines in a practical approach that can be used as a background for addressing SD and environmental linkages. A short introduction to this is given in the following:

Arrow et al., (2004) summarize the controversy between economists and ecologists by saying that ecologists have deemed current consumption patterns to be excessive or deficient in relation to sustainable development, while economists rather have focused on the ability of the economy to maintain living standards. It is here concluded that the sustainability criteria implies that inter-temporal welfare should be optimized in order to ensure that current consumption is not excessive[4]. However, the optimal level of current consumption cannot be determined i.e., due to various uncertainties, and theoretical considerations are therefore focusing on factors that could be predicted to make current consumption unsustainable. These factors include the relationship between market rates of return on investments and social discount rates, and the relationship between market prices of consumption goods (including capital goods) and the social costs of these commodities.

A key issue that arises from this approach is what is meant by consumption patterns, and how these should be understood in relation to human well-being and its major components. Energy is as already said a key component in consumption both at macroeconomic- and household-level, and energy to a large extent is based on exhaustible resources and creates pollution.

Furthermore, it is important to recognize that developing countries exhibit some specific institutional factors that are key framework conditions for individual and collective consumption choices, which go beyond market frameworks due to inefficiencies, limited information, and weak institutional capacities in these countries. One of the implications of these institutional weaknesses in developing countries is that the use of various production factors including energy is very inefficient, which both implies supply constraints, high costs, and high pollution intensity.

The Development, Energy and Climate project includes a number of analytical steps and are covered in detail in Halsnaes et al. (2006). These provide a methodology up-scaling the results from individual country case studies and link them in a macroeconomic national modelling framework.

The next section will briefly present country case studies. The country study results included here are a short summary of some of the main findings and do not provide all details of the work that has been undertaken. Some of the countries, in particular those with fast growing economies and energy sectors such as Brazil, China, India and South Africa have conducted a general scenario analysis of the energy sector and explored some policies in more depth, while the country studies for Bangladesh and Senegal where the energy sector is less developed have focused more on specific issues related to energy access and the electricity sector.

[4] Arrow et al. (2004) state that "actual consumption today is excessive if lowering it and increasing investment (or reducing disinvestment) in capital assets could raise future utility enough to more than compensate (even after discounting) for the loss in current utility."


EMPORIUM

CHAPTER – 2

China's National Socio-economic Profile

All paths to the future start from the current. This chapter will provide a brief overview of the social, economic, energy, and GHG profile of China today.

2.1 Social Profile

The Chinese economy and society bear some distinct characteristics and a profile of it may include the following aspects:

2.1.1 Population and literacy

China is the most populous country on earth and by the end of 2005, the total population was 1308 million on China's mainland. China witnessed rapid population growth during the period of planning economy. Its 1.3 billion people represent some 21% of the world total.

Due to the one-child policy, the country's population growth has been slowing down, now growing at around 7 to 8 million per year. It is a concern that China's population may reach aging levels before China achieves development levels equal to those of the western world. The continual population growth means enormous pressure for the economy to expand quickly so as to create jobs for its huge labour force.

The literacy rate is 93% and among the Chinese population, around 3.6% have received colleague or university education (CNSB, 2006). Although the Law of Compulsory Education enacted in 1986 stipulated that it is compulsory for each child to accept nine years of education, this law is not properly enforced in some poor rural areas. The Chinese government has now set the target of offering free 9-year education from 2008 onwards.

2.1.2 Poverty

According to the World Bank, in 2004, 16.81% of China's rural population and 0.27%[5] of China's urban population lived below the poverty line of 1 US$[6]/per day. This means that 128.7 million[7] Chinese are still living below the international poverty line.

2.2 Economic Profile

China now has a nominal GDP of 1,931.7 bn USD in 2004, the sixth in the world following the United States, Japan, UK, Germany and France. But as many things are much cheaper in China, its 2004 GDP on PPP basis is 7,642.3 bn USD, ranking already the second biggest in the world (UNDP, 2006).

Enormous regional diversity is a salient feature of the Chinese economy and social life. Because of differences in natural conditions, social capital, and differences in the pace of opening up to the outside world, the Chinese economy is facing enormous regional disparity. Generally, the east coastal areas are of higher population density, more advanced economy, higher education level, and better climate.
So far, around 43% of the Chinese population are urban residents. A large number of labourers, high rural population and small arable per capita land holdings result in slower increase in farmers' incomes as compared to those of urban residents. As a result, currently, rural residents are as a whole having a much lower income than those living in cities. In 2006, the per capita net income of rural residents was RMB 3,587, less than one-third the per capita disposable income of urban residents of RMB 11,759 (see Table 3).

In recent years, to tackle the problem of enormous income disparity, China has cancelled taxes on agricultural products and rural residents. The annual income growth rate of urban residents remains several percentage points higher than that of people living in rural areas.

2.3 Energy Profile

China's energy consumption has been increasing quickly. Coal contributes to about two-thirds of the country's energy consumption. Compared with the developed countries, oil, natural gas, as well as nuclear plays a smaller role in China's energy supply. Booming domestic energy demand, fueled by rapid economic growth and income level increase among households, leads to rapid increase in oil consumption and import.

Table 3: Per capita income in China–2005

	East	Central	West	North-east
Per Capita Annual Disposable Income of Urban Residents (RMB)	13375	8809	8783	8730
Per Capita Annual Net Income of rural residents (RMB)	4720	2957	2379	3379

Source: 2006 China Statistical Yearbook, CNSB, 2006

2.3.1 Coal-dominated energy mix

China has a coal-dominated energy endowment. Among its proved fossil fuel reserve, 96% is coal and petroleum and natural gas together only accounts for 4% (Zhou D.D, 2003). Despite great efforts to optimize the country's energy structure, coal still contributes two-thirds of the total primary energy consumed in the country (CNSB, 2005).

2.3.2 Energy efficiency

Through technology progress and conducting energy-conservation technology renovation, the unit energy consumption of China's major energy-intensive products has seen a dramatic decrease. However, compared with international advanced levels, China still has much space for the improvement of energy efficiency.

In 2002, China's energy efficiency was 4,600 US$[8] /toe, equal to the world average level, much lower than the 5,100 US$/toe of OECD countries, the 5,700 US$/toe in Japan, the 6,200 US$/toe in Germany. There is still much space for energy

[5] Data from the World Bank database http://iresearch.worldbank.org/povcalnet/.
[6] The World Bank poverty definition of 'Population below $1 a day' is the percentages of the population living on less than $1.08 a day at 1993 international prices.
[7] Based on the population data in China Statistical Yearbook 2006.

efficiency improvement and saving.
According to the National Development Reform Commission, in 2003 China accounted for a significant proportion of world consumption: 7% of crude oil, 25% of aluminium, 27% of steel products, 30% of iron ore, 31% of coal and 40% of the global consumption of cement. Such developments have already significantly decoupled GDP growth and energy consumption at the international level.

2.3.3 Energy import dependence

The country became a net energy importer for the first time in 1993, since then its oil import has been increasing at a high speed. In 2005, over 40% of the country's oil consumption was relying on import. Rapid increase in coal consumption is placing unprecedented pressure on supplies of coal. In the first two months of 2007, China for the first time became a net coal importer (FT, 24 April 2007). China is the world's largest producer and consumer of coal and in 2006, the country's coal production reached a record high of 2.38 bn tonnes, about double the total in the US, the second highest producer. China's coal exports have been declining since reaching a high of 70m tonnes in 2003 and are now being outpaced by imports, mainly from Indonesia and Australia.

2.4 Environment Profile

2.4.1 Low per capita resource possession

Such a large population base means low resource possession in terms of per capita average. For instance, China has 7% of the world arable land and its per capita arable land possession is only 40% of the world average level. Its per capita fresh water possession, 2,285 m^3 is approximately one-fourth of the average per capita level on earth.

2.4.2 Severe pollution

Air, water, and soil pollution is severe in China. The SO_2, dust, NO_x, emissions from coal combustion is damaging human health, air and water quality, agriculture and ultimately the economy. In 2006, a World Bank pollution survey showed that, of the 20 most polluted cities in the world, 16 are in China.

Due to lack of wastewater treatment facilities and municipal solid waste collection and treatment facilities, as well as wastewater and solid waste from industrial process, all the major rivers in China face some extent of pollution; in some part, the water is too heavily polluted for any irrigation or industrial use. The rapidly increasing municipal solid waste is dumped in landfills on the outskirts of large cities, leading to soil and underground water pollution.

2.4.3 Air pollution—SO_2 emissions

China is now the biggest SO_2 emitter, the second biggest energy consumer, and the second biggest GHG emitter on earth. Its coal dominated energy structure makes air pollution a serious problem in China.

In 2000, China's SO_2 emission overtook that of the US and became number one in the world. During the 2000–05 period, environmental indicators are the only ones that the country failed to realize in its established targets. In its 10th Five-year Plan for the 2000–05 period, China set two targets related to SO_2 emission control: one is reducing its SO_2 emissions by 20% on the 2000 basis and the other is some alleviation to acid rain pollution in the country. However, it turned out that neither target was realized, actually the country's SO_2 emission was 27.8% higher than level in 2000.

Today, one-third of the Chinese land territory suffers from acid rain precipitation and it is estimated that each year, the economic losses from acid rain pollution is more than RMB 110 bn (Xinhua News Agency, 2004).

2.4.4 Other kinds of air pollution

Nearly three decades of rapid economic growth, increasing motorization, industrialization, urbanization, energy consumption and historic mismanagement of natural resources generate

[8] Based on 2000 PPP US$, from the 2005 Human Development Report—HDI of UNDP.

major air pollution problems for China. Large-scale industry relying on coal for energy production contributes to this, particularly in the northern provinces. According to the 2006 World Development Indicators of the World Bank, 24 out of the 30 cities with most severe SO_2 pollution are in China, and all the 15 cities with worst NO_2 pollution are also from China.

Indoor air pollution, primarily from firewood, straw and coal burnt in homes for cooking and heating, is also contributing significantly to ill health in China through increased risk of chronic obstructive airways disease, pulmonary and lung cancers. Indoor air pollution disproportionately harms women, the young, and people from less developed regions of China. According to the World Health Organization, 80% of the Chinese population rely on solid fuel/biomass for cooking, making it one of the 21 worst-affected countries where approximately 5% of death and disease is caused by indoor air pollution.

2.4.5 Water pollution

It is a country of severe water shortage. China has 6% of the world fresh water resources, but the per capita water possession is only one-fourth of the world average, one of the lowest one in the world. However, wasteful use of water is still rampant in China. In 2002, China's fresh water use was around 13% of the world total fresh water usage, 1.2 times the US level in 1995.

Statistics show that currently, the annual water supply shortage is around 40 bn m^3 per year in China, around 2 to 2.6 million km^2 of the country's 9.6 million km^2 of territory is drought-stricken in recent years. Moreover, around 70 million people face drinking water shortage each year.

China's water resource distribution is highly uneven. In the region of the Yangtze River basin and south of the Yangtze River is home to 54% of the Chinese population and possesses 81% of the country's total water resources; in contrast, north China is home to 46% of the country's population, yet the water resources constitute only 19% of the national total. It is estimated that because of rapid economic growth and climate change, the water resources in the north will further decline and that in the south will further increase.

As much of the waste water is discharged into rivers before treated, water pollution has become a serious problem. Over 70% of Chinese rivers, lakes, reservoirs, and seas have been polluted. Due to poor water quality, even in the regions that have many rivers and lakes, it is difficult to find enough clean water for production and life.

2.4.6 Soil pollution

Soil pollution has also been a severe problem. The rapid expansion of cities, the discharge of solid wastes and water pollution has caused much concern about soil pollution. In 2006, the Chinese State Environmental Protection Administration and the Ministry of Land and Resources launched a soil pollution survey, the first of its kind in China in July 2006, which is expected to be finished by the end of 2007.

The content of heavy metals in grains, pesticide residue in vegetables, and the quality of drinking water sources, are all directly subject to the influence of soil quality. Yet due to lack of data, soil pollution has been an environmental problem not included in the government's policy agenda.

2.5 GHG Emission Profile

Continual rapid increase in energy demand and consumption, and a large share of the energy consumption being in the form of fossil fuel consumption will lead to large increase in GHG emissions. A country's GHG emission performance can be measured from multiple aspects: total emissions, share of different GHG emissions, per capita emission, and the GDP intensity of GHG emission.

In China, due to the ongoing efforts for reforestation, land use change is a sector with net contribution of GHG sequestration. For example, data in the CAIT of WRI (2007) indicated that in 2000, China's total GHG emissions excluding land use change is 4963.1 $MtCO_2$, higher than the 4915.8 $MtCO_2$ when land use change is included (see Tables 4 and 5).

2.5.1 Total GHG emissions

China is currently the second biggest GHG emitter on earth and its GHG emissions are continuously rising. As in many other areas, China's large population make its total emissions the second largest in the world and the IEA WEO 2006 predicted that China may overtake the US and become the biggest GHG emitter in 2010.

2.5.2 Emissions of different GHG gases

In China, the biggest source of GHG emission is from fossil fuel combustion. China's total GHG emission in 2004 is about 6,100 million tCO_2e (5,600 million tons of net emissions), of which 5,050 million tons of CO_2, 720 million t CO_2e of CH4 and 330 million t CO_2e of N_2O. From 1994 to 2004, the annual average growth rate of GHG emissions is around 4%, and the share of CO_2 in total GHG emissions increased from 76% to 83% (NDRC, 2007).

2.5.3 GHG intensity

Since the 1980s, the GHG intensity of Chinese economy has more than halved, setting a good example of decoupling economic growth and GHG emissions. According to IEA, China's emission intensity falls to 2.76 kg CO_2/US$ (constant 2000 US dollar) in 2004, as compared to 5.47 kg CO_2/US$ in 1990, a 49.5% decrease. For the same period, emission intensity of the world average dropped only 12.6% and that of the OECD countries dropped 16.1%.

2.5.4 Per capita GHG emissions

Despite it ranks the second biggest in GHG emission on earth, due to its large population, China's per capita GHG emission is only two-thirds the world average, far lower than the level in developed countries and only one-sixth the level of the United States. Statistics from the International Energy Agency (IEA) indicates

Table 4: China's CO_2 emissions by sector in 2003 (excludes land use change)

Sector	$MtCO_2$	%
Energy	3919.5	89.6
Electricity & Heat	798.6	16.2
Manufacturing & Construction	644.7	13.1
Transportation	5.9	0.1
Other Fuel Combustion	41.8	0.8
Fugitive Emissions	-	-
Industrial Processes	429.6	10.4
Total	4,149.0	100

Table 5: China's total GHG Emissions by gas in 2000 (includes land use change)

Gas	$MtCO_2$	%
CO_2	3421.6	69.6
CH_4	798.6	16.2
N_2O	644.7	13.1
PFC	5.9	0.1
HFC	41.8	0.8
SF_6	3.2	0.1
Total	4951.8	100

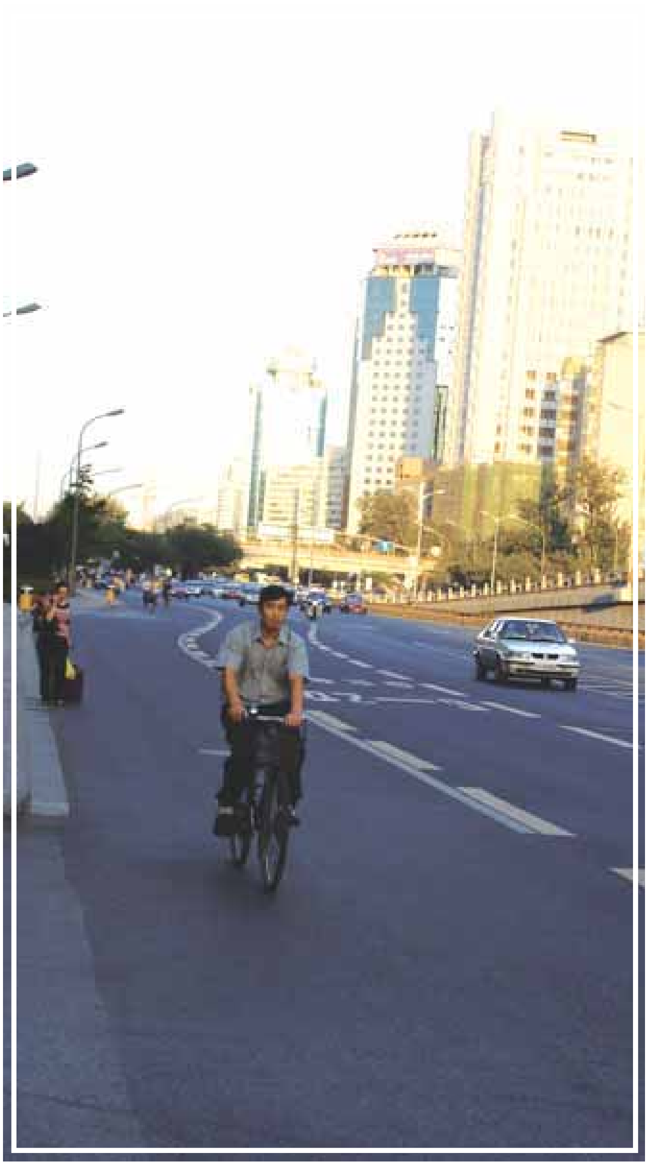
Source: Climate Analysis Indicators Tool (CAIT) Version 4.0. (Washington, DC: World Resources Institute, 2007

that per capita CO_2 emissions from fossil fuel combustion were 3.65 tons in 2004 in China, equivalent to only 87% of the world average and 33% of the level in Organization for Economic Cooperation and Development (OECD) countries (IEA, 2006).

According to the study carried out by the World Resource Institute (WRI), China's CO_2 emissions from fossil fuel combustion were 79 Mt in 1950, contributing only 1.13% of the world total at that time; cumulative emissions of CO_2 from fossil fuel combustion accounted for only 9.33% of the world total during the period of 1950–2002, and the cumulative CO_2 emissions per capita are 61.7 tons over the same period, ranking the 92nd in the world. Statistics from the International Energy Agency (IEA) indicates that per capita CO_2 emissions from fossil fuel combustion were 3.65 tons in 2004 in China, equivalent to only 87% of the world average and 33% of the level in OECD countries.

CHAPTER – 3

China's National Development Goals and Targets



3.1 National Development Goals

3.1.1 Theoretical framework

Since opening up and reform, several generations of Chinese leaders have announced different development blueprints for the country. The theoretical framework underpinning the transition process may be traced back to the concept of the Four Modernisations (sige xiandaihua), announced by Zhou Enlai in the mid-1960s. It envisaged the development of the Chinese economy until the middle of the 21st century by modernizing agriculture, industry, national defence and science and technology.

In the mid-1980s, Deng Xiaoping elaborated "three steps" for development. The first was to double the level of real GDP during the 1980s and thus solve the problem of inadequate clothing and food (wenbao wenti). The second was to build a Xiaokang (well-off) society by the year 2000 by quadrupling the real GDP level. The third was to raise per capita GDP within 30–50 years to the level of an intermediate developed country.

Jiang Zemin's concept of Three Represents (sange daibiao) in 2000 mainly served to re-orient and reposition the Communist Party of China, but it is also an officially legitimized private entrepreneurship for the first time.

Two concepts put forward by the fourth generation leadership (Hu Jintao/Wen Jiabao) in 2004, the Scientific Development Concept (kexue fazhan guan) and the Harmonious Society (hexie shehui) concept, take a more comprehensive approach towards development. This adds a social dimension to China's modernization blueprint and stresses the need to reconcile conflicts between rural and urban areas and between different social groups to promote social stability. The "Scientific Development Concept" attaches high importance to the needs of individuals and to harmonious and sustainable development. The hexie shehui concept is further linked to the notions of social welfare and more equal income distribution and to the rule of law. The concept stresses a closer relationship between the government and people.

3.1.2 Sustainable policy framework

China has a goal of building a well-off society in an all-around way (xiaokang society). Its rapid economic growth has brought about increasing environmental pressure and some social problems, including heavy pollution, wider income gap, and in some cases social unrest. As a result, sustainability has been increasingly emphasized.

The first document about sustainability was *China Agenda 21*, published in 1994, shortly after the Earth Summit in 1992. At the 3rd Session of the 16th People's Congress, the idea of "five-harmonisations" was emphasized: harmonise social and economic development, harmonise natural resources, harmonise rural and urban development, and harmonise domestic development and internal cooperation.

Due to ever increasing resource insufficiency and environment pollution in the course of rapid economic and social development and as a reflection of the world's greater understanding about sustainable and common development and on the basis of accumulation, since the 1990s, sustainable development has gradually become a fundamental national strategy of China.

In 1994, the Chinese government published *China's Agenda 21—White Paper on China's Population, Environment and Development in the 21st Century* as a platform document for guiding the country's social and economic development. That document marked the beginning of the sustainable development as a national strategy in China.

After the 2002 Earth Summit, there came another milestone in China's sustainable development. To help implement the sustainable development strategy, the Chinese government promulgated the "Program of Action for Sustainable Development in China in the Early 21st Century", which examines the achievements China had made through a decade's pursuit of sustainable development and the problems facing China, and sets the guidelines, objectives and principles, and specifies the priority areas, as well as specific measures to guarantee the realization of the targets fixed towards 2010.

China's sustainable development is aimed at promoting harmony between social and economic development on one side and population, resources and the environment on the other, steadily enhancing China's overall national strength and competitiveness, laying a solid foundation for the realization of the goal of building a comprehensive xiaokang (moderate prosperity) society by 2020 through focusing on economic growth and improving the quality of life for the people, seeking breakthroughs via scientific and institutional innovations.

After more than 10 years of efforts, sustainable development strategies have been integrated into various fields of Chinese economic and social development and strongly promote the sustainable and harmony development economy, population, resources, and environment.

3.1.3 Sustainable development goals

China has its own sets of sustainable development goals. This represents the vision of establishing an all-around 'Xiao Kang' and harmonious society by 2020. In the early days after opening up and reform, economic growth has been taken as the most imperative issues and environmental pollution and degradation was regarded as a necessary price to be paid during the early stage of economic development that could be naturally addressed when the country reaches intermediate development level. However, this belief of "development first and environment pollution could wait" has been changing when the environmental and resource pressure is increasingly felt in the country's economic development.

3.1.4 Development plans in China

In China, the national development plans could be divided into several types: 1) the medium-and long-term development plans on specific fields. So far the Chinese government has released a few plans for the period until 2020. Examples include the 2020 Energy Conservation Plan, the 2020 Renewable Energy Plan, the 2020 Science and Technology Plan. 2) the Five-year Plans. Since the first five-year plan was made in the 1950s, China has so far finished implementing 10 five-year plans; 3) moreover, annual plans are also made by the government to guide its work for a certain year. Besides the national plans, there are also plans for local-level governments. However, only five-year and 2020 national development plans are covered in this report because of the long time-span covered in the scenarios (2000 to 2030).

The 11th Five-year plans for the period from 2006 to 2010, have been released. These government plans, drafted by various government agencies and approved by the National People's Congress or its standing committee, set targets for the country's development and reflect the importance attached by the government on different issues.

3.2 Social Development Goals

The most comprehensive development goals are indicated in Outlines of the 11th Five-year Program for China National Economy and Social Development (see Table 6)

3.3 Economic Development Goals

The "Three-step" development strategy established in 1987 on economic development: Step 1: doubling 1980 GDP level and solve the subsistence problem of the country's people—this target has been realized in late 1980s. Step 2: quadrupling the country's 1980 GDP by the end of the 20th Century—this target has also been realized. Step 3: generally realize modernization by mid of the 21st century, per capita GDP reach the medium-level among developed countries and the people lead a relatively rich life.

3.3.1 Economic development goals

With China's planning economy tradition, economic plans are much more frequently used as a way of guiding the country's development and also a form of government commitment. Previously, there were only plans about economic growth. Today, although economic growth is still an important content of the various government plans, other indicators have been introduced.

In the recent greater reiteration of scientific development and social harmony, economic growth is taken more as a means, not the ultimate purpose. Hence, in the recent government development plans, the economic goals are just "for guidance", not binding. For the 2006–2010 period, the goal for average annual economic growth is 7.5% (estimate) and the goal for per capita GDP average annual growth rate is 6.6%, which is a bit slower national economy growth due to continuing population increase.

3.3.2 Change growth mode and economic structure optimization

With ever more concerns about environmental pollution and resource constraints caused by its rapid economic growth and large industrial sector, China is seeking to optimize its economic structure and industrial structure. The target of economic structure optimization is increasing the share of service sector in the country's GDP and making its economic growth more driven by technology advance instead of by increases in raw material and natural resource input, so as reduce the resource elasticity of economic growth and boost economic growth through the development of high quality and value-added products.

3.4 Environmental Goals

Pollution control has become an increasingly important component in the country's various development plans. The binding targets for air pollution and water pollution control are included in the *Outlines of the 11th Five-year Plan for National Economy and Social*

Table 6 Main indicators for economic and social development

Type	Indicator	2005	2010	Average annual growth rate (%)	Nature[9]
Economic growth	GDP (trillion RMB)	18.2	26.1	7.5	Expected
	Per capita GDP (RMB)	13985	19270	6.6	Expected
Economic structure	% of tertiary sector in GDP	40.3	43.3	[3]	Expected
	% of tertiary sector in total employment	31.3	35.3	[4]	Expected
	% of R&D expenditure in GDP	1.3	2	[0.7]	Expected
	Urbanisation rate (%)	43	47	[4]	Expected
Population, ressources, environment	Total national population (mn)	130756	136000	<8‰	Binding
	Decrease in energy intensity of GDP			[20]	Binding
	Decreases in water use for per unit of industrial value-added			[30]	Binding
	Effective utilisation factor of water for agricultural irrigation	0.45	0.50	[0.05]	Expected
	Utilisation rate of industrial solid waste	55.8	60	[4.2]	Expected
	Arable land (mn hectares)	122	120	-30	Binding
	Decreases in the total emissions of main pollutants[10] (%)			[10]	Binding
	% of land territory with forest coverage	18.2%	20%	[1.8]	Expected
Public service and People's Life	Average length of school education by the citizens (years)	8.5	9	[0.5]	Binding
	People covered by urban basic pension insurance (mn persons)	174	223	51	Binding
	Coverage rate of new rural cooperative medicare system (%)	23.5	>80	>[56.5]	Binding
	Increases in urban jobs over the 5 years (thousand)			[4500]	Expected
	Rural labour migration to urban areas (thousand)			[4500]	Expected
	Registered urban unemployment rate (%)	4.2	5		Expected
	Per capita annual disposable income of urban residents (RMB)	10493	13390	5	Expected
	Per capita annual net income of rural residents (RMB)	3255	4150	5	Expected

Source: Xianhua news agency
Note: all the data in '[]' represents accumulated total over the five years.

[9]Expected targets: the development targets expected by the country and their realization will mainly rely on the independent operation of market mechanisms. The government mainly focuses on creating sound macro environment, institutional arrangements, and market environment, and timely adjust the direction and strength of macro regulation, comprehensively using various policies to channel the deployment of various resources, and try to realize these targets. Binding targets: these targets are set on the basis on expectation and government agencies' responsibilities for their realization are intensified. They are requirements set by the central government to local governments and relevant departments of the central government on public service and areas related to public interests. The government shall guarantee the realization of these targets through properly deploying public resources and effectively exerting administrative power.

[10] The main pollutants here refer to SO_2 for air pollution and COD (chemical oxygen demand) for water pollution.

Development, which stipulates that China's total SO_2 emissions and chemical oxygen demand (COD) emission in 2010 shall be 10% less than the level in 2005.

3.4.1 Pollution control targets

For the 2006–2010 period covered under the 11th Five-year Plan for Environmental Protection, the pollution control target is lowering the total emissions of SO_2 to the atmosphere and chemical oxygen demand (COD) to water by 10% in 2010 on the 2005 basis. To realize the targets, the Chinese government has further split the 10% nationwide goal into binding targets for different provinces, autonomous regions, and municipalities (see Table 7).

Table 7: China's plans for capping SO_2 emissions during the 2005–10 period

Unit: $MtSO_2$

Province	2005 Emissions	2010		2010/2005 (%)
		Emission cap	Of which: Electricity sector	
Beijing	19.1	15.2	5.0	-20.4
Tianjin	26.5	24.0	13.1	-9.4
Hebei	149.6	127.1	48.1	-15.0
Shanxi	151.6	130.4	59.3	-14.0
Inner Mongolia	145.6	140.0	68.7	-3.8
Liaoning	119.7	105.3	37.2	-12.0
Of Which: Dalian City	11.89	10.11	3.54	-15.0
Jilin	38.2	36.4	18.2	-4.7
Heilongjiang	50.8	49.8	33.3	-2.0
Shanghai	51.3	38.0	13.4	-25.9
Jiangsu	137.3	112.6	55.0	-18.0
Zhejiang	86.0	73.1	41.9	-15.0
Of Which:¡¡Ningbo City	21.33	11.12	7.78	-47.9
Anhui	57.1	54.8	35.7	-4.0
Fujian	46.1	42.4	17.3	-8.0
Of Which: Xiamen City	6.77	4.93	2.17	-27.2
Jiangxi	61.3	57.0	19.9	-7.0
Shandong	200.3	160.2	75.7	-20.0
Of Which: Qingdao City	15.54	11.45	4.86	-26.3
Henan	162.5	139.7	73.8	-14.0
Hubei	71.7	66.1	31.0	-7.8
Hunan	91.9	83.6	19.6	-9.0
Guangdong	129.4	110.0	55.4	-15.0
Of which: Shenzhen City	4.35	3.48	2.78	-20.0
Guangxi	102.3	92.2	21.0	-9.9
Hainan	2.2	2.2	1.6	0
Chongqing	83.7	73.7	17.6	-11.9
Sichuan	129.9	114.4	39.5	-11.9
Guizhou	135.8	115.4	35.8	-15.0
Yunnan	52.2	50.1	25.3	-4.0
Tibet	0.2	0.2	0.1	0
Shannxi	92.2	81.1	31.2	-12.0
Gansu	56.3	56.3	19.0	0
Qinghai	12.4	12.4	6.2	0
Ningxia	34.3	31.1	16.2	-9.3
Xinjiang	51.9	51.9	16.6	0
Total	2549.4	2246.7	951.7	-11.9

Note: The country's target for 2010 is reducing SO_2 emissions by 10% from the 2000 level, to 22.94 million tons. The allocations to all the provinces totalled 22.47 $MtSO_2$. The central government retains 0.48 million tons for paid allocation and experiments with SO_2 emission trading.

3.4.3 Reforestation target

There have been targets for further reforestation. Several major government-funded afforestation and reforestation projects have significantly increased the forest coverage in the country.

The "11th Five-year Plan and Medium and Long-term Plan on Forestry Development" issued by the State Forestry Administration of China in 2006 indicated specific targets for forestry development in the country for the short-term (2006–10), the medium-term (2006–2020) and long-term (2006–2050).

Short-term targets (2006–2010)
Forest coverage of the country's territory to 20%

Medium term targets (2020)
Forest coverage of the country's land territory to 23%. Throughout the country, ecological environment as a whole enters a stage of continual improvement. The ecological conditions in western China sees salient improvement and in eastern China, the ecological problems are generally solved. The forestry sector's total productivity witnesses significant consolidation, reaching the level of countries with medium advanced forestry in the world.

Long term targets (2006–2050): 26%
By 2050, the country's forest coverage reaches and stabilizes at 26% or above, beautiful landscape is generally realized, the shortage of forest products is relaxed, and a complete forest ecological system and advanced forest industrial system is established.
Source: *China State Forestry Administration, 2006*

Recent performance
In the last two decades, the Chinese government has made enormous efforts for reforestation, forest protection and management improvement. Specific measures include the implementation of several large government-funded reforestation programs, to protect the major watersheds, to alleviate sandstorms, and to stop desertification. Also in cities, plantations are increased in the competition for attracting investment. Due to these efforts, the country's forest coverage has increased from the bottom of only around 13% in the late 1970s to 21% now.

Policies
(1) Ban grazing and logging
(2) Government-funded reforestation, airplane seedling,
(3) Better forest management and forest fire and pest control
(4) Incentives to forestation and orchard by households (long-term tenure enables farmers for long-term investment and forestation a good option for farmers)

Another thing is that the ongoing migration of farmers into cities, in the size of around 10 million per year, leads to rural population reduction. Especially many farmers living in regions of fragile natural environment, moving to towns and villages, the transition from firewood to coal and other commercial energy, also contribute to alleviating the pressure on local forests.

3.5 Energy Development Goals

The extraordinarily fast growth in China's energy consumption in the last few years have made energy an issue on top of China's policy agenda. Vowed to rein its energy demand growth, China has set long-term and short-term binding targets for making its economy more energy efficient and ambitious plans have been unveiled to enlarge the share of energy from renewable sources. Table 8 shows the goals China has set for the 2006–2010 period.

3.5.1 Energy conservation goals

The energy conservation target system include long-term ones (till 2020), medium-term (till 2010), and annual ones. The long-term goal is 2004–2020. Having GDP energy intensity, the binding target for the 2006–2010 period is 20% reduction in GDP energy intensity, which is further interpreted into annual targets of around 4% reduction in GDP energy intensity.

Table 8: Energy development goals of China

Indicator	2005	2010
Primary Energy Consumption (bn toc)	2.2	2.7
Of which: Coal (%)	69.1	66.1
Oil (%)	21.0	20.5
Natural gas (%)	2.8	5.3
Nuclear (%)	0.8	0.9
Hydropower (%)	6.2	6.8
Other renewable energy (%)	0.1	0.4
Primary Energy Supply (bn toc)	2.06	2.45
Of which: Coal (%)	76.5	74.7
Oil (%)	12.6	11.3
Natural gas (%)	3.2	5.0
Nuclear (%)	0.9	1.0
Hydropower (%)	6.7	7.5
Other renewable energy (%)	0.1	0.5

Source: NDRC, 2007

3.5.2 Renewable energy development plan

In 2005, China's total primary energy production was 2.06 billion toc, and its total consumption, 2.25 bn toc, respectively accounting for 13.7% and 14.8% of the world total. China is now the 2nd biggest energy consumer and producer on earth. In the year, the country produced 2.2 billion tons of coal, providing a pillar to the country's on-going development (NDRC, 2007).

Targets for Renewable Energy Development
Tapping its vast potential for renewable energy development is increasingly integrated in China's policy agenda. In its 2020 Renewable Energy Development Plan issued in 2006, China made ambitious plans for increasing the share of renewable energy sources in its energy supply (see Table 9).

- Increase the share of Renewables in Total Primary Energy Supply from the current 7% to around 15%;
- To realize this target, in the 2006–2020 period, China needs to invest around 185,000 million US$ (1.5 trillion RMB) in renewable energy development.
- Specific targets

Table 9: Targets for renewable energy development in China

	2010	2020
Hydro power	180GW	300GW(70GW)
Wind power	5GW	30GW
Biomass	19 bn m^3	44 bn m^3
	2 Mt fuel ethanol, 0.2 Mt bio-diesel	10 Mt fuel ethanol, 2 Mt bio-diesel
	5500 MW	30GW
Solar	300 MW	1800MW
	150 Mm^2	300 M m^2

Source: NDRC, 2007, www.ndrc.gov.cn

3.6 Climate Plans

China strongly insists that developed countries should take the lead in GHG mitigation and China and other developing countries, should not be subject to binding emission reduction targets in the near future.

China released a long-awaited National Climate Change Programme in June 2007, shortly before the G8 meeting. The new national plan offered few new targets on reducing greenhouse gas emissions, but outlined how it intended to meet the goals it has already set for energy efficiency improvement, increasing the utilization of renewable energy, and expanding the forest coverage of its territory. The specific measures include the use of more wind, nuclear, and hydropower as well as making coal-fired plants more efficient. It stressed that the country's first priority remained "sustainable development and poverty eradication".

However, China's ambitious plans for energy efficiency improvement and renewable energy promotion have strong implications for climate change and could be interpreted into ambitious climate plans. In the China 1st National Assessment which on Climate Change, a report Under the guidance of the National Climate Change Coordinating Committee (an inter-ministry organization, also the highest authority on climate change related issues and international negotiations in China, known as NCCCC), 12 Chinese ministries and organizations[11] participated in the preparation and release of the Assessment was approved at the 10th Meeting of the NCCCC held on 15 August 2006, it is indicated that China will try to reduce the CO_2 emission intensity of its GDP by 40% on the 2000 level in 2020. Meanwhile, it will try to increase the annual carbon absorption through forest protection, management, and afforestation, as well as intensified farming and pasture management, the country will try to realize an annual growth of carbon sink of 120 MtC per year on the 1990 basis. By the 2050, the country will reduce the CO_2 emission intensity of its GDP by around 80%. In the second half of the 21st century, increases in the country's energy demand will be mainly relying on supply from renewable sources and new forms of energy (He et al., 2006).

3.7 MDGs and Performance

With increasing globalization, to achieve common development and prosperity has become the pressing task for all countries. At the 2000 World Summit, heads of state and government of 189 countries adopted the Millennium Declaration setting up a series of development goals for global economic and social development for the 15 years thereafter, referred to as the Millennium Development Goals (MDGs). Set up by the United Nations for the first time, the goals are comprehensive, quantitative, time-bound, and cover poverty reduction, health care, education, gender equity, international partnership. The MDGs consist of 8 goals, 18 targets, and 48 indicators. They have been used by the international community as a yardstick for measuring development progress.

As the largest developing country, China gives top priority to economic and social development and improves the living standard of its 1.3 billion people. Building a well-off society and a harmonious society is the localization of the MDGs in China. As the largest developing country home to one-fifth of the world population, China's efforts to realize modernization and build a well-off society and a harmonious society are important contribution to the realization of the MDGs. There exists a rare correspondence between the MDGs and "Xiao Kang", as both focuses on the kind of development that makes a visible, measurable difference in the lives of people.

Due to its continual rapid economic growth since late 1970s, China has achieved before other developing countries the first and most important MDG of halving the proportion of people living in extreme poverty based on the 1990 level. Generally, China has been doing very well in realizing the MDGs of universal primary education and poverty alleviation, yet it needs to make more efforts for reducing pollution (see Table 10).

[11] MOST, CMA, CAS, Ministry of Foreign Affairs, the State Development and Reform Commission, State Environmental Protection Agency, Ministry of Education, Ministry of Agriculture, Ministry of Water Resources, China Forestry Administration, China Marine Administration, and China Natural Science Foundation

Table 10: China's MDG performance

MDGs	Targets	Indicators	1990-1995 Earliest	1996-2005 Latest	Comments
Goal 1- Eradicate extreme poverty & hunger	1. Halve, between 1990 and 2015, the proportion of people living in extreme poverty	1) Proportion of population below $1 (PPP) 1993 a day	33.0 (90)	16.6 (01)	Early achiever
		2) Poverty gap ratio (incidence x depth of poverty)	8.9 (90)	3.9 (01)	Early achiever
		3) % of poorest quintile in national consumption	NA	4.7 /1 (01)	On track
	2. Halve, between 1990 and 2015, the proportion of people who suffer from hunger	4) Prevalence of underweight in children under 5 (%)	19.1 /1 (90)	7.8 (02)	Early achiever
		5) % of population below minimum level of dietary energy consumption	16 (91)	12 /2 (02)	Slow progress
Goal 2-Achieve universal primary education	3. Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling	6)Net enrolment ratio in primary education	97.4 /1 (91)	…	On track
		7) Proportion of pupils starting grade 1 who reach grade 5	78.3 (91)	…	On track
		8) Literacy rates of 15-24 years old, both sexes, percentage	93.1 (90)	98.5 /2 (04)	On track
Goal 3- Promote gender equality and empower women	4.Eliminate gender disparity in primary and secondary education, preferably by 2005, and in all levels of education no later than 2015	9) Ratio of girls to boys in primary, secondary, and tertiary education	0.9 (91) ???	1.0 (04) ???	On track
		10) Ratio of literate women to men ages 15- to 24	1.0 (90)	1.0 /1 (04)	Early achiever
		11) Share of women in wage employment in the non-agricultural sector	37.7 (90)	40.9 /2 (04)	Slow progress
		12) % of seats held by women in national parliament	21.3 (90)	20.3 (06)	Regressing
Goal 4-Reduce child mortality	5. Reduce by two thirds, between 1990 and 2015, the under-five mortality rate	13) Under-five mortality rate (Per 1000 live births)	49.0 (90)	31.0 (04)	Slow
		14) Infant mortality rate (Per 1000 live births)	38 (90)	26 (04)	On track
		15) % of one-year-old children immunized against measles	98 (90)	84 (04)	Regressing
Goal 5- Improve maternal health	6. Reduce by three quarters, between 1990 and 2015, the maternal mortality ratio	16) Maternal mortality ratio (Per 100,000 live births)	95.0 /1 (90)	56.0 /1 (00)	Early achiever
		17) Proportion of births attended by skilled health personnel	…	95.9 (03)	Early achiever

contd…

MDGs	Targets	Indicators	1990-1995 Earliest	1996-2005 Latest	Comments
Goal 6-Combat HIV/AIDS, malaria & other diseases	7. Have halted by 2015 and begun to reverse the spread of HIV/AIDS	18) HIV prevalence among pregnant women ages 15- to 24	…	…	Regressing
		19) Contraceptive use among currently married women aged 15-49, any method, %	83.4 (92)	83.8 (97)	Slow progress
		20) Ratio of school attendance of orphans to school attendance on non-orphans ages 10-14	…	…	Lack of data
	8. Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases	21) Malaria death rate per 100,000			Lack of data
		22) Proportion of population in malaria-risk areas using effective malaria prevention and treatment measures	…	…	Lack of data
		23) Tuberculosis death rate per 100,000	24.8 (90)	16.6 (04)	On track
		24) Proportion of tuberculosis cases detected and cured under directly observed treatment short course (DOTS)	94 (94)	93.6 (03)	Regressing
Goal 7-Ensure environmental sustainability	9. Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources	25) Proportion of land area covered by forest	16.8 / 1 (90)	21.2 / 1 (05)	Early achiever
		26) Ratio of area protected to maintain biological diversity to surface area	11.636 (90)	14.856 (05)	Early achiever
		27) Energy use (kilograms of oil equivalent) per $1 GDP (PPP)	485 / 2 (90)	220 / 2 (03)	Early achiever
		28a) CO_2 emissions (per capita)	2.1 (90)	3.2 (03)	Regressing
		28b) Ozone-depleting CFCs consumption in ODP metric tons	41829 / 1 (90)	17903 / 1 (04)	On track
	10. Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation	30a) % of population with sustainable access to an improved water source -rural	59.0 (90)	67.0 (04)	Slow progress
		30b)% of population with sustainable access to an improved water source -rural	99 (90)	93 (04)	Regressing

contd…

MDGs	Targets	Indicators	1990-1995 Earliest	1996-2005 Latest	Comments
	11. By 2020, to have achieved a significant improvement in the lives of at least 100 mn slum-dwellers	31a) % of population with access to improved sanitation-rural	7.0 (90)	28.0 (04)	Slow progress
		31b) % of population with access to improved sanitation-urban	64 (90)	69 (04)	Slow progress
		31) Proportion of households with access to secure tenure	43.6 (90)	37.8 (01)	Regressing
Goal 8-Develop a global partnership for development	12. Develop further an open, rule-based, predictable, non-discriminatory trading and financial system	32) Net ODA total and to the least developed countries, as a % of OECD/DAC donors' GNI			
		33) % of bilateral, sector-allocable ODA of OECD/DAC donors for basic social services (basic education, primary health care, nutrition, safe water, and sanitation)			
		For developed countries, inapplicable to China			
	13. Address the special needs of the least developed countries, landlocked countries and small island developing States	34) Proportion of bilateral official development assistance ODA of OECD/ DAC donors that is untied			
		35) ODA received in landlocked countries as proportion of their gross national incomes			
		36) ODA received in small island developing states as proportion of their GNI			
		For least development countries, landlocked countries and small island developing states, inapplicable to China			
	Target 14: Address the special needs of landlocked countries and small island developing states (through the Program of Action for the Sustainable Development of Small Island Developing States and 22nd General Assembly provisions)	37). Proportion of total developed country imports (by value and excluding arms) from developing countries and from least developed countries, admitted free of duty			
		38) Average tariffs imposed by developed countries on agricultural products and textiles and clothing from developing countries			
		39) Agricultural support estimate for OECD countries as a percentage of their gross domestic product			
		40). Proportion of ODA provided to help build trade capacity			
		Inapplicable			
		For landlocked countries and small island countries, inapplicable to China			
	15: Deal comprehensively with the debt problems of developing countries through national and international measures in order to make debt sustainable in the long term	41). Total number of countries that have reached their HIPC decision points and number that have reached their HIPC completion points (cumulative)			
		42) Debt relief committed under HIPC initiative			
		For developed countries, inapplicable to China			
		43) Debt service as a percentage of exports of goods and services	10.6 / 1 (90)	1.2 / 1 (04)	
	16: In cooperation with developing countries, develop and implement strategies for decent and productive work for youth	44) Unemployment rate of 15- to 24-year-olds, male and female and total	…	3.1 / 1 (00)	

contd…

MDGs	Targets	Indicators	1990-1995 Earliest	1996-2005 Latest	Comments
	17: In cooperation with pharmaceutical companies, provide access to affordable essential drugs in developing countries	45) % of population with access to affordable, essential drugs on a sustainable basis		...	Lack of data
	18. In cooperation with the private sector, make available the benefits of new technologies, especially information and communications	47. Telephone lines and cellular subscribers per 100 population	0.6 (90)	49.7 (04)	Early achiever
		48a.Personal computers in use per 100 population	0.04 (90)	4.08 (04)	Early achiever
		48b.Internet users per 100 population	0 (90)	7.23 (04)	Early achiever

Source: UNESC Asia Pacific, UNDP, ADB, 2006


三里河南三区综合菜市场
龙昌皮衣保养中心
皮衣、换皮、换衬、修补、护理
兰州拉面
三里河南三区综合菜市场

Part II

Future Paths

CHAPTER – 4

Driving Forces to Future Energy and Emission Development

4.1 Development Trends

Chinese economy has been growing at high speed—so has its energy consumption.

4.1.1 Economic development tendencies

China has seen robust growth in energy production and consumption. For years, the Chinese economy has been growing at a higher than expected speed. Curbing overheating has been the problem topping China's policy agenda for some time. After over two decades of rapid economic development, the country's economic growth is showing no evidence of slowing down. During the 2001 to 2005 period, the economic growth targets set in its 10th Five-year plan was only 7%, however it turned out that the country's economy had been growing much faster than expected during the first 5 years of the 21st country. Moreover, instead of slowing down, the Chinese economy has been accelerating despite multiple government measures to "cool down" the economy. In the first half of 2007, this trend continues, with the country's GDP further increasing at 11.5% on fixed-price basis (see Figure 1).

4.1.2 Energy development tendencies

A side-effect of the rapid economic growth in recent years is the hike in energy consumption, which shows a remarkably high increase in 2003 and 2004. Although the speed slowed down in 2005 and 2006, it is still showing a growth rate of around 9 to 10 per cent. As a result, China's total primary energy consumption has more

Figure 1: China's GDP growth, 2002–06
Source: China National Statistical Bureau, 2007

than doubled during the 2001 to 2006 period. Moreover, the dominant position of coal is further consolidated, contributing over two-thirds of China's primary energy consumption. In the last six years, China's oil consumption increased from 212 million tons in 2000 to 320 million tons in 2006. Natural gas consumption and production, though growing quickly in recent years, only contribute less than 2% of the country's primary energy consumption. Although the extraordinary phenomenon of energy consumption staying at several percentage points higher than GDP growth rate and wide blackouts and brownouts in 2002 and 2003 no longer exist, energy consumption still maintains a high-speed growth (see Figure 2). As energy consumption growth continues to be robust, there has been increasing doubts whether China could realize the target of 20% reduction in its GDP energy intensity over the 2006–10 period.

4.1.3 Emission development tendencies

Rapid economic growth and the associated natural resource consumption, including energy consumption, generate ever more pollutants. Significant increases in China's fossil fuel consumption have led to upward adjustments to estimated GHG emissions from China. In 2006, IEA predicted that China will overtake the US to become the biggest emitter of GHG within "three years". In its 1st National Climate Change Action Programme published in March 2007, China admitted that its CO_2 emissions in 2005 were 6.2 billion tons.

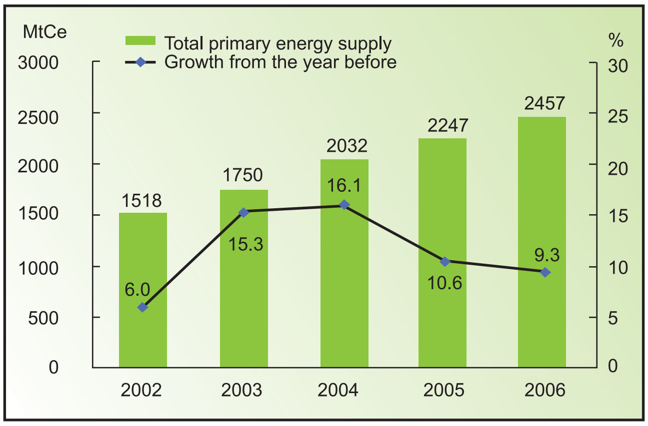


Figure 2: China's primary energy consumption
Source: China National Statistical Bureau, 2007

In March 2007, a dutch organization MNP released a report indicating that China has already overtaken the USA to become the largest GHG emitter on earth. Different sources gave different estimates about the timing, ranging from 2006 to 2008. Whatever the exact time of this, the key point is that China's GHG has grown dramatically in recent years and is continuously growing.

Not only CO_2 and other greenhouse gases, China's other pollutant emissions have also been witnessing rapid growth in recent years (see Table 11).

4.2 Driving Forces to Future Energy and Emission Developments

4.2.1 Population growth

It takes decades to change the population profile of a country, especially if the population base is large as China's. The Chinese population is still growing at the speed of around 7 million a year (see Table 12). It is generally expected that the growth trends will continue in the next three to four decades before the Chinese population growing from the current 1.3 billion to the peak of about 1.5 billion, starts a slow decline. A population growth of around 200 million in the next few decades will be a major driving force to energy demand.

4.2.2 Rapid urbanization

China is in the stage of rapid urbanization. China's urbanization rate is 43%, far lower than the around 70% in developed countries. Since 1978, the share of urban residents in China's total population has increased from 18% to the current 44% (CNSB, 2007).

The large redundant labour and the much higher income level in cities attract massive immigration from rural areas to cities, at a scale of 15 million people a year (see Table 13). It is expected that rapid urbanization will continue till the next few decades, such rapid increases in urban population is a strong driving force to energy demand increase and generates huge pressure for more job creation.

Table 11: China's major air pollutant emissions in recent years

Unit (million tons)

Item Year	SO_2			Soot			Industrial Dust
	Total	Industrial	Residential	Total	Industrial	Residential	
2001	19.48	15.67	3.81	10.70	8.52	2.18	9.91
2002	19.27	15.62	3.65	10.13	8.04	2.09	9.41
2003	21.59	17.91	3.67	10.49	8.46	2.03	10.21
2004	22.55	18.91	3.64	10.95	8.86	2.09	9.05
2005	25.49	21.68	3.81	11.83	9.49	2.34	9.11
2006	25.89			10.78	8.55	2.24	8.08

Source: China State Environmental Protection Administration, 2007

Table 12: Population growth in China

	2001	2002	2003	2004	2005	2006
Population Growth (million)	8.84	8.26	7.74	7.61	7.68	6.92
Growth Rate (‰)	6.95	6.45	6.01	5.87	5.89	5.28

Source: China National Statistical Bureau, 2006 & 2007

Table 13: Speed of urbanization in China

	2001	2002	2003	2004	2005	2006
Urban Population Growth (mn)	21.58	21.48	21.64	19.07	19.29	14.94
% of urban population in total	37.7	39.1	40.5	41.8	43.0	43.9

Source: China National Statistical Bureau, 2006 & 2007

Major differences in income level and lifestyle means that an urban resident consumes much more energy than a rural resident in daily life. In 2003, the per capita residential electricity consumption of urban residents is 259 kWh, yet that of rural residents is 115 kWh.

Moreover, the majority of rural residents still rely on agricultural waste and firewood as the main source of energy for cooking and heating, however when they move into cities, they generally transit to commercial energy, mainly in the form of fossil fuel and electricity. This will also lead to significant increase in energy demand.

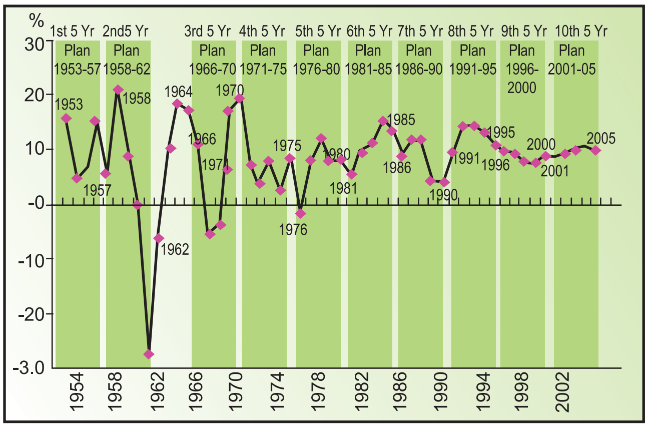


Figure 3: Fluctuations of growth rate in China 1954 to 2005: unstable to stable, reduced rate of growth

Source: Based on China National Statistical Yearbooks, China National Statistical Bureau

4.2.3 Economic growth

Rapid economic growth

China has been undergoing rapid economic growth in the last three decades and so far there is no evidence that the growth is slowing down. In contrast, the growth has been continual at over 10% and preventing the economy from being "overheated" has been a challenge facing the Chinese government in recent years. China's average annual economic growth is 8.5% during the 1975–2004 period, and even higher at 8.9% during the 1990–2004 period, much higher than any other country during the same period (see Figure 3).

Economic structure

Currently industry contributes over 50% of China's GDP, far higher than the world average

Table 14: Industry as a percent of GDP

Country	Brazil	China	South Korea	Mexico	Mid-income countries
% of industry in GDP	19%	53%	35%	26%	36%

Source: World FactBook 2006, Sept. 2005

of around 33%. The tertiary sector is under developed. Ongoing industrialization continues to make industry the pillar for the country's economic growth.

China is still in the period of rapid industrialization. Being the biggest FDI destination among developing countries for 12 consecutive years, China is becoming the world-manufacturing centre. Industry, especially manufacturing, has been the pillar of China's economic development. The share of the secondary sector, including industry and construction is much higher than many post-industrialization developed countries as well as mid-income countries (see Table 14). Besides, in China, among the total primary energy consumption, 70% goes to the industry and construction (China National Statistics Bureau, 2005).

Foreign trade dependence
Commodity exports and imports accounted for 63.6% of China's GDP in 2005, indicating that the Chinese economy depends highly on foreign trade (see Figure 4). Compared with domestic consumption, among the three driving forces to economic growth, export has been growing much faster than domestic consumption and investment. As a result, the Chinese economy has a high dependence rate on foreign trade and is also sometimes referred to as the "world manufacturing centre".

Such rapid increase in exports of mass products has created lot of jobs; however it also leads to high exposure to the risks of the global market, foreign exchange rate volatility, as well as lots of disputes in foreign trade.

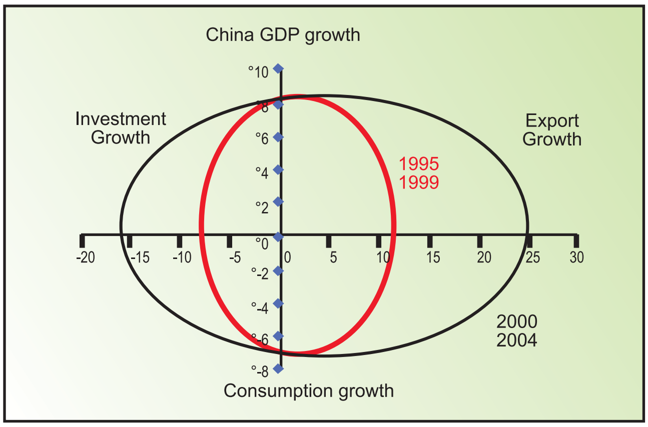


Figure 4: China's growth path
Source: OEF database, www.oef.co.uk

4.2.4 Rapid increase in income level

With their income level still low and growing quickly (see Table 15), more and more Chinese families will be able to afford and buy more consumer products, larger homes, and long-distance travelling. All these will end up in more energy consumption directly or indirectly.

In recent years, many Chinese families buy or build their own apartments and houses, leading to a booming real estate sector, which has become a major driving force to China's energy demand and consumption. Each year, around 600 million square meters of new housing were built and put onto the market (See Table 16). All this leads to higher living standard and consequently more energy consumption. China's energy demand will grow as incomes rise and more households can afford cars and energy-consuming household appliances.

4.2.5 Economic and industrial structure

Continual rapid growth of the industry and construction sector
China's economic growth in recent years is characterized by the rapid growth of its heavy industries, most of which is energy intensive. Industrial sector contributes more than half of China's GDP and is still growing faster than the agriculture sector and the service sector. The rapid growth of industrial sector, especially such energy-intensive sectors as steel, cement, building materials, chemicals, leads to rapid

Table 15: Per capita income in China

		2001	2002	2003	2004	2005	2006
Per capita net income of rural residents	Amount (RMB)	2366	2476	2622	2936	3255	3587
	Year-on-year growth rate (%)	5.0	4.8	4.3	6.8	6.2	7.4
Per capita disposable income of urban residents	Amount (RMB)	6860	7703	8472	9422	10493	11759
	Year-on-year growth rate (%)	9.2	13.4	9.0	7.7	9.6	10.4

Source: CNSB, 2007

Table 16: Housing construction and possession in China

	Floor space of newly built housing in urban areas (million sq. m)	Floor space of newly built housing in rural areas (million sq. m)	Per capita floor area of housing in urban areas (sq. m)	Per capita floor area of housing in rural areas (sq. m)
2000	549	797	20.3	24.8
2002	598	742	22.8	26.5
2004	569	680	25.0	27.9
2005	661	667	26.1	29.7

Source: CNSB, 2006

Table 17: China's production of major industrial products

	2000	2002	2004	2006
Chemical fibre (Mt)	6.9	9.9	17.0	20.3
Pig iron (Mt)	131.0	170.8	268.3	404.2
Rolled Steel(Mt)	131.5	192.5	319.8	473.4
Cement(Mt)	597.0	725.0	966.8	1240.0
Sulfuric Acid(Mt)	24.3	30.5	39.3	49.8
Caustic soda(Mt)	6.7	8.8	10.4	15.1
Ethylene (Mt)	4.7	5.4	6.3	9.4
Chemical fertilizer(Mt)	31.9	37.9	48.0	55.9
Cars (million)	0.7	1.1	2.3	3.9

Source: CNSB, 2006 & 2007

increase in energy demand. As indicated in Table 17, China's output of major energy-intensive products have seen a dramatic increase in the past few years, giving a strong boost to increases in the country's energy consumption and poses enormous challenges to the government's efforts of building a harmonious society.

4.2.6 Transportation

In developed countries, transportation usually contributes around one-third of the total energy demand. However, in China, this share is around 10% in China. Passenger car possession is only 15 per 1000 population, far lower than the level in OECD countries. China is in the stage of rapid motorization. In 1995, the total civil vehicle possession was only 10.4 million in China, by 2005, this figure had tripled. This leads to rapid increase in oil consumption.

4.3 Development Constraints

Such speed of development and natural resource consumption exceeds the support capacity of the country's natural ecological systems, leading to heavy life and economic losses, severe air, water, and soil pollution, and accumulated social tensions. It also causes fierce competition for major minerals, raw materials, and oil on the international market and drives up prices.

4.3.1 Energy resource constraints

China's per capita oil reserve is small and already the country is relying on import for meeting more than half its oil consumption (see Figure 5). As there is little space for the expansion of oil production from its domestic oilfields, continuing increase in demand means a high dependence on oil imports from unstable parts of the world. Despite hard efforts of building up national strategic oil inventory and diversifying the sources of oil import, energy security, especially oil security, is still a major concern for the country, especially in the context of highly volatile and unpredictable oil price rises on the world market in a few years (see Figure 5).

Unlike oil, China has enough coal reserve to support its consumption for the next few decades. Insufficient and outdated production capacity, long-distance of coal transportation, from west China where the coal mines are located to east China, where the demand is

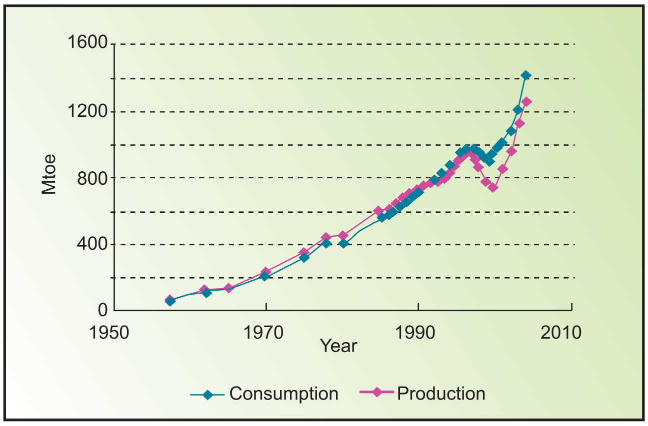


Figure 5: Energy production and consumption in China, 1957-2004

Source: Kejun Jiang, 'Energy Future and Policies', 2006

concentrated, has also caused various problems, in the form of long lines of coal-transporting trucks blocking roads to major cities, pressure on railway freight transport capacity, poor working conditions and major accidents of coal miners.

4.3.2 Constraints in terms of arable land and water

China is a country of low per capita resource possession, this is especially true in terms of water and arable land. China's per capita fresh water possession is 2,200 cubic meters, only about one-fourth of the world average per capita possession level. Continued increases in water consumption for industrial, residential, and agricultural purposes have led to declines in the level of underground water and landslides in many places, reducing the support strength of land, and causing building, road, and infrastructure damage in some places.

Water pollution is deteriorating the problem, causing water shortage even in southern and eastern China where there is no lack of water and in the lower reaches of some large rivers.

The massive construction of railway, highways, and rapid expansion of Chinese cities are eroding into the arable land. In China, the average per capita arable land is only 0.1 hectare, which is less than 40% of the world average level. Moreover, more than half the Chinese population are farmers living in rural areas. Land provides the source of income and way of living for them. The increasing number of farmers losing their land due to big infrastructure construction projects and city expansion, is a major source of social unrest and tensions.

The per capita possession of 45 kinds of main minerals in China is less than half of the world average. With the rapid economic growth, China's dependence on export of major minerals will also increase and the constraints of resource shortage will be increasingly felt in the course of China's rapid economic development.

Table 18: Environmental targets for the 10th five year plan vs. environmental performance (million tons)

Indicators	Actual 2000	Planned 2005	Actual 2005 (completed by 6/17/06	Comparison with planned 2005 (+/-%)
Air pollution				
SO2 emissions	19.9	17.9	25.5	42
Industry	16.1	14.5	21.7	50
Domestic	3.8	3.5	3.8	9
Soot emissions	11.7	10.6	11.8	11
Industry	9.5	8.5	9.5	12
Domestic	2.1	2.1	2.3	10
Industrial dust emissions	10.9	8.98	9.1	1
Water pollution				
COD discharge	14.5	13.0	14.1	8
Industry	7.0	6.7	5.5	-18
Domestic	7.4	6.5	8.6	32
Ammonia Nitrogen	1.8	1.65	1.5	-9
Industry	0.8	0.7	0.525	-25
Domestic	1.1	0.9	0.973	8

Source: Based China Environmental Yearbook 2001 and 2006, the 10th Five Year Plan for Environmental Protection and status of the China environment report, 2005

4.3.3 Environmental pollution

During the 2001–2005 period, China failed to realize most of its environmental pollution control targets (see Table 18). It also announced the target to cap its major pollutant emissions by the year 2010. However even with robust economic growth and significant increase in government spending on pollution control, it remains a question whether these environmental targets would be realized.

A research conducted by the Chinese State Environmental Agency and Statistical Agency (SEPA & CNSB, 2006) estimated that in 2003, the economic loss caused by environmental pollution reaches 511.8 billion yuan, accounting for 3.05% of China's national GDP in 2004. The majority of the economic losses come from water pollution and air pollution, which account for 55.9% and 42.9% of the total respectively, while another 1.2% is caused by solid waste and pollution accidents. Moreover, the research results do not include the costs of natural resource depletion and ecological damage. Hence the actual environmental price China is paying for its rapid development is even higher. According to a recent report "Cost of Pollution in China: Economic Estimates of Physical Damages" jointly released by the World Bank and China's environmental administration agency (WB & SEPA, 2007) indicate that evaluation of the health losses due to ambient air pollution using willingness-to-pay measures raises the cost to 3.8 percent of GDP. About 460,000 Chinese die prematurely each year from breathing polluted air and drinking dirty water, according to a World Bank study.


同仁堂
体育专卖
前门文化体育用品公司


88
87
78

CHAPTER – 5

China's Existing Energy Policies

The rapid increase in energy demand has sent alarms to the Chinese policy makers. Numerous policies have been released in recent years, in the form of legislation, national five-year and long-term development plans, as well as national rules and regulations.

5.1 Economic Structure Optimization

China attributed the recent rapid growth of its energy consumption and deteriorating environmental pollution to its improper economic structure: the low added-value of its industrial outputs and the faster than average growth of its energy-intensive and highly polluting industries. Hence economic structure and industrial structure optimization has been identified as a key strategy for slowing down energy consumption growth and pursuing development of higher sustainability.

According to Kai Ma, Minister of China's Development and Reform Commission (2007), if the share of GDP from China's tertiary sector goes up one percentage point and that of the secondary sector correspondingly drops one percentage point, China's total primary energy consumption will decline 25 million tCe, which represents around 1 percentage decline in the country's GDP energy intensity. Besides, based on China's existing economic structure, if one percent of the country's GDP from such energy-intensive industries as metallurgy, building material, and chemicals could be replaced by GDP from high-tech industry, then China's total primary energy consumption will reduce 27.75 million tCe, leading to 1.3 percentage points drop in the country's GDP energy intensity.

5.1.1 Boosting the development of tertiary sector

China is boosting the development of its service sector through deregulating the market entry and supporting the development of information industry. Priority is given to support the development of logistics, finance, information, consulting, tourism, and community services.

5.1.2 Slowing down the investment in energy-intensive industries

One of the major efforts taken by the government is reducing the outdated and redundant production capacity of energy-intensive industries. Each year, the government set mandatory targets of shutting down outdated and redundant industrial product capacity, processes, and equipment. Small, less energy efficient, and polluting coal-fired power plants, aluminium and other energy-intensive production facilities are replaced with more energy efficient large ones. Strict scrutiny is adopted in the approval of investment of the energy-intensive industries. For 2005, the government plans to close 10 GW of small coal-fired generating units, eliminating 30 million of outdated iron production capacity and 35 million of outdated steel production capacity.

5.2 Renwable Energy Promotion

5.2.1 Legislation and law enforcement

A series of legislation has been carried out in recent years about energy conservation, renewable energy development, and the energy development. The Renewable Energy Law entered into force on Jan 1, 2006, together with 9 monitorial regulations about its implementation. Currently, China is revising its Coal Law, Electricity Law, and Energy Conservation Law. Meanwhile, Energy Law, Building Energy Conservation Ordinance, and a few other related laws and regulations are being drafted.

Long-term energy efficiency plan and renewable energy development plan are made and issued to offer long-term guidance to enterprises and local governments. China has released 2020 and 2010 plans for energy efficiency improvement and renewable energy development. These targets are further specified into mandatory targets for local governments, energy-intensive products, and major energy-consuming equipment.

5.2.2 Market-based incentives for renewable energy development

The feed-in-tariff for electricity from biomass is also higher than that from coal-fired power plants. With feed-in tariff at coal fire plant plus 0.25 Yuan/kWh, the range of biomass for power will be about 0.50–0.72 RMB/kWh.

Cost sharing for renewable energy power
As the costs of electricity of renewable sources are higher than coal-fired power plants, the Chinese government stipulates that the extra cost should be shared by all end-users. This is a major policy for boosting renewable electricity project development as it addresses the problem that the local grid operators are reluctant to buy electricity from renewable sources.

- Surcharge: 0.001 Yuan/kWh (0.4–0.6 Yuan/kWh for residential electricity) to cover the aforementioned costs
- Grid corporations collect Renewable Power surcharge
- Tax free for surcharge
  - Systems for record, report, monitor (regulation ongoing)

Market for renewable energy development
The government supports the establishment of renewable energy market through government investment and licensing. To create stable market for renewable energy, it is established in the Renewable Energy Law request that the State Grid Company and oil sales companies must purchase all available renewable energy products at government established prices.

Proper development of hydro on the basis of ecology protection
China takes hydro development as an major part of the transition towards low carbon and clean development. Under the precondition of proper environmental protection and immigrant resettlement, the utilization of the excellent resources for hydro development, especially small hydro development, in western China has been speeded up.

Actively promote nuclear power development
China is enlarging the share of nuclear power in its electricity generation through technology

cooperation, purchase, and research and development.

For renewable power's pricing

- Define the principle for renewable power pricing
- The IRR of renewable power project should be more than the average IRR of conventional energy power project
- Government fix price and Government guiding price (tender price)
- Prices for various renewable power technologies

One measure to boost wind power is through offering feed-in-tariff to electricity from wind farms. The licenses for building and running wind farms in areas with good wind resources are issued through competitive tender: interested companies are invited to submit bids in the form of wholesale prices of the electricity generated and the bidder offering the lowest price are chosen as winners of the licenses. However, this approach is effective for large wind power projects, and it is still unclear how the electricity prices of small wind power projects will be determined.

A *Renewable Energy Development Fund* has been established to boost the development of biofuel, wind, solar technologies through offering government subsidy.

Mandatory target for local government
The program of energy-saving, monitoring and technical service system establishment are binding targets for local governments.

5.3 Energy Efficiency Improvement

5.3.1 Mandatory targets for local governments and enterprises

Based on the national energy efficiency target and taking into account local circumstances, the National Development and Reform Commission proposed the energy efficiency improvement target for specific provinces, autonomous regions, and municipalities (see Table 19). Chinese State Council adjusted the targets of some provinces and formally issued the targets on 17 September, 2006. Local governments are ordered to realize these targets, which then further divide the targets among local prefectures and counties.

Table 19: Energy efficiency targets for different provinces during the 2006–2010 period

Region	2005 Actual Level (toc/ 10,000 RMB)	2010 Target[12] (toe/ 10000 RMB)	Decline (%)
Nationwide	1.22	0.98	20
Beijing	0.80	0.64	20
Tianjin	1.11	0.89	20
Hebei	1.96	1.57	20
Shanxi	2.95	2.21	25
Inner Mongolia	2.48	1.86	25
Liaoning	1.83	1.46	20
Jilin	1.65	1.16	30
Heilongjiang	1.46	1.17	20
Shanghai	0.88	0.70	20
Jiangsu	0.92	0.74	20
Zhejiang	0.90	0.72	20
Anhui	1.21	0.97	20
Fujian	0.94	0.79	16
Jiangxi	1.06	0.85	20
Shandong	1.28	1.00	22
Henan	1.38	1.10	20
Hebei	1.51	1.21	20
Hunan	1.40	1.12	20
Guangdong	0.79	0.66	16
Guangxi	1.22	1.04	15
Hainan	0.92	0.81	12
Chongqing	1.42	1.14	20
Sichuan	1.53	1.22	20
Guizhou	3.25	2.60	20
Yunnan	1.73	1.44	17
Tibet	1.45	1.28	12
Shannxi	1.48	1.18	20
Gansu	2.26	1.81	20
Qinghai	3.07	2.55	17
Ningxia	4.14	3.31	20
Xinjiang	2.11	1.69	20

Source: NDRC, 2006

[12] The 2010 Targets are based on 2005 price.

Energy Efficiency Targets for Major Energy-Consuming Enterprises—the Thousand-enterprise Action

To realize the target of lowering the energy intensity of its GDP by 20% during the 2006–2010 period, industry plays an important role. In China, industry sector contributes to around 70% of the total primary energy consumption. The large energy consumers of key energy-intensive industries are the major contributors to industrial energy consumption.

To curb its rapid energy demand increase, the Chinese government identified 1,008 industrial enterprises each consuming more than 180,000 toc energy in 2004 from 9 energy-intensive industries, which are iron and steel, metallurgical, coal, electricity, oil and petrochemical, chemicals, building material, textile, and paper.

These 1,008 industrial enterprises' total energy consumption in 2004 was 670 million toc, accounting for 33% of China's energy consumption and 47% of the energy consumption by the industrial sector (see Table 20).

5.3.2 Energy efficiency standards and labelling

Energy intensity targets for key products

To generally reach or approach international advanced level in early 1990s by 2010, for large and medium enterprises, the energy efficiency should reach international advanced level at early 2000s; to reach or approach international advanced level by 2020 (see Table 21).

Energy efficiency targets for major energy-consuming equipment

By 2010, the EE of major newly produced energy-consuming equipment should reach or approach international advanced level. Some vehicles, motor engines, and household appliances should reach international advanced level (see Table 22).

Table 20: Industry distribution of enterprises under the thousand-enterprise action program

Industry	Iron & Steel	Oil & Petrochem	Coal	Chemicals	Building material
No. of enterprises	263	100	58	240	97
Industry	Paper	Electricity	Metallurgical	Textile	
No. of enterprises	24	132	71	23	

Source: NDRC, www.ndrc.gov.cn

Table 21: Energy intensity targets for key products

	Unit	2000	2005	2010	2020
Thermal-power generation	gram oe/kWh	268	258	246	219
Steel production (total)	Kg oe/tonne	619	519	499	478
Steel production (comparable)	Kg oe/tonne	536	478	468	437
10 non-ferrous metal (average)	toe/tonne	3.29	3.19	3.14	3.04
Aluminium (total)	toe/tonne	6.78	6.55	6.47	6.30
Copper (total)	toe/tonne	3.22	3.00	2.91	2.73
Refinery	kg oe/tonne-factor	14	13	12	10
ethylene	Kg oe/tonne	848	700	650	600
Ammonia (large enterprise)	kg oe/tonne	937	827	779	683
sodium ash	kg oe/tonne	1061	1027	956	888
Cement	Kg oe/tonne	123.6	108.6	101.1	88.1
Flat glass	Kg oe/weight case	20.5	17.8	16.4	13.7
Building ceramics	kg oe/m^2	6.9	6.8	6.3	4.9
Railway transport	toe/million tonne-km	7.1	6.6	6.4	6.1

Source: NDRC, www.ndrc.gov.cn

Table 22: Energy efficiency indicators of major energy consumption equipment

	Unit	2000	2010
Coal-fired industrial boilers (operating/capacity)	%	65	70-80
Small and medium-sized motors (designed)	%	87	90-92
Wind turbine (designed capacity)	%	75	80-85
Pump (designed)	%	75-80	83-87
Air compressor (designed)	%	75	80-84
Automobile (passenger£©average oil consumption	litre/100 km	9.5	8.2-6.7
Room air conditioner (energy efficiency ratio)[13]		2.4	3.2-4
Refrigerator (energy efficiency index)[14]	%	80	62-50
Household gas stove (heat efficiency)	%	55	60-65
Household gas-fired water heaters (heat efficiency)	%	80	90-95

Source: NDRC, www.ndrc.gov.cn

5.3.3 Market entry restriction on investments

Energy efficiency based new investment approval

In China, fixed asset investments are subject to government approval. The government has made it explicit that investments toward low-energy efficiency and polluting activities are forbidden. Environment impact assessment is a mandatory requirement and in recent years, the State Environmental Protection Administration has stopped the construction of multiple large investments in new projects based on environment performance considerations.

The overall guidance on investments are released in the "Industrial Catalogue for Foreign Investment", "Catalogue of Advantaged Industries for Foreign Investment in Mid-west China" and the "Guiding Catalogue for the Adjustment of Industrial Structure". These catalogues are updated regularly to highlight government policies for foreign and Chinese investments in different areas and technologies. The first two are for foreign investment and the third one is for China's domestic investment. In these catalogues, industries, industrial processes, and technologies are classified into categories subject to government encouragement, forbidding investment, restricting investment, and others, which consist of industries that neither enjoy preferential tax treatment nor subject to restriction and government barriers.

In all these catalogues, investment in energy efficient, clean, and advancement technologies and industrial processes as well as renewable energy are listed in the encouraging category and subject to favourable treatment in taxes and tariff in equipment import. The government has cancelled the tax rebate for the export of coke and other energy-intensive, highly polluting, and resource products.

Discouraging loans to low energy efficiency products

To curb the growth of investment toward energy-intensive and highly polluting industries, in July 2007, the State Environmental Protection Administration, China's Central Bank, and its Banking Regulatory Commission jointly issued a notice forbidding Chinese banks to offer new loans to projects and enterprises belonging to the category, subject to early elimination and restriction in national policies on industrial investment and requesting them ask for early repayment of existing loans to such projects and loans.

[13] A measure of the relative efficiency of a heating or cooling appliance, such as an air conditioner, that is equal to the unit's output in BTUs per hour divided by its consumption of energy, measured in watts.

[14] Formula for calculating the Energy Efficiency Index of Refrigerators:

$$\text{energy efficiency ratio} = \frac{\text{actual electricity consumption}}{\text{electricity consumption limit } E_{max}} \times 100\%,$$

Source: GB12021.2-2003, *China National Standards for Refrigerator Electricity Consumption Limit and Grading*

5.3.4 Market deregulation and price reform

China is gradually deregulating its energy sector, including encouraging private and foreign investment in electricity generating based on renewable resources, opening up its retail market for oil, and energy distribution. For the numerous small consumers of energy, the most effective way of encouraging energy conservation is through pricing. China is loosening its control on the price of coal for electricity generation and significantly raising the prices of oil. The price of electricity has also seen some increase in 2006. Besides, the discussion about levying fuel tax has been going on for some time.

5.3.5 Government-initiated key programs

Further carry out the 10 key energy conservation priority programmes in the Medium- and Long-Term Energy Conservation Plan. These are listed below:

- The coal-fired industrial boiler renovation program;
- Regional heat and electricity co-generation program;
- Waste heat and waste pressure capture and using program;
- Oil saving and replacement program;
- Motor engine system energy saving program;
- Energy system optimization program;
- Building energy-saving program;
- Green lighting program;
- The program of energy-saving in governmental agencies

5.3.6 Government purchase and subsidies

The central government issues list of energy efficient equipment and appliances for government purchase. Moreover, energy service companies, which tend to be partially funded by the government, are also offering consultancy service to local governments and enterprises on energy efficiency improvement. Local governments often offer some subsidies to enterprises' activities for energy efficiency improvement.

5.4 Technology Research, Development, and Deployment

5.4.1 Clean coal technology

China is optimizing the structure of its thermal power generation via eliminating outdated and inefficient small coal-fired generating units and boosting the development of distributed power generation based on natural gas and coal mine methane. The government is encouraging the development of highly efficient and clean coal-generation technologies of 600 MW or bigger super critical and large co-generating units.

China has become a testing field for a wide range of new energy technologies, including super-critical coal, coal liquification and gasification, coal mine methane capture and utilization, as well as carbon sequestration. In realization of its abundant coal reserve and the dominant role of coal in its energy mix in the decades to come, China is investing heavily for using coal in a cleaner way and aims at making clean coal technology its area of expertise in the international arena.

5.4.2 Technology localization

China is also energetically speeding up its energy technology through encouraging joint ventures between international leading energy equipment makers and Chinese enterprises.

5.4.3 Nuclear power plans and policies

The 2020 Nuclear Electricity Development Plan was approved by the State Council's Working group in 2006. The targets are: to build at least 30 nuclear power generating units during the 2006–2020 period, increasing total installed capacity of nuclear electricity generating units to 12 GW in 2010; increasing the share of in-operation nuclear generating units in the country's total installed generating capacity to 4%, and get another 18 GW of installed capacity under construction in 2020.

Although the share is small, the development speed will be very high and represents a difficult task. So far few projects have started construction, but the countries major power corporations are prepared to build their own nuclear power plants. So far in addition to the 2 provinces that already have electricity, another 11 provinces and metropolitans have made plans for nuclear electricity development.

The current international level of nuclear power plant construction costs is around 2,000 USD per kW, to have 40 GW of nuclear power in operation and 18 GW under construction by 2020, the total investment demand will be around 100 bn USD.

5.5 Energy Security Strategies

In 2005, coal contributed 70% of China's primary energy consumption and 81.5% of China's electricity supply is from coal-fired power plants.

The price of oil has spiked considerably since 2003. High oil prices expose major importers, including most of the world's biggest economies, to significant geopolitical and economic vulnerabilities. As a consequence, significant investments are currently being made in clean and renewable energies.

5.5.1 Building up strategic energy stock

To buffer the impacts of wide fluctuations of oil prices on the world market and guarantee supply, China is following the practice of OECD countries—building up oil stock. China's oil stock system under building will include four parts: national strategic oil stock, oil stock by local governments, corporate oil stock by the three big Chinese oil companies, and corporate oil stock by small and medium-sized enterprises.

At the national level, four large oil stock bases will be built. The long-term targets of China's oil stock building efforts is building a stock of about 90 days of the country's oil imports.

5.5.2 Diversifying sources of energy imports

Chinese state-owned oil and natural gas companies are actively seeking oilfields and natural gas fields contracts in African, Middle East, as well as other parts of the world. The government is also seeking energy cooperation with oil and natural gas exporting countries, including building natural gas pipelines from Central Asia.

5.6 International Cooperation

5.6.1 The Asia-Pacific partnership on clean development and climate

In July 2005, six Asia-Pacific Countries, Australia, India, Japan, China, South Korea, and the United States reached an international non-treaty agreement of the Asia-Pacific Partnership on Clean Development and Climate, also known as AP6. The partner countries agreed to cooperate on development and transfer of technology which enables reduction of greenhouse gas emissions. Instead of setting mandatory limits on greenhouse gas emissions, this agreement allows member countries to set their goals for reducing emissions individually, with no mandatory enforcement mechanism.

Four main areas for cooperation:

- develop, deploy and transfer existing and emerging clean technology;
- meet increased energy needs and explore ways to reduce greenhouse gas without hurting the economies
- build human and institutional capacity to strengthen cooperative efforts; and
- seek ways to engage the private sector.

The six countries agree to work together and with private sector partners to meet goals for energy security, national air pollution reduction, and climate change in ways that promote sustainable economic growth and poverty reduction. The partnership will focus on expanding investment and trade in cleaner energy technologies, goods and services in key market sectors. The partners have approved eight public-private sector task forces covering:

- Aluminium
- Buildings and Appliances
- Cement
- Cleaner Use of Fossil Energy
- Coal Mining

- Power Generation and Transmission
- Renewable Energy and Distributed Generation
- Steel

The six partner countries represent about half of the world's economy, population and energy use, and they produce about 65 per cent of the world's coal, 48 per cent of the world's steel, 37 per cent of world's aluminium, and 61 per cent of the world's cement.

5.6.2 China-EU partnership on climate change

China and the EU established a bilateral partnership on Climate Change at the EU-China Summit in Beijing in September 2005. The partnership is to provide a mechanism for the EU and China to take a strategic view of shared climate change objectives, and to take an overview of, give direction to and develop bilateral cooperation activities that contribute to these objectives. As stated in the Joint Declaration, the key objectives of the EU-China Partnership are to:

- strengthen dialogue on climate change policies and exchange views on key issues in the climate change negotiations;
- significantly improve the energy intensity of our economies through cooperation;
- strengthen practical cooperation on the development, deployment and transfer of low carbon technology, to enhance energy efficiency and promote the low carbon economy;
- encourage low carbon technology development, deployment and dissemination and work jointly to ensure that the technologies become affordable energy options;
- explore financing issues including the role of the private sector, joint ventures, public-private partnerships, and the potential role of carbon finance and export credits;
- cooperate to address barriers to the development, deployment and transfer of technology;
- develop and demonstrate in China and the EU advanced, near-zero emissions coal technology through carbon capture and storage;
- reduce significantly the cost of key energy technologies and promote their deployment and dissemination;
- strengthen the implementation of the Clean Development Mechanism (CDM), exchange information on CDM projects and encourage our companies to engage in CDM projects cooperation;
- exchange information and experience on the design and practical implementation of other market-based instruments such as emissions trading and on assessing the costs and benefits of their use;
- strengthen cooperation on adaptation to the impacts of climate change;
- enhance cooperation in capacity building and strengthening institutions.

For the purpose of this partnership, the partners recognize the importance of practical cooperation in the following priority areas:

- Energy efficiency and energy conservation;
- New and renewable energy;
- Clean coal technologies and carbon dioxide capture and storage for near-zero emissions power generation
- Methane recovery and use
- Hydrogen energy and fuel cells
- Power generation, transmission and distribution
- Clean Development Mechanism and other market-based instruments such as Emissions Trading Schemes
- Impacts of and adaptation to climate change
- Capacity building, strengthening institutions and raising public awareness.

5.6.3 Other bilateral cooperation

China-Japan cooperation on energy saving and Environmental protection

During the visit by the Chinese Premier Wen Jiabao to Japan in April 2007, one major agreement is that Japan will offer more environmental pollution control and energy-saving technologies to China, in return China promised to take an active role in post-2012 international climate regime building.

A summary of energy policies considered in the reference scenario for projecting China's energy and emissions future are appended in Table 23.

Table 23: Existing Chinese energy policies in the reference scenario

Year	Scope	Policy Name	Balancing Energy, Development, and climate change
Framework Policy			
1980	National	Deng Xiaoping's said	General secretary of the CPC Central Committee Deng Xiaoping said:" Energy is the primary problem of economic"
1986	National	National Energy Technology Policy Main Point	Promote to improve decision-making concept, method and program in energy field, improve democracy and scientific extent.
1994	National	China's Agenda21	Promote to deeply understand sustainable development concept, implement sustainable policy in all fields of society activities
1997	National	Law on Energy Conservation	Entities producing energy -intensive products should comply with legal limits for energy consumption per physical unit of product. They also shall display energy conservation labels or indicators on product specifications and identification
1998	National	10th Five-Year Plan for Energy conservation and Resources Comprehensive Utilization	By 2005, energy intensity (TPES per GDP)shall be reduced by 4.5% per year. Energy consumption per ton of steel production shall be reduced to less than 0.8 tce, while the overall energy consumption of cement production shall be reduced by 20%. Coal consumption per power supply shall be reduced to 380 gce per KWh. Oil consumption per 100 km for various types of vehicles shall be reduced 10 to 15% on average. The efficiency of electric motor system shall improve by 10 to 12%
2002	National	Clean Production Promote Law	The low aim to promote clean production, increase resources utilization efficiency, reduce and avoid pollution, protect and improve environment quality, ensure physical health, promote sustainable development of economic and society. Country should implement favourable tax policy for clean production.
2005	National	Energy Medium-Long-term Development programming (2004-2020)(draft)	Give the resources conservation the top priority status; highly recognize the energy security .Notably increase energy efficiency. Adjust and optimize energy structure, insist on the development strategy that coal is the main energy source, power is the center, coal, power, oil, gas and renewable energy entirely develop. Depend on technology progress and innovation, develop energy construction. Strengthen environment protection, increase energy investment
2004	National	Medium-Long-term Energy Conversation programming	By 2010, energy consumption per ten thousand GDP shall be reduced form 2.68 tce in 2002 to 2.25tce, annual energy conservation rate is 2.2%, By 2020, energy consumption per ten thousand GDP shall be reduced to 1.54 tce , annual energy conservation rate is 2.2%, conservation energy 1400 mtce, that means reduce SO_2 emission 21 million ton
Coal			
1983	National	The Report about Quickly Develop Small Mine	Promote small mine factory quickly develop, further relax policy, give small local mine factory more open development room

contd…

Year	Scope	Policy Name	Balancing Energy, Development, and climate change
1996	National	Law on Coal	Coal resources belongs Country. The low aim to guide the coal resources exploited activity and coal business activity, promote an ensure coal industry development. The administration implement uniform exploited and utilization program
1996	National	China Green Lighting Project	Promote development of China's illumination electrical equipment industry, Substitute low efficiency and traditional illumination equipment as high efficiency illumination equipment, expand China's high efficiency illumination equipment share in international market
1995	National	Law on Power	The low aim to ensure and promote power industry development, protect power industry investors, operators and users' legal interest, ensure power industry safely function
1997	National	Acid Rain Control Zone and Sulfur Dioxide Control Zone Divided Project	Divide acid rain control zone and sulfur dioxide control zone, implement total emission amount control. By 2000, the industry pollution source in " two control zone" reaches the national sulfur dioxide emission standard; the sulfur dioxide emission amount in " two control zone" less than or equal to national index; the important cities in " two control zone" reaches the national environment standard; the bad acid rain trend become better. By 2010, the pollution situation of acid rain and sulfur dioxide get notably improvement.
2005	National	About Promote Coal Industry Healthy Development	Range rom 2005 to 2008 or 2010, constitue coal resources exploit criterion, get progress in constructing great coal base, construct some hundred million tons coal produce base and enterprises.Amend coal exploit safe condition,effectively deal with coal bed methane accident,the digging zones' ecosystem become better and better.In next five years, form the good supervision system characterized rationaly protection and strengthening conservation, form the legal and policy adjust system based on Low on Coal and Low on Mine Resources
Power			
1985	National	Energy Industry Development Policy	Power is the center of energy industry development
1983	National	Rural electrical pilot project	Construct one hundred electrical pilot counties
1998	National	The some regulate about Development Heating-Power Combination Production	Give the conception of heating-power combination production, set the new assess standard on this. The regulate require to actively develop city hot water supply and centralize cold production in making heating-power combination production, improve annual load factor. The total heating efficiency annual average should be more than 45%
2004	National	The regulate about Development Heating-Power Combination Production	Cover all The Some Regulate about Development Heating-Power Combination Production(1998) content. Add assess standard about combustion engine heating power, the regulate about the examine and approve right, civil heating charge system reform the principle about the power heating prices

contd…

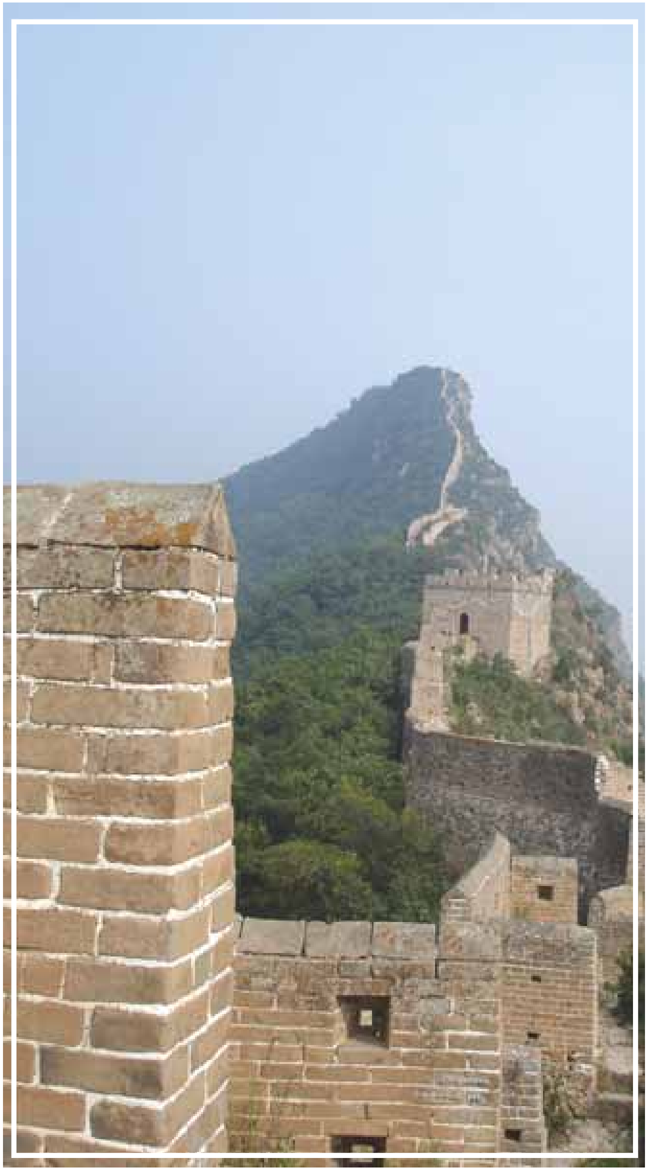
Year	Scope	Policy Name	Balancing Energy, Development, and climate change
Transport			
1998	National	Minimum Fuel Economy Standards on New Cars	Fuel economic of new cars and trucks produced in China on average should be improved by 8% by 2005 and further 7% by 2008. Targets differ depending on the weight of the vehicles. In 2005,new cars in China get two more miles a gallon of fuel than average required in US in2005 and five more miles in 2008
2004	National	Limit Value of Cars Fuel Consumption	This mandatory national standard effect in M1 type cars, require cars industry implement limit value of cars fuel consumption by divided implement periods, ensure cars fuel consumption reduced by 85% in 2009
2005	National		Actively develop new energy conservation and environment friendly cars. The related administration should constitute related policy that aim to introduce and encourage consumer use low energy consumption, low pollution, energy efficient small cars, new drive car. Constitute the industry policy that encourages the development of new energy conservation and environment friendly cars. Constitute favourable tax policy, abolish the limit policy for the energy efficient small cars
Renewable Energy			
2005	National		The country gives priority to the renewable energy utilization and promotes to construct and develop the renewable energy market. Any kinds of economic entities are encouraged to take part in renewable energy utilization activity, the country protect the developer's legality rights and interests according to the law.
2005	National	Wind power Construction Administration	The wind power is one kind of important energy resources, it should be rational utilized and developed. The National Development and Reform Commission has the exclusive right to approve the wind power factories' construction application that is more than 50 MW. It is the one item criteria that the up 70% wind power equipment should be made in China. The import wind power equipment should be imposed on custom
Residential sector			
2005	National Cities and Towns	Further Promote City Heating Supply system reform	Experiment stop welfare heating supply, implement heating supply market reform, implement building energy conservation reconstruction , cultivate heating market, promote energy conservation in heating supply
2005	National	Civil Architecture Energy Conservation Administration Rule(No.143)	Strengthen civil architecture energy conservation management, increase energy utilization efficiency, improve room inner heat environment.
2005	National	Public Architecture Energy Conservation Design Standard	This design standard effect in new building, enlarge building and reconstruction, through improvement maintenance structure heat preservation, heat insulation, energy effect ration. Compare to public building in 1980s, the total energy consumption of the public building reduce 50% on the condition ensuring the room inner heating environment

contd…

Year	Scope	Policy Name	Balancing Energy, Development, and climate change
2005	National	Guideline for Development Energy Conservation Type House Building and Public Building	By 2010, new town architecture energy conservation reaches 50%; by 2020, north and along ocean developed zone and metropolis should get energy conservation 65%. In all, by 2020, energy conservation level of house building and public building close to or reach modern medium developed countries.
1998	National	Labelling Programmes and Energy Efficiency Standards for household Electrical Appliances	The revision of existing standards for refrigerators, electronic ballast, air conditioners and fluorescent lamps throughout 2000 and 2001.TVs, washing machines, iron, cooker, radio and fan are also subject to these standards. There are certain formula to derive the energy consumption limits
Other			
1997	National	ESCO Pilot Project	State Economic and Trade Commission cooperation with World Bank and Global Environment Fund introduce and promote EMC energy conservation mechanism development in China. Construct pilot project in Beijing, Liaoning province and Shandong province
1998	National	Energy conservation Voluntary Agreement Pilot Project	Voluntary agreement among steel producing enterprises in Shandong is calculated by comparing the energy intensity for each enterprise with benchmark intensities that represent the state -of-the-art technologies. After the first phase to 2005,evaluation will be made to decide the target of the second phase to 2010
2004	National	China Energy Label	The country constitute and publish the Product Catalog of Implementing Energy Efficiency Label of The People's Republic of China, make the uniform product energy efficiency standard, implementing rule, and energy efficiency label .The products arranged in Catalog should show the energy efficiency label (China Energy Label) on the product package, show in the product explain note
2004	National	Resources Conservation Activity	In three years, aim to strengthen the resources conservation intention of the people and official, especially for the main official. Strengthen the allocation function of the resources market, increase the resources utilization efficiency, and improve the management level. Energy intensity of GDP drop by 5%
2004	National	Government Purchase Plan for Energy Conservation	Ministry of Finance and National Development and Reform Commission consider the situation of Government purchase reform and energy conservation product market, publicize 'Government Purchase Bill for Energy Conservation Production' .All level governments and institutions which use finance capital should give priority to the energy conversation products

CHAPTER – 6

Future Energy Demand and Emissions in China: Scenarios and Policy Options



Recent rapid growth of energy use in China exerts great pressure on energy supply and environment. This study provides scenarios of future energy development and resulting pollutant and greenhouse gas emissions, taking into account the most up-to-date data and recent policy discussions that will affect future economic, industrial and energy supply trends. To address uncertainties, especially uncertainties surrounding the level of energy intensive production in the next several decades, three scenarios were defined, which reasonably represent the range of plausible futures for energy development. The results from quantitative analysis show that energy demand in China could be as high as 2.9 billion toe in 2030, which could exceed the available energy supply. Comparing with previous energy scenario studies, this result is much higher. By using various policy options discussed in the paper, however, there is potential to reduce this high demand to 2.4 billion toe in 2030.

6.1 Models Used

The IPAC-Emission model and IPAC-AIM/Technology model—components of the Integrated Policy Assessment Model for China (IPAC)—were used to perform the quantitative scenario and policy option analysis. The models project future energy and pollutant emissions.

The IPAC-Emission model is a global model developed for the study of greenhouse gas (GHG) emission scenarios (Jiang et al., 2000a; IPCC, 2001b). It divides the world into nine regions covering 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 (S.E. Asia), Africa, and Latin America (LA). Major emission sources including energy activities, industries, land use, agriculture, and forests, can be simulated in the model framework. The model consists of three modules: (i) macroeconomic module, (ii) end-use module and (iii) land-use module. The macroeconomic module was developed based on the Edmonds-Reilly-Barns (ERB) model (Edmonds and Reilly, 1983; Edmonds et al., 1993), a macroeconomic, partial-equilibrium model, which forecasts energy demand over the long term. 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 (Japan). The land-use module was developed from the Agriculture Land Use Model developed by Pacific-Northwest National Lab (PNNL) to model GHG emissions from land use (Edmonds et al., 1993).

6.1.1 IPAC-AIM/technology model

IPAC-AIM/Technology model is a single region model for China, composing of three modules, i.e., energy service demand projection module, energy efficiency estimation module, and technology selection module. It is a typical bottom-up type model. The structure of this model is given in Figure 6. The demand sector is divided into industrial, agricultural, service, residential and transportation, and these sectors are further divided into sub-sectors. For both demand and supply side, totally more than 400 technologies are considered, including existing as well as advance technologies that may be used in future. Sector output services (such as steel output) in future are key driver. In order to provide these output service, a group of technologies will be selected. Then energy demand could be calculated by these technologies. The model searches for the least-cost technology mix to meet the given energy service demand.

Policies and countermeasures for technology selection, progress, energy price etc., could be simulated in the model. Data for these technologies were collected from large amount of reports, journals and publications, and by consulting experts. The data was kept updated to follow new information collected. Even now we are still working on the updated data for the model.

6.1.2 IPAC-SGM model

IPAC-SGM was selected from IPAC model family. CGE model has the advantage to understand the overall economy activities by implantation of policies or countermeasures. CGE model plays important role in the world for policy assessment. Many modelling teams used CGE model for simulation on economic activities and policy implementation. IPAC-SGM is basically extended from SGM (Second Generation Model), which is developed by Pacific North-West National Laboratory (PNNL) of the United States. The SGM is a computable general equilibrium (CGE) economic model that projects economic activity, energy consumption, and carbon emissions for 12 world regions. IPAC-SGM is the extended version of SGM for China by establishment of data for China and some non-market based sector such as biomass and unclear, hydropower etc., were revised in IPAC-SGM (see Figure 6).

The IPAC-AIM/technology model has nine producing sectors, eleven consuming sectors, with focus on energy production detail,

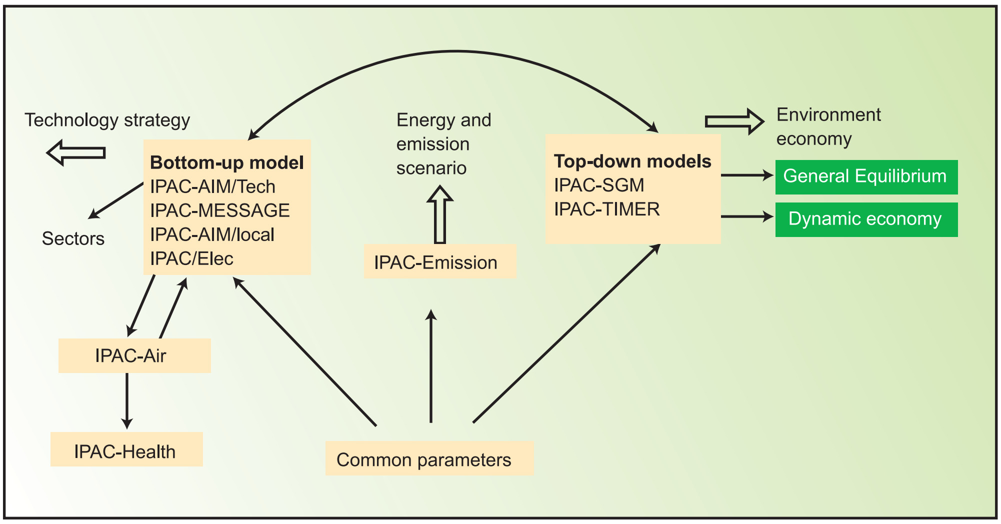


Figure 6: Linkage of the IPAC models

vintaged capital stocks, and a suite of anthropogenic greenhouse gases (see Table 24). The model was developed with recognition that energy production and use is the most important set of human activities associated with greenhouse gas emissions.

6.1.3 Linkage between the IPAC-SGM model and the IPAC-AIM/ technology module

Linking these two models provides both detailed analyses of various sectors and a global analysis of China's energy future. The same scenarios and related model assumptions were used for both models. Energy demand for China was basically given by the IPAC-AIM/ technology model by calculating demand from sectors with detailed technology information; whereas energy price and energy import data are derived from the IPAC-Emission model. The global energy analysis is given based on SRES B2 scenario (IPCC, 2001b), while the part for China is revised in this study. Figure 6 presents the link between two models.

Both models will use same package of scenario parameters, such as population, GDP, technology efficiency, energy resource, energy price, sector output, to keep the two models in line with same analysis framework. Because these two models are different in analysis mechanisms and have different input and output parameters, it is useful to use each other's data.

In order to better use the functions of the two models, soft linkage is established by the past data in the following ways:

- ❑ Technology progress rate could be calculated by IPAC-AIM/technology model after adoption of policies including taxes, and then the progress rate will be inputted into IPAC-SGM model.
- ❑ Sector activities level could be calculated by IPAC-SGM model, such as steel output, cement output etc., could be input into IPAC-AIM/technology model.
- ❑ Energy Price could be calculated by IPAC-SGM model, and then input into IPAC-AIM/ technology model.

Table 24: Classification of energy end use sectors and sub-sectors

Sectors	Sub-sectors
Agriculture	Irrigation, Farming works, Agricultural products processing, Fishery, Animal husbandry
Industry	Iron & Steel, Non-ferrous, Building Materials, Chemical Industry, Petrochemical Industry, Paper-making, Textile
Sector	**Urban:** space heating, cooling, lighting, cooking and hot water, household electric appliance
Agriculture	
Other sectors	
Crude oil production	
Natural gas production	**Rural:** space heating, cooling, lighting, cooking and hot water, household electric appliance
Coal production	
Coke production	
Products from coal	
[Hydrogen fuel]	
Heat supply	
Wood production	
Electricity generation	Oil, Gas, Coal, Biomass, Nuclear, Hydro, Solar/Wind
Oil refining	
Distributed gas	
Chemicals	
Cement	
Primary metals	
Food processing	
Other industry and construction	
Passenger transport	[by transport mode]
Freight transport	[by transport mode]
Household	
Service	Space heating, cooling, lighting, cooking and hot water, electric appliance
Transportation	**Passenger:** railway, highway, waterway, airway
	Freight: railway, highway, waterway, airway

- ❑ Subsidy for energy efficient technology and renewable energy could be simulated by IPAC-SGM model and input into IPAC-AIM/ technology model.

Some of the sectors, such as electricity generation, also contain sub-sectors. Each production sector in the IPAC-SGM represents a unique product with its own unique equilibrium price. Sub-sectors within a sector represent different ways of producing the same product (see Table 24). For example, there are many technologies for generating electricity, represented by the several electricity sub-sectors.

6.2 Model Assumptions

The major assumptions used in this study (including population, GDP growth and mix) are given in the following Table 25 and Table 26. The assumptions for population come from other studies. The assumed GDP growth rate is consistent with government targets and research by the Development Research Centre (Zheng et al., 1999; Tan et al., 2002; Qu, 2003; Liu et al., 2002).

In order to analyze 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, which 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. On balance, the B2 world is one of the central tendencies that can be characterized 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 two per cent per year, reaching about US$ 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 polices vary widely. Major assumptions are given in Tables 27 to 29.

Table 25: Population assumption, (million)

	2000	2010	2020	2030
Population	1267	1380	1460	1530
Urban	459	656	847	995
Rural	809	725	613	536

Note: Assumptions by authors, based on review of relevant studies

Table 26: GDP growth in China

	2000-2010	2010-2020	2020-2030
Annual GDP Growth Rate	8.2%	7.0%	5.6%

For the Developing Asia-Pacific region, the B2 scenario assumes that economic development utilizes resources so as to maintain equity for the future, while maintaining balance among regions as well as between urban and rural areas. Such an approach is introduced 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 characterized by limited population growth, medium economic growth, inequality reduction, weak global governance but strong national and regional governance, a strong de-urbanization 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 by 2100. All of China's emission

Table 27: Key scenario drivers assumed for the developing Asia-Pacific and the world in 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% from 1990 to 2050, 3.8% 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 of non-OECD (now 13 times).
AEEI	1.0%-1.2%
International Trade	Low trade across regions High trade cost
Urbanization	Increase in developing world before 2050, decrease in developed world

Table 28: Assumptions for B2 scenario for the developing Asia-Pacific and the world

Item	Assumptions
Resource availability	Oil/gas: medium; Biomass: high
Energy exploitation cost	Medium
Non-carbon renewable energy cost	High for nuclear, medium for solar and others
Biomass availability	Medium
End-use technology efficiency improvement	Medium
Social efficiency improvement	Medium
Transport conservation	High
Dematerialization trend	Medium
Land-use productivity improvement	Medium
Meat-oriented food habit	Low
Desulphurization degree	High

Table 29: Factors influenced by key driving forces

Driving forces	Sectors	Factors	Policies to promote the Change
Social Efficiency Change	Industry	Value added change by sub-sectors within the sector (as service demand of some sub-sectors including machinery, other chemical, other mining, other industry sector etc.) Products 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, cooling; use of more efficient electric appliances etc.)	Public education, price policies
	Transport	Change of transport mode (more public transport, non-mobility etc.) Traffic volume conservation (use less private car)	Transport development policies, public education
Technology progress	For all sectors	Efficiency progress for technology(unit energy use improvement) Technology mix change(, more advanced technologies) Fuel mix change(more renewable energy and nuclear)	Technology R&D promotion, market oriented policies, international collaboration Market oriented policies, environmental regulation National energy industry policies, import & export policies, tax system

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

The reason to select SRES B2 scenario is the assumption on economy development, population growth, and technology progress trend is quite similar with the scenario study in China.

6.3 Energy Resources and Supply

6.3.1 Fossil fuel

Among confirmed energy resources, coal is the dominant resource with 96% share of total fossil energy resources; confirmed and remaining oil reserves in China are 2.36 billion tons by end of 2003; natural gas is 572.3 trillion m^3 by end of 2000, economic reserve is only 1 trillion m^3. This gives the future for coal supply in a relative low price, and coal will play key role in energy security concern in China. In the recent years, with environment protection, natural gas is recognized as a clean fuel. Historically less attention was given to natural gas with much less investment on resource exploration. Chinese government and companies put much more investment on natural gas resource exploration. In the last two years, three very large natural gas resources were founded in Mainland China.

6.3.2 Hydropower

China has planetary hydropower resource, with very uneven distribution. 70% of the hydropower resources are located in south-west China, which is far from the consumption centre. In recent years, transmission of western electric power to the eastern economic centres has been the key to the development of the western region. Water resources appropriate to small-scale hydropower are plentiful in China. According to the results of China's latest hydropower resource survey, the potential total capacity of small-scale hydropower that could be feasibly developed in the country is 125 gigawatts (GW). The resource base is widely distributed, including sites in over 1,600 counties (or cities), spread over 30 of China's provinces (or provincial-level municipalities). Of 1,600 counties, 65% are located in South-west China; and the small-scale hydropower resources of this region account for over 50% of total national potential capacity.

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

However, development of hydropower also faced several problems such as bad transportation, difficulty in construction, economic problem for long-distance transmit, ecosystem problems, long pay-back-period and difficult fund raising etc.

6.3.3 Nuclear power

China is in a good condition to develop nuclear power. Economically exploitable uranium reserves are 650 Kt in China. International uranium resources are also quite large with around 3 to 4 million tons reserves available below US$ 80/kgU—enough for more than 50 years use for power generation. If it is used in fast breed reactors, the resource is enough for more than 3000 years. Chinese companies already have 300 MW light water reactor technologies, and nuclear power plants could be constructed with own technologies. Chinese companies already have the ability to produce three to four set of nuclear power generators. There are more than 40 to 50 GW nuclear power plants allocated in China. China also has the ability to produce, supply nuclear fuel, and process used fuels.

6.3.4 Biomass energy

China's main biomass resources are agricultural wastes, scraps from the forestry and forest product industries, and municipal waste. Agricultural wastes are widely distributed. Among them, the annual production of crop stalks alone surpasses 600 million tons; and crop stalks suitable to energy production are estimated to represent a potential of 12,000 PJ annually.

Wastes from the processing of agricultural products and manure from livestock farms in theory could yield nearly 80 billion cubic meters of biogas. Scraps from forestry and forest product industries represent a resource equivalent to 8,000 PJ per annum. Furthermore, with the implementation of China's Natural Forest Protection Program (which includes logging bans and logging reductions over much of the nation's natural forests) and its Sloping Cropland Conversion Program (which calls for the conversion of much of the nation's sloping cropland to trees and grasses), it is expected that the amount of scraps from forestry and forest product industries used in energy applications will increase substantially, with the potential of reaching 12,000 PJ per annum by 2020. Municipal waste in China is expected to reach 210 million tons per annum in 2020. If 60 per cent of this is used in landfill methane applications, two to ten billion cubic meters of methane could be produced. Finally, "energy crops" are a biomass energy resource with the potential for commercialization. There are many types of energy crops that are suited to growing in China. Chief among these are rapeseed and other edible oil plants and some plants that grow in the wild, such as sumac, Chinese goldthread, and sweet broomcorn. By 2020, such crops could potentially yield over 50 million tons of liquid fuel annually, including over 28 million tons of ethanol and 24 million tons of biodiesel. In sum, whether burned directly, used to produce electricity, or used as a substitute liquid fuel, biomass energy resources have the potential for playing a decisive role in China's energy supply.

6.3.5 Wind power

With a large land mass and long coastline, China has relatively abundant wind resources.

According to estimates by the China Meteorology Research Institute, land-based, exploitable wind resources represent a potential power generation capacity of 253 GW. (Note: This estimate is based on wind resources at a height of ten meters above the ground). The institute has further estimated ocean-based wind resources to represent an exploitable potential of about 750 GW, so that the total estimated wind power potential of China is about 1,000 GW. Areas rich in wind resources are located mainly along the southeast coast and nearby islands and in Inner Mongolia, Xinjiang, Gansu Province's Hexi Corridor, and in some parts of Northeast China, Northwest China, North China, and the Qinghai-Tibetan Plateau. Besides, there are also certain areas in China's interior that are rich in wind resources. China has large marine areas; and ocean-based wind resources are plentiful. With current technology, wind turbines can be installed in the ocean up to 10 kilometres away from the coast and at ocean depths of up to 20 meters.

By the end of 2003, total grid-connected installed capacity of wind power in China was 560 MW. (See Figure 7 for growth in installed wind capacity over the past 13 years.) Currently, China is tenth in the world in terms of total installed wind power capacity. Aside from grid-connected installations, China also

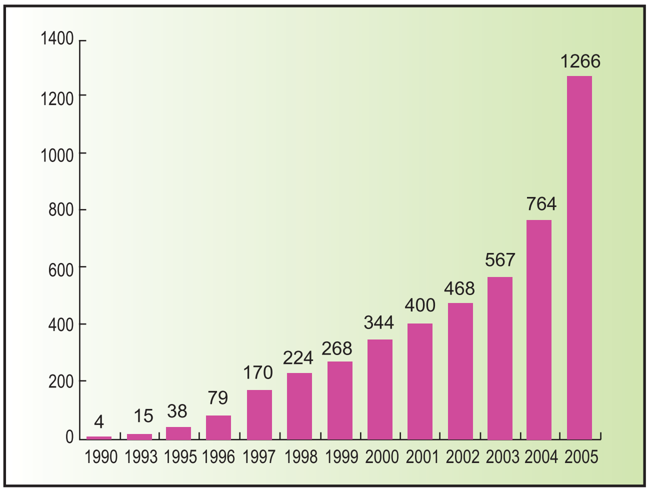


Figure 7: Existing Installed Capacity of Wind Farms in China
Source: China Wind Energy Association (CWEA), 2006

has about 200,000 stand-alone small-scale wind turbines (with installed capacity of 25 MW) that provide electricity to rural households located in remote areas. China has completely mastered the manufacture of large-scale wind turbines of 750 kW or less and is in the process of developing megawatt-scale turbines, which are expected to be available very soon. China has also established 40 wind farms and has mastered wind farm operation and management. The nation now has qualified technical personnel in the areas of wind power design and construction. Thus, a sound base for developing large-scale wind power in China has been developed.

6.4 Future Scenarios Analyzed

In order to analyze future energy demand and emissions in China, we consider three scenarios. Considering the uncertainty for energy intensive products demand with impact of WTO accession, a baseline scenario and a high demand scenario were given. Another one is policy scenario. The three scenarios are defined as follows:

- ***Baseline scenario***: This scenario gives a basic trend to describe future economic activities.
There will be better international trading and China's economy will be part of global economy. Therefore China could rely on international markets and energy resource imports to meet part of its energy supply needs.

- ***High demand scenario***: This scenario presents 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, which will bring more energy-intensive product production to China, such as steel, non-ferrous products and building materials. At the same time, more technology transfer and R&D on high efficiency energy use technologies is also assumed.

- ***Policy scenario***: Various energy and emission control policies are assumed for this low demand scenario, which reflects energy supply and environmental constraints.

Table 30: Energy intensive products assumption in the model

	Unit	2002	Baseline scenario/ Policy scenario		High demand scenario	
			2020	2030	2020	2030
Steel	Mt	182.4	380	320	430	380
Copper	Mt	1.63	4.5	5.2	5.2	5.8
Aluminium	Mt	4.51	10	14	12	18
Ethylene	Mt	5.43	12	16	14	20
Ammonia	Mt	36.75	47	49	50	56
Chemical fertilizer	Mt	37.9	48	50	52	58
Cement	Mt	725	1000	900	1100	1100
Glass	Million cases	234.4	480	530	520	560
Vehicles	Million	3.25	11	12	15	17

Table 31: Policy options used in the modelling study

Policy options	Explanation
Technology promotion policy	End use technology efficiency increase by using new technologies
Energy efficiency standard for buildings	New buildings reach 75% increase standard in 2030
Renewable energy development policy	Promote use of renewable energy(subsidy for wind power, biomass power generation; government supporting village biogas supply system)
Energy tax	Introduce vehicle tax by 2005, and energy tax by 2015
Public transport policies	In cities public transport in 2030 will take 10 to 15% higher share than 2000.
Transport Efficiency Improvement	High fuel efficiency vehicles widely used, including hybrid vehicle, compact cars, advanced diesel car
Power Generation Efficiency	Efficiency of coal fired power plants increase to 40% by 2030
Nature Gas Incentive	Enhance natural gas supply, localization of technology to reduce cost
Nuclear power development	National promotion program by setting up target, enhanced government investment, technology development

The basic assumptions for the three scenarios, such as population and GDP growth, are the same. Sector service output for the three scenarios is given in Table 30. For the global B2 scenario, there is no change for other regions for these three scenarios.

Policy options to be considered in the policy scenario are given in Table 31. These policy options were defined based on policy potential in China and technology trends (Qu, 2003; Liu et al., 2002; IPCC, 2001a; IPCC, 2002). Many of these policies are already in place but need further implementation and strict standard, such as technology efficiency standard, renewable energy targets and fiscal policies, national energy targets etc. Some new policies including taxes are also designed here.

6.5 Modelling Results

6.5.1 Energy

This study also simulated future energy production in China. Figures 8 and 9 give energy production in the baseline and high demand scenarios. Coal production could reach 1.31 billion toe by 2020 and 1.48 billion toe by 2030. Chinese coal industry experts estimate an upper bound of coal production of 1.2 billion toe by 2020. Coal demand, therefore, could exceed domestic coal production in China. Oil production is projected to be 190 million tons in 2020 and 175 million tons in 2030. 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

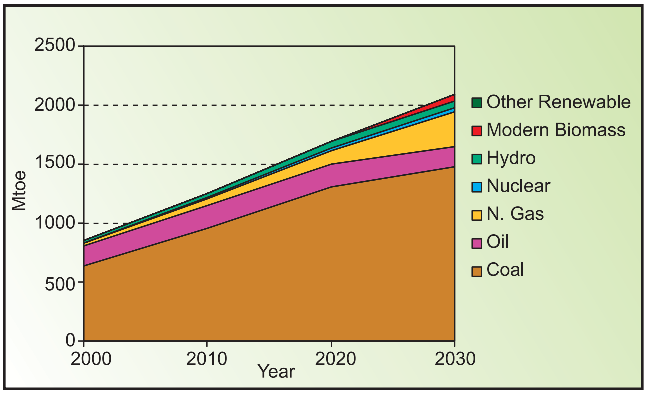


Figure 8: Energy production in baseline scenario

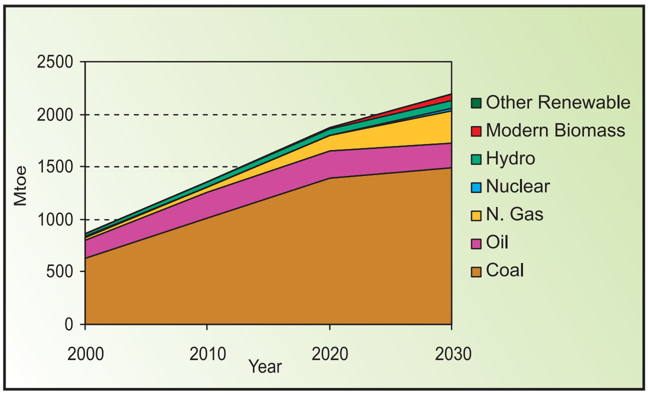


Figure 9: Energy production in high demand scenario

m³ in 2020 and 312 billion m³ in 2030. The production of natural gas is within the range of natural gas production forecast by energy experts, which ranges from 130 to 150 billion m³ 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 and 344 TWh in 2030, compared with 16.7 TWh in 2000. The installed capacity will be 39,400 MW in 2020 and 53,030 MW in 2030. Hydropower output will increase from 224 TWh in 2000 to 555 TWh in 2020 and 722 TWh in 2030, with capacity reaching 154 GW in 2020 and 201 GW in 2030.

According to the energy demand and production, we can calculate the need for future energy imports (see Figures 10 and 11). In baseline scenario, future fossil energy imports could reach 375 million toe annually in 2020 and 562 million toe in 2030 (for comparison, in 2000, the USA imported 870 million tce). Oil will be the major energy source to be imported: oil imports will reach 230 million tons in 2020 and 300 million tons by 2030. Natural gas imports will amount to 154 billion and 183 billion m³ in 2020 and 2030, respectively. Even coal will be imported after 2020, with 129 million tons of coal needed annually by 2030.

In the high demand scenario, energy imports are much bigger. Total fossil energy import will be 445 million toe in 2020 and 680 million toe in 2030. There will be more coal import in this scenario, reaching 189 million toe in 2030.

Energy demand is calculated using the IPAC-Emission model, Baseline scenario results are given in Figures 12 and 13.

Primary energy demand in the baseline scenario could go to 2.1 billion toe in 2020 and 2.7 billion toe in 2030. The annual growth rate from 2000 to 2030 is 3.6%, while energy elasticity of GDP is 0.58. Coal will be the major component energy in China (1.5 billion toe in 2030), with a 58% share in total energy demand. There is a rapid increase for natural

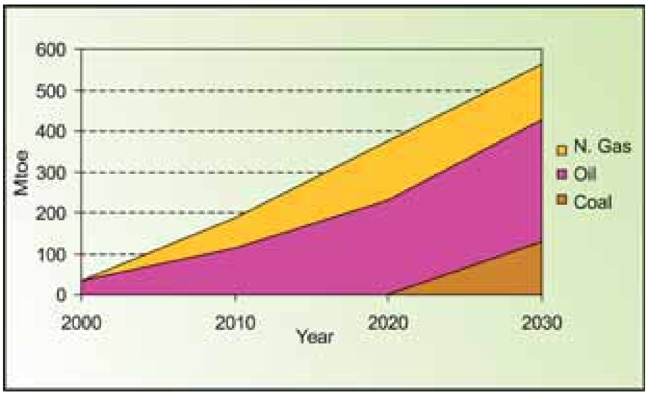


Figure 10: Energy imports in the baseline scenario

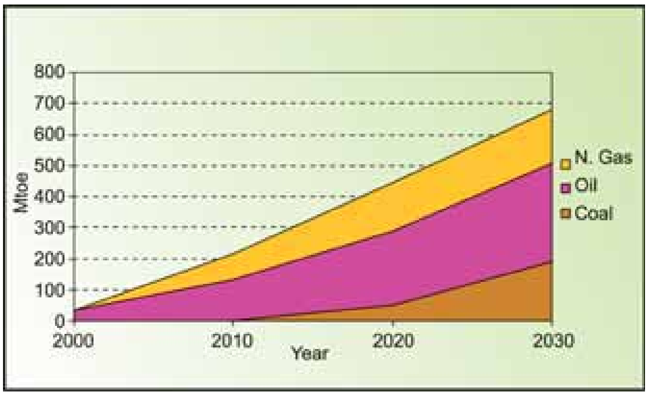


Figure 11: Energy imports in the high demand scenario

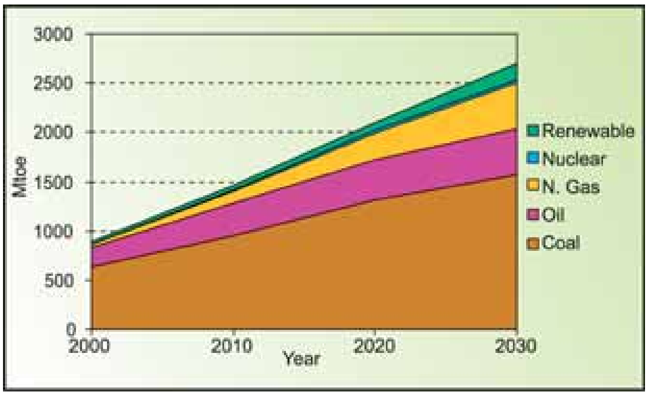


Figure 12: Primary energy demand for baseline scenario

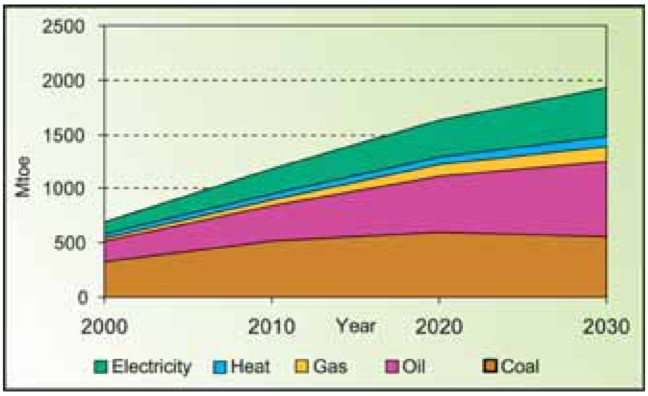


Figure 13: Final energy demand for baseline scenario

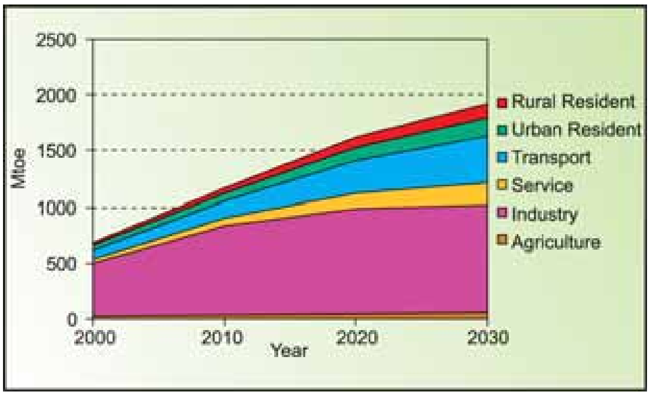


Figure 14: Final energy demand by sector in baseline scenario

gas demand in China, with its share in total primary energy use increasing from 4% in 2000 to 17.3% in 2030 (average annual growth rate: 10%).

With respect to final energy use, electricity and oil increase rapidly. Electricity demand increases from 112 million toe in 2000 to 451 million toe in 2030. 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, steel industry and cement industry. 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 74 million toe in 2000 to 410 million toe in 2030 (see Figure 14).

For the high demand scenario, primary energy demand in 2030 is 2.9 billion toe, which is 250 million tons higher than the baseline scenario. Of the total primary energy demand, coal provides 59.1%, oil 16.1%, natural gas 17.8%, and nuclear 1.2%. Because this scenario assumes better integration in international markets, there is greater reliance on imported energy such as natural gas and oil (see Figures 15 and 16).

By assuming the adoption of energy and environmental policy measures, the policy scenario results are described in Figures 17 and 18. Compared to the baseline scenario, there is nearly 245 million toe energy demand reduction in 2020, 280 Mtoe in 2030. By exploring the policy options, we found there is big pressure to apply these policy options in order to reach the lower energy demand

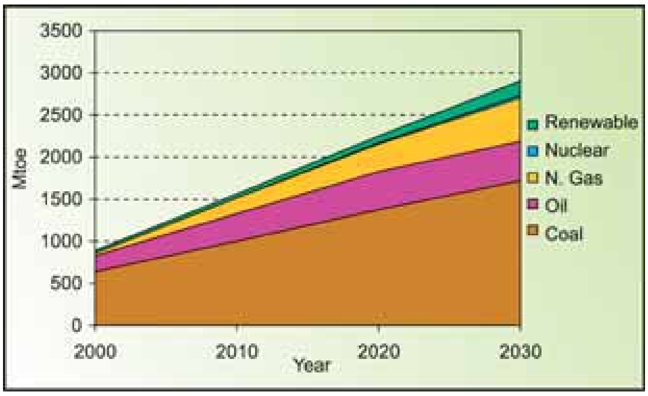


Figure 15: Primary energy demand in high demand scenario

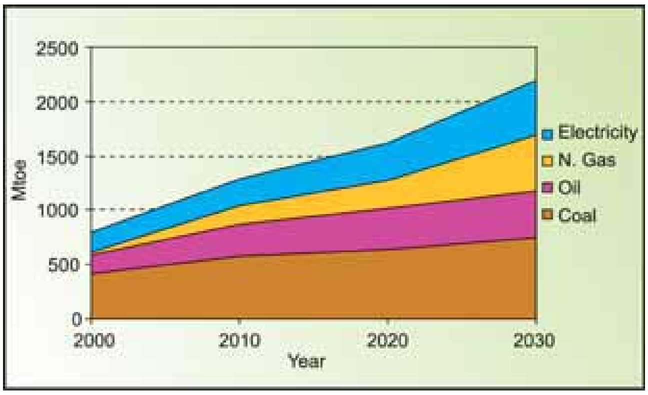


Figure 16: Final energy demand in high demand scenario

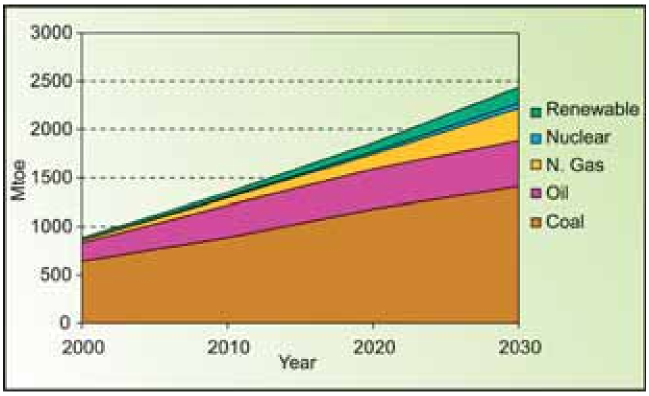


Figure 17: Primary energy demand in policy scenario

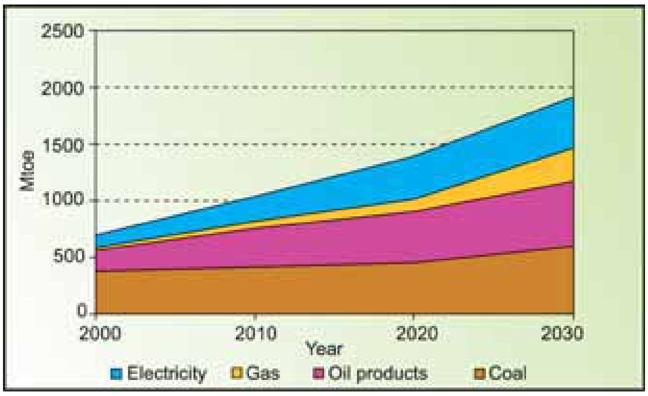


Figure 18: Final energy demand in policy scenario

scenario, and also need to be introduced at early time because of long life span of energy technologies.

Primary energy demand in the baseline scenario could go to 2.1 billion toe (Btoe) in 2020 and 2.7 Btoe in 2030 (Figure 12). The annual growth rate from 2000 to 2030 is 3.6%, while commercial energy elasticity of GDP is well below unity. Coal will be the major energy component in China (1.5 Btoe in 2030), with a 58% share in total energy demand. 61% of coal is consumed for power generation in 2030, while the remaining is used by other industrial sectors. There is a rapid increase for natural gas demand in China, with its share in total primary energy use increasing from 4% in 2000 to 17.3% in 2030. This implies an annual average growth of 10% over this period.

With respect to final energy use, electricity and oil increase rapidly. Electricity demand increases from 112 million toe (Mtoe) in 2000 to 451 Mtoe in 2030 (Figure 13). 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, steel industry and cement industry etc., due to increase of energy intensive industry. 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 74 Mtoe in 2000 to 410 Mtoe in 2030 (Figure 14).

The transport sector is growing rapidly in China with road transport taking the maximum share. In the year 2000, out of a total of 1,378 billion person km (BPKM) passenger traffic volume in China, 817 BPKM was supplied by road, 453 by railways, 97 by aviation and 10 by navigation. The passenger traffic volume is projected to increase by almost six-folds during 2000–2030. Road traffic would grow six-folds, while air traffic is projected to grow by over 15-times from a low current base. Freight transport was 4,859 billion ton-km (BTKM) in 2000, with almost 46% supplied by navigation. This is projected to increase to 23,000 BTKM in 2030, with navigation supplying 43%, road 33% and railways 23%. Transport sector is projected to be dominated by fossil-based technologies in short to medium-terms. Hybrid vehicles, electric cars and such cleaner technologies from local air pollution perspective are also projected to penetrate to some extent. Public transport also expands.

Table 32: Clean coal technologies in reference scenario

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

Table 33: Clean coal technology in alternative policy scenario

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

6.5.2 Clean coal technologies

In the reference scenario, development of these technologies was set up in a preliminary diffusion way. Table 32 shows the technology involvement in the reference scenario. Industry, including the power sector, is projected to witness a thrust on energy efficiency improvement through deeper penetration of advanced boilers, advanced kilns and super critical pulverized coal technology. Another promising technology IGCC does not however penetrate so much under the reference scenario policies for power generation. However, FGD technologies for SO_2 removal from the flue gases gain much ground acquiring a 58% share in 2030 from almost none currently.

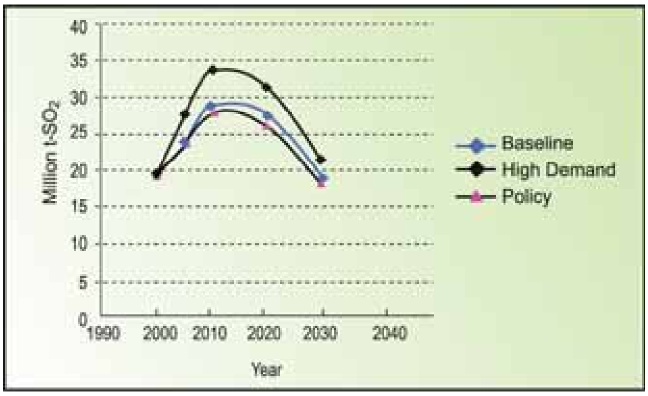


Figure 19: SO_2 emission in China

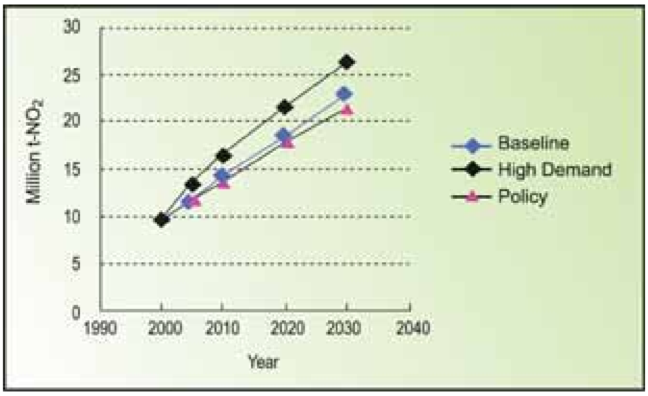


Figure 20: NO_x emission in China

In the alternative policy scenario, among policy options, clean coal technology development and diffusion is one of the key components. Table 33 presents the clean coal technology diffusion in alternative policy scenario. Adoption of policy options to reduce energy demand, GHG and local pollutant emissions has impact on economy activities and social development. Clean coal technologies penetrate much deeper than in the reference scenario.

6.5.3 Emissions

With the calculation of energy demand, several pollutant emissions were calculated. Figures 19 to 22 give SO_2, NOx, TSP and CO_2 emission from energy activities. SO_2 emission will keep increasing before 2010 with the rapid increase of coal use in China. After 2010, more and more desulphurization technologies will be used and therefore SO_2 emission will be reduced from fossil fuel use. Compared with high demand scenario, SO_2 emission for baseline scenario in 2010 is 4.5 million tons lower, but still increase 9.45 million ton from 2000. This will be big challenge for government target. Because of lack of policy to control NO_x, its emission keeps going up. Same trend is seen for TSP emission

The energy saving and CO_2 emission reduction potential by sector was simulated with a wider cost range of up to US$ 50/tC. Emission reduction potential by these sectors with cost less than US$ 50/tC is shown in Figure 23. It indicates that much of the mitigation potential comes from no-regret options.

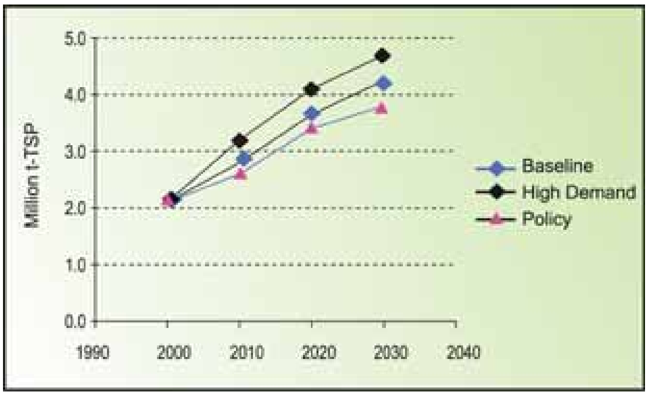


Figure 21: TSP emission in China

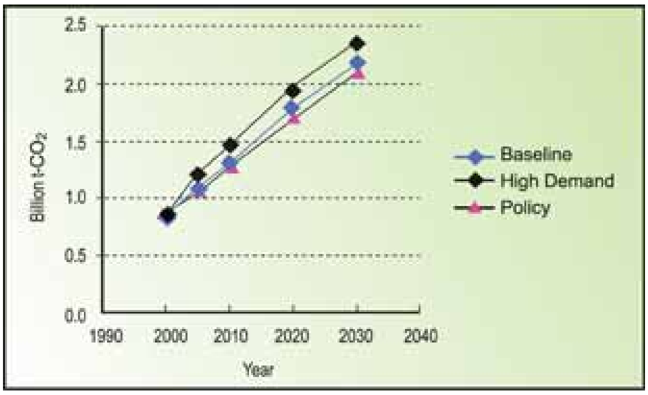


Figure 22: CO_2 Emission in China

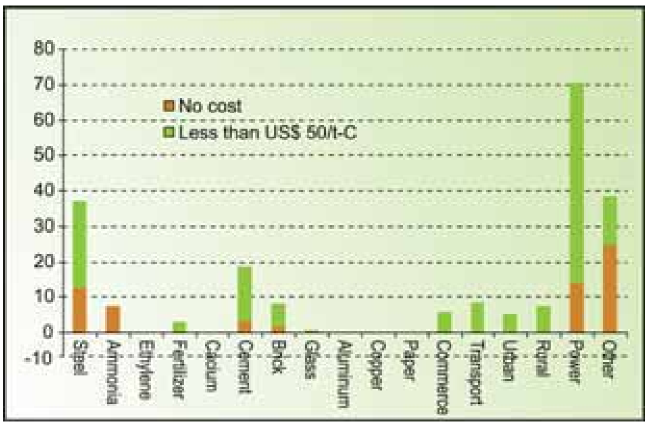


Figure 23: Emission reduction potentials by sectors

Table 34: Technologies contributing to energy saving and GHG emission reduction in short and middle-term

Sector	Technologies
Steel Industry	Large size equipment (Coke Oven, Blast furnace, Basic oxygen furnace ,etc.), Equipment of coke dry quenching, Continuous casting machine, TRT Continuous rolling machine, Equipment of coke oven gas, OH gas and Blast Furnace gas recovery , DC-electric arc furnace
Chemical Industry	Large size equipment for Chemical Production, Waste Heat Recover System, Ion membrane technology, Existing Technology Improving
Paper Making	Co-generation System, facilities of residue heat utilization, Black liquor recovery system, Continuous distillation system
Textile	Co-generation System, Shuttleless loom, High Speed Printing and Dyeing
Non-ferrous metal	Reverberator furnace, Waste Heat Recover System, QSL for lead and zinc production
Building Materials	Dry process rotary kiln with pre-calciner, Electric power generator with residue heat, Colburn process, Hoffman kiln, Tunnel kiln
Machinery	High speed cutting, Electric-hydraulic hammer, Heat Preservation Furnace
Residential	Cooking by gas, Centralized Space Heating System, Energy Saving Electric Appliance, High Efficient Lighting, Solar thermal for hot water, insulation of building and energy efficient windows
Service	Centralized Space Heating System, Centralized Cooling Heating System, Co-generation System, Energy Saving Electric Appliance, High Efficient Lighting
Transport	Hybrid vehicle, advanced diesel truck, Low Energy Use Car, Electric Car, Fuel cell vehicle, Natural Gas Car, Electric Railway Locomotives, public transport development
Common Use Technology	High Efficiency Boiler, Fluid Bed Combustion Technology, High Efficiency Electric Motor Speed Adjustable Motor, Centrifugal Electric Fun, Energy Saving Lighting
Power generation	Super critical unit, Natural Gas Combined Cycle, Pressured Fluid Bed Combustion Boiler, Wind turbine, Integrated Gasification Combined Cycle, Smaller Scale Hydropower, biomass based power generation

If we look at the effects for policy options used in the policy scenario, by comparing with baseline scenario and high demand scenario, we found there are a package of policy options that could be adopted now to reduce the growth rate of energy demand. For example policy to promote penetration rate of high energy efficiency technologies (see Table 34), fiscal energy and environment policies including vehicle fuel taxes, subsidies for renewable energy, emission taxes, resource taxes etc., and policy to promote public involvement, are important for China to go to a low energy demand scenario.

6.6 Conclusions

This scenario study shows primary energy demand in 2020 could range from 1.9 billion toe to 2.4 billion toe. This depends on technology progress, energy intensive sector development, and polices applied, etc. Such a large amount of energy demand will bring serious pressure on energy supply in China.

Studies show that by 2020 the largest domestic oil supply could reach 200 million tons, natural gas 160 billion m^3, and coal 2.8 billion tons. This means for lowest energy demand scenario 200 million tons oil and 100 billion m^3 natural gas shall have to be imported; for high energy demand scenario, nearly 400 million tons oil, 260 billion m^3 natural gas and 300 million tons coal shall have to be imported.

Such a large amount of energy demand and imports, will put high pressure on the energy supply industry in China, therefore a well-designed strategy for energy system and energy industry development in China should be prepared. Considering the possibility of policy options analyzed in this study, the following suggestion are given:

- Technology progress is a key to reach future low energy demand and a cleaner future and much more emphasis should be put on development of new generation technologies. In the scenario study, technology progress will contribute much of the energy saving, while not disturbing welfare.
- Using of energy tax, resource tax, export tax for energy intensive products etc., has good effect on energy saving and optimization of economic structure. These should be given much more attention.
- Similar to other developed countries which have large amounts of energy import, China should establish an energy security system. However the size of strategic storage should be decided based on global perspective of oil demand.
- Multi-energy system should be established to diversify energy supply. Renewable energy should be developed as alternative energy source. Biofuel for vehicle fuel could reduce energy import.
- Various national laws, regulations, and standards for energy industry should be prepared to reach the target of a clean energy system. So far there is very weak legislation system to promote a clean energy system.
- Clean coal technology should be emphasized to mitigate emission from coal combustion. Only a few countries in the world are using coal on a large scale, therefore development of clean coal technologies depends on them. China is the biggest country to use coal, and in future the coal use will increase quickly, which could equal more than 40% 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 better to work in close coordination with other countries to develop a new generation of clean coal technologies.

Due to low cost of production, it’s likely that China will become a major manufacturing centre in the world relying on energy intensive and resource intensive products. This trend should be controlled to avoid China becoming a country to provide raw material and cause damage to environment. External cost should be included into production cost. Planning for energy and resource intensive products should be made, to avoid possible environment and economic damage.

Part III

Comparative Results

CHAPTER – 7

Sustainable Development Indicators for China

7.1 Current Status of SD Indicators

In this report, the set of indicators are used to measure the sustainable development effects of different policy scenarios. This chapter will start with a snapshot of China's current development performance captured with eight sustainable development indicators.

- ❑ CO_2 intensity of GDP (CO_2/GDP)
- ❑ CO_2 intensity of total final energy consumption (CO_2/TFEC)
- ❑ Energy intensity of GDP (TFEC/GDP)
- ❑ Fuel imports
- ❑ Average costs of electricity
- ❑ Household electricity access
- ❑ Per capita electricity consumption
- ❑ Renewable share in power production

For the first five indicators, lower index values mean positive impacts on SD while for the last three, higher values means better SD performance.

The modelling exercise for China provides projections for future energy and related SD indicators. Table 35 and 36 give these for some key parameters for the period 2005[15].

Fuel imports

As indicated in Table 37, China is a major player in the international energy market, and its

Table 35: Key parameters for China

Parameter	2005
GDP (Billion US$, 2000 constant prices)	1684.7[16]
Population (Million)	1307.56
TPES (PJ)	65432.5
Investments in new power plants (US$ billion, 2000 prices) *	81.33[17]
Energy infrastructure including T&D lines, gas pipelines, LNG Terminals, Refineries etc. (Billion US$, 2000 prices) *	40.72
Fuel imports (oil and gas) (Billion US$, 2000 prices)	45.60
Coal consumption (million ton)	2370
Oil product consumption	325.35
CO_2 (Mt-CO_2)	3719.4[18]
SO_2 (Mt-SO_2)	25.49

[15] To make calculation easier, in this report the data are just about China's mainland, excluding data about Hong Kong, Macao, and Taiwan.
[16] GDP using Exchange Rates (billion 2000 US$). 2003 figure in IEA 2005 b, IEA Energy Balances of Non-OECD Countries, multiply the index of GDP growth based on fixed price, as given in 2006 China Statistical Yearbook
[17] Investment in the Production and Supply of Electricity and heat is 755.44 bn RMB in 2005 average exchange rate in 2005: 1USD = 8.1917 RMB (CNSB, 2006). 1US$ 2005 = 0.882 US$ 2000 (http://oregonstate.edu/cla/polisci/faculty/sahr/sahr.htm)
[18] 2003 data, source: IEA 2005.

Table 36: Energy price in China: 2004-2006

Item	Unit	2004		2005		2006		
		Jan.	July	Jan.	July	Jan.	July	Oct.
Bitu Coal for Coking	US$/ton	47.69	54.43	57.32	64.50	70.13	70.57	74.23
Bitu Coal for industrial Boiler	US$/ton	38.26	44.89	51.98	63.61	410.26	527.77	488.05
Gasoline	US$/ton	542.85	588.21	623.00	694.21	743.70	880.16	891.02
Diesel	US$/ton	432.63	465.92	499.10	556.05	592.51	685.11	694.14
Exchange rate	RMB/US$	827.7	827.67	827.65	811.28	806.20	798.77	790.07

Source: Beijing Energy Efficiency Centre, www.beconchina.org

Table 37: China's import and export commodities

Item	2004 (bn US$)		2005 (bn US$)	
	Exports	Imports	Exports	Imports
Mineral Fuels; Lubricants; Asphalt; Mineral Wax	14.48	48.03	17.62 bn	64.09
Of which: Coal	3.81	0.89	4.27	1.38
Coke and Semi-coke	3.95		2.34	
Crude oil	1.32	33.91	2.70	47.72
Finished oil products	3.96	9.24	6.41	10.43
Other	1.44	3.99	1.9	4.56

Source: China Statistical Yearbook 2006

import has been increasing. In 2005, China's net import of crude oil and finished oil products totalled 136 million tons, accounting for 42.9% of the total. Because of resource constraints, there is small space for further increase of annual domestic production and the rapid increase in demand for cars, leads to a strong momentum of domestic demand increase. It is widely expected that China's future increase in oil demand will mainly rely on more imports.

In this report, it is assumed that the import of gas is 4.56 bn US$, and that of natural gas, 1.9 bn US$ in 2005. Therefore, the net spending on oil and natural gas import is 45.60 bn US$ (2000 prices).

Coal consumption
China consumed 2.17 billion tons of coal in 2005, of which 93% went to industrial sector and residential consumption only accounted for around 4% (CNSB 2006). The trend of increases in coal consumption has been continuing, in the year 2006, the consumption further increased to a new record high of 2.37 bn tons (CNSB, 2007).

Investment in new power plants
The official statistics about investment in electricity production and supply of electricity and heat is 643.73 bn Yuan in 2005 (CNSB, 2006). In 2005, China's total installed capacity of electricity generating units in operation increased 66.02 GW, of which 54.65 GW from thermal power, accounting for 82.78% of the total increase, the hydro capacity increased by 11.28 GW, accounting for 17.09% of the increase, win power 80 MW, accounting for 0.12% of the total. Currently, the investment costs of thermal power stand around 5,000 RMB/kW and that of wind power is around 10,000 RMB/kW (NDRC, 2006). Investment cost of coal-fired power plants is around 4,000 RMB/kW, that of hydropower 7,000 to 8,000 RMB/kW, and that of wind power around 10000 RMB/kW (internet).

Oil product consumption
China's oil product consumption totalled 325.35 million tons of crude oil in 2005, up 45% from the 2000 level. This leads to much concern about energy security in China, especially in a

Table 38: Investment in energy infrastructure including transmission and distribution lines, gas pipelines, LNG terminals, refineries etc. (Billion US$, 2000 prices)

Item	Investment (bn RMB 2005)	Investment (bn US$ 2000)
Processing of Petroleum, Coking, Processing of Nuclear Fuel	80.13	8.63
Transport Via Pipelines	7.96	0.86
Production and Supply of Gas	27.46	2.96
Mining and Washing of Coal	116.29	12.52
Extraction of Petroleum and Natural Gas	146.36	15.76
Total	378.2	40.72

time of high and volatile oil prices on the international market.

CO_2 emissions

China's mainland experienced the third largest percentage increase (64.9%) in CO_2 emissions from 1990 to 2003 (see Figure 24). Then China entered a period of spikes in energy consumption, leading to rapid expansion of the country's CO_2 emissions from fossil fuel consumption.

SO_2 emissions

China emitted 25.49 million tons of SO_2 in 2005, 85% was from the industrial sector and the other 15% from residential sector (CNSB, 2006).

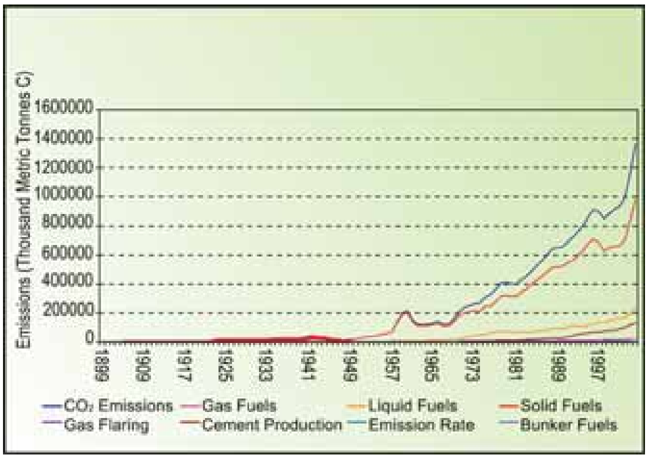


Figure 24: CO_2 emissions from Mainland China.
Source: Marland, G., T.A. Boden, and R.J. Andres. 2006. Global, Regional, and National CO_2 Emissions. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A.

7.2 SD Indicators Under the Reference Scenario

In China, developing the economy and improving the living standards of people are the primary short- and long-term targets set out by the Chinese government. At the same time, sustainable development is recognized as an important issue. Agenda 21 for China, announced by the Chinese government in 1994, explicitly states that;

"Taking the path of sustainable development is a choice China must make in order to ensure its future development in the century. Because China is a developing country, the goal of increasing social productivity, enhancing overall national strength and improving people's quality of life can not be realized without giving primacy…. At the same time, it will be necessary to conserve natural resources and to improve the environment, so that the country will see long-term, stable development."

Since 1994, Agenda 21's objectives have been translated into other policy plans, including the successive Five-Year plans. Other objectives include reducing the large differences in wealth in different areas (especially the rural areas and the regions in the west of the country), and hence to reduce poverty and to control population growth. The goal for energy is to supply enough energy for national economic development and ensuring environmental protection. Controlling urban air pollution is a major aspect of this. The sustainable development indicators for China are given in Figure 25.

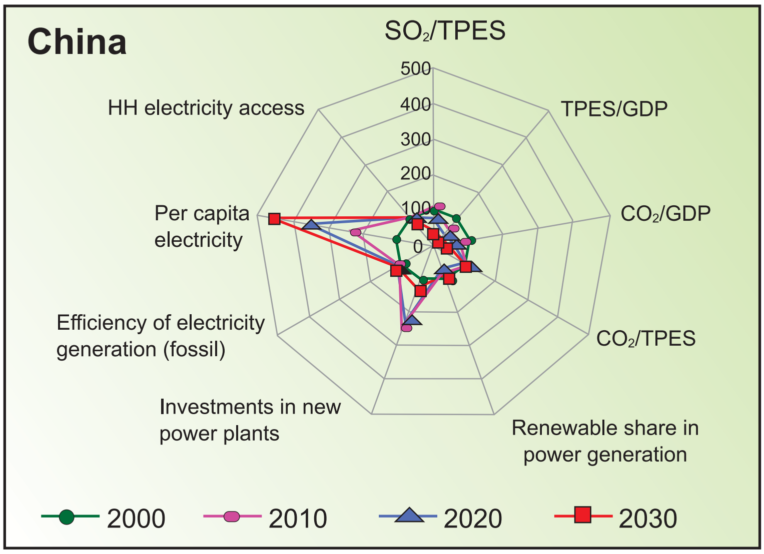


Figure 25: Sustainable development indicator projections for China

7.3 Conclusions

Recent rapid growth of energy use in China exerts great pressure on energy supply and environment. This study provides scenarios of future energy development and resulting pollutant and greenhouse gas emissions, taking into account the most up-to-date data and recent policy discussions that will affect future economic, industrial and energy supply trends. To address uncertainties, especially uncertainties surrounding the level of energy intensive production in the next several decades, two scenarios were defined, which reasonably represent the range of plausible futures for energy development. This study also analyzes benefits of focusing on domestic development target, development strategy, energy policies, and environment policies.

China's energy supply relies on domestic coal as the main energy resource. China consumed over 1.9 billion tonnes of coal during 2004—about 30% of global coal consumption. Such large coal-use poses formidable environmental (local and global), production, transport and infrastructure development challenges. Clean coal technologies, which are now being explored in China, offer possibilities of addressing these concerns while simultaneously neutralizing some of the associated negative externalities. This study takes clean coal technology development as a case study by reviewing coal-use and associated concerns in China, development trends in clean coal technologies globally (including CO_2 capture and storage), and their inter-linkages with sustainable development.

This scenarios study shows primary energy demand in 2020 could range from 1.9 Btoe to 2.4 Btoe. This depends on technology progress, energy intensive sector development, and polices applied etc. Such large amount of energy demand will bring serious pressure on energy supply in China.

It is clear that the coal demand in China will keep growing. It is concluded that emission from coal use will also keep increasing in absence of any specific efforts to mitigate them. Many cities in China suffer from serious air pollution, which adversely effects their sustainable development. The study has shown that the development of clean coal technologies could contribute local sustainable development in following ways:

- Reduce energy demand, which could release pressure on energy supply and energy imports, and enhance energy security.
- This will sustain the whole coal industry in China which has large employment—7.6 million employees in 2004 and projected 7.8 million in 2030. The important thing is that it is good for low income people to find employment opportunities. This helps in distribution of wealth.
- This will help extend economy activities globally. If China takes lead for clean coal technology development in the world, it will bring economic benefits globally. Three power equipment companies in China have become among top manufacturers in the world in 2005 (largest power capacity suppliers for coal fired power plants), and have started to export advanced coal-fired power plants, equipments and machinery at lower prices.
- Clean coal technologies will have very positive environment effects. They will not only reduce CO_2 emissions per unit of power

generated, but will also significantly reduce local air pollutant emissions (such as SO_2, NO_x, and SPM) and water pollution. Clean coal technology development will be crucial for meeting the government's domestic environment target in 11th Five Year Plan.

- It will contribute to global climate change collaboration. Asia-Pacific Partnership on Clean Development and Climate, and China-EU Partnership on Climate Change have component of clean coal technology collaboration

There is urgent demand to reduce coal use in China as very large amount of coal is currently used which is also projected to continue increasing in future. Such large amount of coal use has brought immense pressure on coal mine production safety, transport, environmental degradation including land damage, water pollution and air pollution, etc. The role of clean coal technology development in China and other countries in a similar position is therefore well identified. In order to further promote clean energy future, following recommendations are suggested:

- Clean coal technology should be emphasized to mitigate emissions from coal use. Since only a few countries in the world are using coal in such large scale including China, India, USA, Australia and South Africa, therefore development of clean coal technologies depends on these countries. China is the largest coal consumer in the world, and in future the coal use will increase quickly which could take more than 40% of world total coal use in 2020. Therefore, clean coal technologies are crucial for China. China should therefore have own development plans for clean coal technologies. Simultaneously it is better to work closely with several other countries on development of new generation clean coal technologies.
- Various national laws, regulation, and standards for energy industry should be prepared to reach the target of clean energy system. So far the legal systems are very weak for promoting clean energy system.
- Technology is the key issue for clean energy and a lower energy demand future. Technology R&D must be therefore emphasized. International collaboration for technology transfer and diffusion should be encouraged more. Clean coal technology development should be further worked by China and other few countries.
- Clean coal technology development in China could contribute economic development as an important industrial sector.

Climate change issues raised critical pressure on coal activities, but at the same time, it also provides opportunities for clean coal future. The opportunities should be explored by involving international activities for clean coal technology RD&D (research, design and demonstration) such as clean coal partnership, CDM, etc.


水中
金泰盛达园饭店
23

CHAPTER – 8

Alternative Independent Modelling Studies on China

8.1 Policy Options and Mechanisms

This chapter explores the sustainable development effects of different energy policy options. The study is carried out by the same modelling team from the Energy Research Institute of the China National Development and Reform Commission and using the same IPAC-AIM model, but based on different assumptions from the previous chapters.

8.1.1 Technology options

With the impacts and causes of climate change so deeply rooted in the entire economic system and living patterns of modern society, climate change needs to be tackled from many aspects and with multiple approaches and mechanisms under the framework of sustainable development. However, different options may represent different costs and benefits.

To implement the integrated policies in the most cost-effective way, a lot more need to be done. There are several key issues to be addressed. As coal is the main source of energy for China and will remain so in the several decades to come, how to use coal—the kind of fossil fuel with abundant reserve, much cheaper but also dirtier than other forms of fossil fuel, will be a key issue.

One way is using coal more efficiently, so as to reduce the total consumption of coal. With continual technology progress, this could be achieved, especially as China's current coal use efficiency is still much lower than the level in developed countries. This represents the best option in most cases as it can avoid the various pollutions, be it land surface and ecological system damage in the process of coal mining, SO_2, CO_2, NO_x, dust emissions in the whole life cycle of coal use, from mining, processing, transportation, to final combustion. Moreover, in many conditions energy efficiency measures are self-profitable; the investment on energy efficiency improvement could be paid back in a few years. This could be achieved with critical and supercritical technology, the co-generation of electricity, heat, and even cooling.

Another option is to continue the use of coal, while reducing emissions of various pollutants, including installing scrubbers in coal-fired power plants, processing coal before use so as to reduce the pollutants, building coal-fired power plants near coal mines, so as to avoid emissions and pollution during the long-distance transportation of coal. Collection and energy use of coal bed and coal mine methane is also an important option because of the high global warming potential (GWP) of methane. Also carbon capture and sequestration technology has been progressing, more CO_2 emissions from large point coal-combustion sources could be collected and buried deep at sea bottom or in deserted oilfields.

A third key issue is buildings. Currently, each year around 500 million m^2 of buildings are built in China. In the construction process, lots of energy-intensive material is used, including iron and steel, cement, glasses, tiles, paint, etc. When dismantled, most of these materials, except iron and steel will be used. Most of these building materials are highly energy-intensive and their production consumes much energy. For instance, for each ton of cement produced, more than 3 tons of CO_2 is emitted. Cement-making is an energy- and capital-intensive process. Once built, cement plants may be in operation for 50 years or more. The cement industry is a large source of greenhouse gases, accounting for about 5% of the global man-made carbon dioxide emissions annually. Half of the emission is from the chemical process of clinker production and 40% from fuel combustion. The remaining 10% is split between electricity use and transportation (WBCSD, 2005).

In 2005, China produced 2.19 billion tons of coal and 1.06 billion tons of cement. On average, for each ton of cement production, the total energy consumption is 145 kg of coal equivalent, which is about 15% lower than the world advanced level. In other words, in 2005 the cement industry consumes 7% of China's coal production (China Cement Industrial Association, 2006).

Although the energy consumption for buildings and housing currently accounts for a small share of China's total energy consumption, this is the sector that has strong long-term growth potential, especially with improvement in the income and living standard among households. Most of the cement produced is used in infrastructure and housing construction. As the life of the infrastructure and housing often lasts several decades or even several hundred years and once built, they are fixed to a certain location. It is expensive to renovate them, and therefore the buildings and infrastructure built now will have major influence on the energy consumption pattern and quantity in the many decades to come. Therefore, the quality and energy performance of housing and infrastructure being built now and in the next 15 years will have significant implications on the country's pursuit for energy efficiency improvement, energy security, environment protection, and the building of a well-off and harmonious society.

8.1.2 Policy options

There are many different policy options for realizing the government's goals for energy efficiency improvement, renewable energy promotion, and sustainable development. Generally, these policy options could be divided into the following categories:

Command-and-control options

With its strong planning economy tradition, this approach is widely used by the Chinese government for energy efficiency improvement and environment protection. Mandatory targets are set for local governments at different levels and included in the administration performance assessment of local chief officials and large energy-intensive and emission-intensive enterprises. Although this option is simple and offers environmental effect certainty, its effectiveness depends on the existence of a severe enough non-compliance penalty and powerful monitoring and supervision, otherwise it is likely to be neglected by local governments and enterprises.

Also this approach, due to its high monitoring and verification costs, is difficult to cover all enterprises. For example, in the thousand-enterprise action, the government sets targets for 1,008 large energy-consuming industrial enterprises, while the numerous small and medium-sized enterprises are left untouched.

Taxes and charges
Another way is imposing taxes on fuel and emissions, and charges on polluters. As the decisions about energy consumption is made by over one 1 billion consumers and millions of enterprises in their daily activities, price signal is the most effective way to influence such decisions. Currently, the energy prices in China are still fixed by the government and remain at a low level. This is difficult to make the consumers change their behaviour and reduce wasteful uses of energy. Although the initiative to increase price or levy tax always face opposition from large and powerful production enterprises and often arouse public objection and concerns about depriving low-income groups the substantial supply of energy supply, the role of energy tax makes it a policy instrument that could not be neglected. Especially, the pricing of energy needs to be carefully assessed to avoid perverse incentives that may encourage wasteful uses.

Standards and labelling
For energy efficiency improvement, awareness and information dissemination is a key instrument. It is necessary and significant to make more information about the energy efficiency performance of different products available to consumers so that they can make informed purchase decisions. It also provides the foundation for public supervision and participation. In this way, it can award the makers of environmental friendly products of low emissions and energy consumption in the form of bigger share of the market and better corporate image.

Tradable permits and licenses
This approach will leave the enterprises with greater freedom of choosing whether to realize emission reduction and energy efficiency improvement through internal actions or through purchasing permits and allowances from other enterprises. This approach has the advantage of enabling the full utilization of low-cost action opportunities in the society, hence reducing the overall cost of energy and emission target realization.

As this approach requires a transparent, equitable, and effective permit allocation system and institutional arrangements for monitoring and verification, as well as effective non-compliance penalty, although it is quite popular in developed countries, its application in China is still in the early stage. Despite the experiments on SO_2 emission trading started in 1994, so far it is still far from becoming a major policy instrument in the area of energy-related policy-making.

8.2 Clean Coal Promotion

In the "National Medium- and Long-term Science and Technology Development Program (2006-2020)", specific targets for energy technology development were given. Within 15 years, Chinese researchers are to make breakthroughs in energy development technologies, energy conservation technologies and clean energy technologies. Energy use for manufacturing major industry products is expected to reach or nearly reach the level of advanced countries.

At the beginning of 2006, the State Council announced "Several Suggestions for Accelerating Equipment Manufacture Development in China". In this paper, a specific aim was given: By 2010, a group of large Chinese equipment manufacturing companies should be internationally competitive to meet the demands of energy, transport and raw material production.

8.2.1 National programs and planning

The National High Technology Research and Development Program (863 Program) was launched in March 1986 with the aim of enhancing China's international competitiveness and improving China's overall capability of R&D in high technology. The Program covers 20 subject topics selected from eight priority areas: Biotechnology, Information, Automation, Energy, Advanced Materials, Marine, Space and Laser. The first six areas are managed by the Ministry of Science and Technology (MOST) of the People's Republic of China. In the program, there are several key energy technologies. Clean coal technology development is one component of that. In this program under Tenth-Five-Year Plan, advanced coal-fired power generation, advanced coal conversion, fluid gas purification of coal combustion were put as key research topics.

The Coal-Fired MHD Power Generating Technology Project has completed the designing and manufacturing of a helical electrical MHD propeller used for conducting performance test of the high field superconducting electrical MHD propeller. Through international cooperation, the performance test of a 15-tesla high field helical closed-loop electrical MHD propeller was conducted successfully, the actual field intensity being 14 teslas. Besides, a 700A electrode current and 9.3-14% propeller efficiency were achieved under the high field condition.

By recognizing the importance of coal in China, clean coal focused policies were adopted in China. In 1995, China Clean Coal Ninth-Five-Year Plan and Development Framework up to 2010 were announced by government. This plan mainly covers four areas including coal processing, high efficient clean combustion, coal conversion, emission control and disposal processing. Fourteen technologies were specified in the plan: coal washing and dressing, briquette, coal liquefaction, FBDC, PFBC, IGCC, fuel cell, fluid gas control, utilization of waste from power plants, utilization of coal bed methane, coal stone washing water use, industrial boiler and kiln.

8.2.2 Energy scenarios with focus on clean coal

The future projections are made under a scenario for China. This scenario gives a basic trend to describe future economic activities. There will be better international trading and China's economy will be part of the global economy. Therefore China could rely on international markets and energy resource imports to meet part of its energy supply needs.

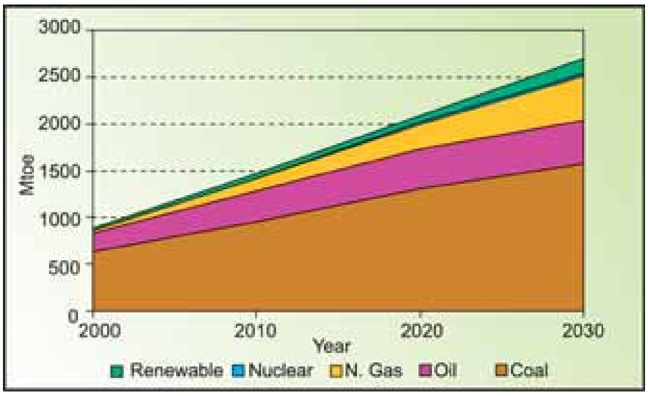


Figure 26: Primary energy demand in China for baseline scenario

With rapid growth of economy in China, primary energy demand in the baseline scenario could go to 2.1 billion toe in 2020 and 2.7 billion toe in 2030 (see Figure 26). The annual growth rate from 2000 to 2030 is 3.6%, while energy elasticity of GDP is 0.58. Coal will keep major energy source in China in next several decades. In baseline scenario, coal use would be 1.4 billion toe in 2020 and 1.7 billion toe in 2030, taking share of 58%, when it is 720 million toe in 2000. There is a rapid increase for natural gas demand in China, with its share in total primary energy use increasing from 4% in 2000 to 17.3% in 2030 (annual growth rate: 10%).

With respect to final energy use, electricity and natural gas increase rapidly. Electricity demand increases from 112 million toe in 2000 to 478 million toe in 2030. Natural gas demand increases from 21 million toe in 2000 to 437 million toe in 2030. Coal and oil demand increase slowly. Coal use in the residential sector will generally decrease and be replaced by gas and electricity; coal will be mainly used in large equipment such as boilers and steel making, building material production. 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 (see Figure 27).

From the results we can see that coal will play very important role in both primary energy supply and final energy supply. Coal production could reach 1.31 billion tce by 2020 and 1.48 billion tce by 2030. Chinese coal industry experts estimate an upper bound of coal production of 1.2 billion tce by 2020. Coal demand, therefore, could exceed domestic coal production in China (Figures 28 and 29).

In the baseline scenario, development of these technologies was set up in a preliminary diffusion way. Table 39 shows the technology involvement in the baseline scenario.

By assuming the adoption of energy and environmental policy measures, the policy scenario results are described in Figures 30 and 31. Compared to the baseline scenario, there is nearly 245 Mtce energy demand lower in 2020, 280 Mtce in 2030. There is 160 mtoe coal saved. By exploring the policy options, we found there is a big pressure to apply these policy options in order to reach the lower energy demand scenario, and these are also to be introduced at early time because of long life span of energy technologies. Among these policy options, clean coal technology development and diffusion is one of the key components. Major assumption for clean coal technology development in this scenario is given in Table 39.

Table 39: Clean coal technologies in baseline scenario

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

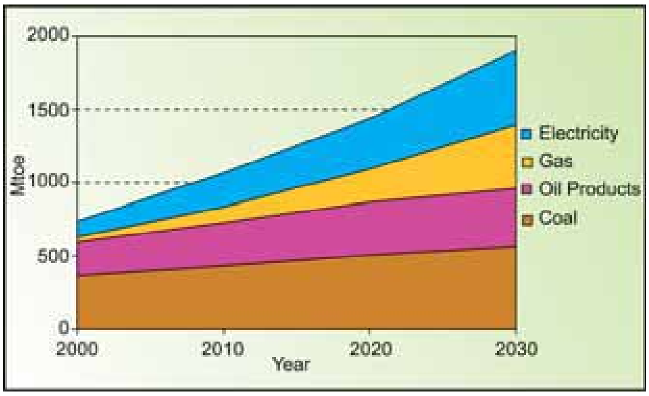


Figure 27: Final energy demand in China for baseline scenario

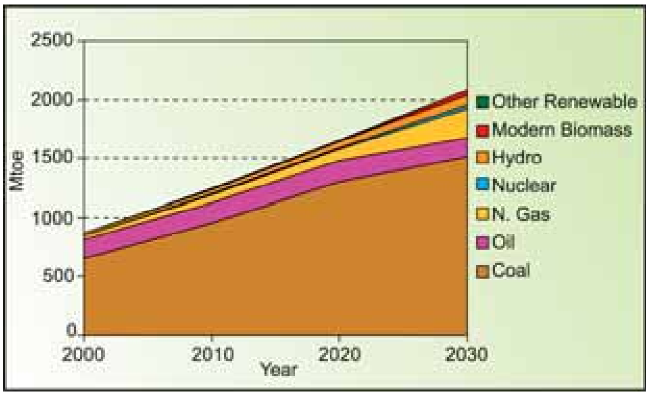


Figure 28: Energy production in baseline scenario

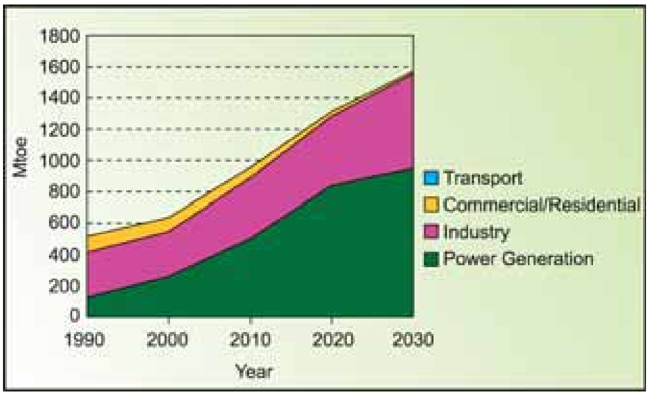


Figure 29: Coal use by sectors

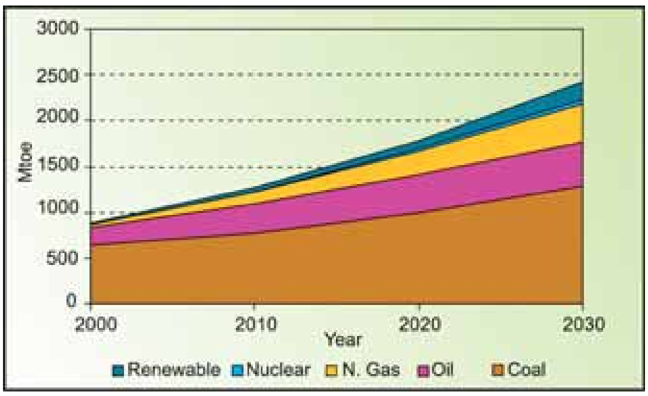


Figure 30: Primary energy demand in policy scenario

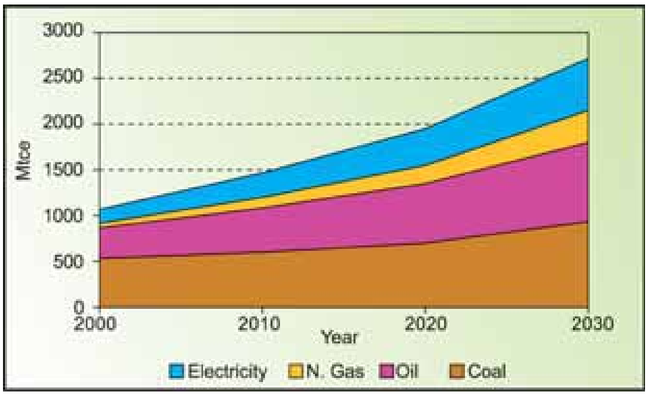


Figure 31: Final energy demand in policy scenario

Table 40 presents the clean coal technology diffusion in policy scenario.

Table 40: Clean coal technology in policy scenario

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

8.2.2 Socio-Economic aspects of clean coal technology development in China

Development of clean coal technologies can contribute to not only energy saving, emission reduction, but also local socio-economic activities. Table 41 presents a brief picture for clean coal future. Chinese clean coal industry could be expected to extend and continue to be one of the important components of economic development.

8.2.3 Discussions and conclusions

It is clear that the coal demand in China will keep growing, it is concluded that emission from coal use will also keep increasing if appropriate measures are not undertaken. Many cities in China suffered from serious air pollution, which damaged their sustainable development. Development of clean coal technology could contribute local sustainable development in the following ways:

- Reduce energy demand, which could release pressure on energy supply and energy import, and increase energy security.
- Fundamental industry in China with large employment: 7.6 million employees in 2004, 7.8 million in 2030, which highlights an important aspect for people in low income groups to find employment opportunities.
- Extend economy activities. Taking lead for clean coal technology in the world will bring economy benefit. Three power equipment

Table 41: Factors for coal related activities

		2005	2010	2020	2030
Total Primary energy demand	Mtoe		2040	2450	2960
Coal use	Mt	2165	2791	2896	3102
Production	Mt	2204	2840	2880	3010
Output value	Bn Yuan	645	867	945	1073
Value added in coal mining and processing	Bn Yuan	314	422	460	523
Share of GDP	%	1.7%	1.5%	0.8%	0.5%
Employee in coal mining and processing	Million	7.8	7.7	6.3	5.2
Death of worker in coal mine	Person/Mt	2.8	2.6	2	1.1
Value added of Coal fired power manufacture	Bn Yuan	21.6	29.8	37	43
Coal fired power manufacture output	MW	5819	6320	6900	6900
Employees in coal fired power manufacture	Person	236400	250000	240000	210000

companies in China are becoming among top manufacturers in the world in 2005 (largest power capacity suppliers for coal fired power plants), and started to export advanced coal fired power plants.

- Very good environment effects. SO_2, NOx, PM emission, water pollution will be significantly reduced by using clean coal technologies, also very important for GHG emission reduction. Clean coal technology development will be crucial for government environment target in 11th Five Year Plan.
- Contribution to global climate change collaboration. Asia-Pacific Partnership on Clean Development and Climate, China-EU Partnership on Climate Change have component of clean coal technology collaboration.

There is an urgent need to reduce coal consumption in China because huge amount of coal is used currently which is projected to keep increasing in future. Such large amounts of coal use created much pressure on coal mine production safety, transport, and environment, including land damage, water pollution, air pollution, etc. The role of clean coal technology development in China and other countries to solve problems faced is well identified. In order to further promote clean energy future, following recommendations are given.

Clean coal technology should be emphasized to mitigate emission from coal combustion. Because only few countries in the world are using coal in large scale, therefore development of clean coal technologies rely on these countries. China is the biggest country to use coal, and in future the coal use will increase quickly which could take more than 40% of world total coal use in 2020. Therefore clean coal technology is crucial for China. China should have its own development plan for clean coal technology. It is better to work closely with several other countries to work on new generation of clean coal technology.

Various national laws, regulation, and standards for energy industry should be prepared to reach the target of a clean energy system. So far there are very weak laws to promote a clean energy system.

Technology is the key issue for clean energy and lower energy demand future. Technology R&D must be emphasized. International collaboration for technology transfer and diffusion should be more encouraged. Clean coal technology development should be further worked by China and the other countries.

Clean coal technology development in China could contribute economic development as an important industrial sector.

Climate change issues raised critical pressure on coal activities, but in the meantime, it also provides opportunities for clean coal future. The opportunities should be explored by involving international activities for clean coal technology research, development, and deployment, such as clean coal partnership, CDM, etc.

8.3 Fuel Tax

8.3.1 Model selection and adjustments

In this study, two models from IPAC model family, IPAC-AIM/technology model and IPAC-SGM model, are selected to combine bottom-up and top-down analysis.

Model extension

Because these two models are originally designed for energy system analysis and GHG mitigation analysis, there are still some limitations for this study. In order to simulate effects of tax and subsidy, the models need to be extended, especially. So far following functions were extended:

- Vehicle fuel tax. In IPAC-SGM model tax is levied based on energy, but transport fuel tax only focus on vehicle fuel. IPAC-SGM model was revised to be suitable for vehicle fuel tax.
- Tax neutral. Tax neutral is widely used in tax analysis, therefore we also need to keep this in mind. The model was revised to do this.
- Subsidy use. Originally in IPAC-SGM model government revenue from tax was used for

normal purpose. But this study needs to use some of the budget for subsidy on energy saving technologies and renewable energy development. Therefore the model needs to be extended for government budget use.

- International energy price. International energy price, especially oil price, was setup to follow recent energy price change.

8.3.2 Model parameters

Some key parameters for this study used in the models are given in Tables 42 to 45. Because of the lack of study on energy tax in China, energy tax rates were given based on experience in other countries, by looking at the share of energy tax in energy price. And now this study is looking at different tax which did not consider linkage between energy tax and fuel tax. This work is being done in following research projects. The baseline scenario is given in other papers (Jiang et al., 2006).

Table 42: Vehicle fuel tax rate, Yuan/liter

	2006	2010	2020	2030
Gasoline	1.1	2.4	3.6	4.6
Diesel	1	2.1	2.7	3.4
GTL		2.1	2.7	3.4
Ethonal/Methonal	1	1	1	1
Bio-Diesel		1	1	1

Table 43: Energy tax rate, Yuan/tce

	2006	2010	2020	2030
Coal	0	50	80	120
Oil	0	50	70	100
Natural Gas	0	50	60	80
Hydro	0	0	0	0
Renewable	0	0	0	0

Table 44: Carbon tax rate, Yuan/tC

	2005	2010	2020	2030
Carbon tax rate	0	100	150	200

Table 45: International energy price, US$/GJ

	2005	2010	2020	2030
OIL	5.02	5.87	8.16	9.66
GAS	1.63	1.6	1.81	2.09
SOLIDS	1.5	1.51	1.53	1.48

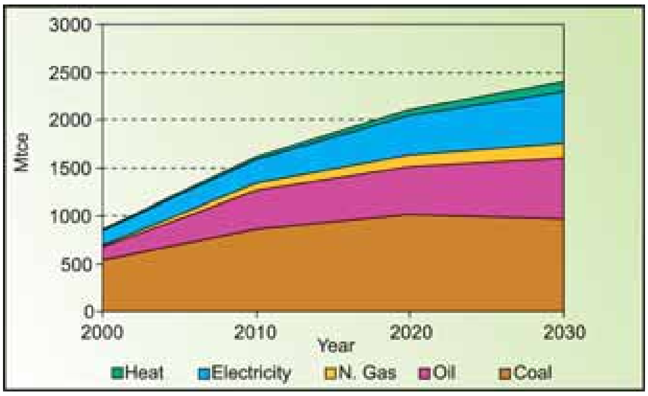


Figure 32: Final energy demand in baseline scenario

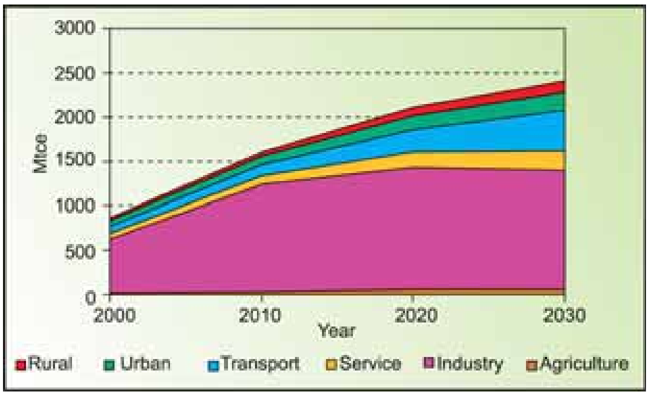


Figure 33: Final energy demand by sector in baseline scenario

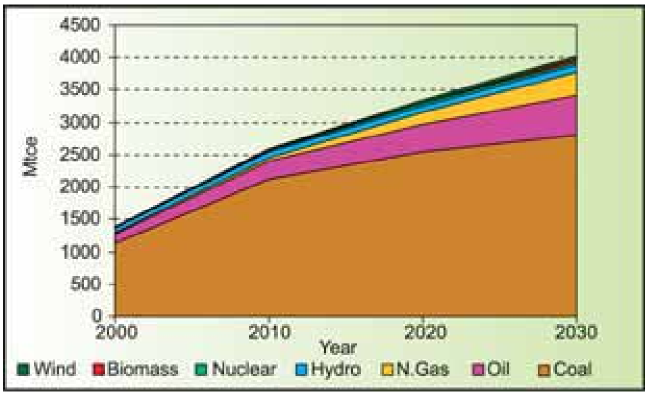


Figure 34: Primary energy demand in baseline scenario

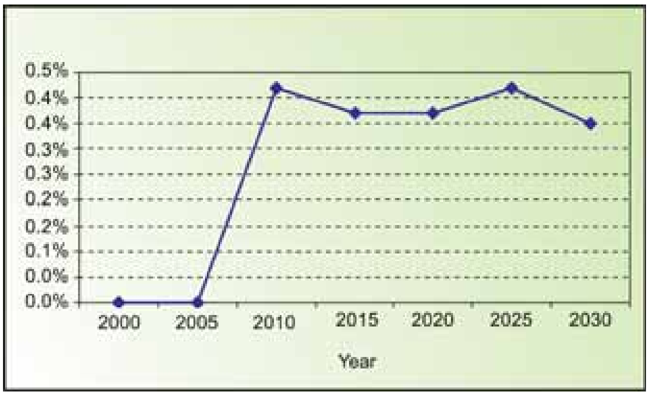


Figure 35: Impact on GDP by using energy tax

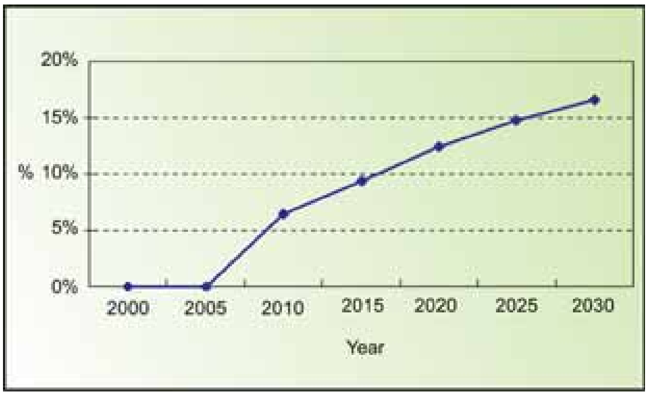


Figure 36: Impact on energy demand by using energy tax

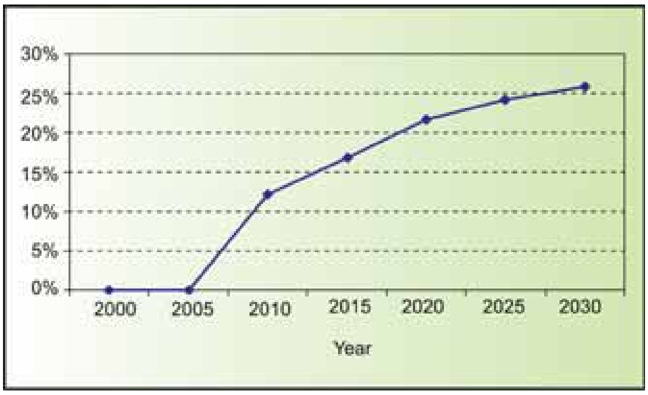


Figure 37: CO_2 emission reduction effect of carbon tax

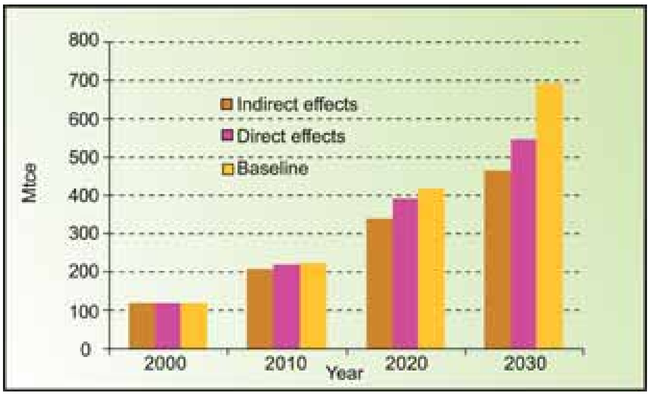


Figure 38: Impact on transport energy demand by fuel tax

8.3.3 Results

By applying taxes mentioned above, modelling results for baseline scenario are given in Figure 32 to Figure 38.

8.3.4 Conclusion

This analysis shows that the use of energy tax has significant impact on energy use. By 2010 with tax rate 50 yuan/tce, energy demand will decrease 6.3%, around 123 million tce, compared with baseline scenario. By 2030 with tax rate 120 yuan/tce, energy demand will decrease 16.2%, around 400 million tce. There will be some negative impact on GDP, but the impact is limited. In 2010, loss would be 0.4% and 0.36% in 2030. Main reason is the reduction of output from energy industry due to energy saving, and impact on other sectors due to energy price increase. But this modelling study did not fully reflect the impact of reduced energy import, and new economic activities due to more investment on other new sectors. If these factors could be considered, the negative impact on GDP development could be abated. In the meantime, such a GDP loss could not be reflected in change of GDP growth rate. And more important thing is green GDP concept could further abate the negative impact.

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

And thinking about the social cost of rapid energy system development in China, such as cost of energy security, cost of extending international market, environmental cost, benefit of energy tax levy could be more significant. Especially the recent wide discussion on vehicle fuel tax, which provides a very good basis for the application of energy tax. It is necessary to think about adoption of energy tax from now.

From long-term view point, use of carbon tax, or combined energy tax and carbon tax, could be a good choice. Use of carbon tax has good effect on carbon reduction and optimization of energy system in China, and has limited impact on GDP. Use of carbon tax could stimulate new technology manufacture sectors such as clean coal technology, new and renewable energy, energy services, and also upgrade technology in China, therefore promoting economic development.

These energy-related fiscal policy options are still in the initial period for discussion and face some difficulties. These difficulties could appear in the beginning period, but could be removed with adoption of some countermeasures and further studies. Some difficulty for vehicle fuel such as how to collect taxes, how to return tax revenue or subsidy for non-road transport users including farmers for agriculture production use. These difficulties also exist in other countries. Some options could be selected after detailed study even though this is not perfect. Vehicle fuel tax should be adopted at an early time because the policy has quite good effects and the difficulty could not be perfectly removed. Early use of fuel tax could avoid large amount of money used for oil import. Recently increased oil price could be a good basis to introduce vehicle fuel tax. During rapid socio-economic development period in China, clear policy options should be announced by the government to influence social choice such as city layout, public transport development, infrastructure development. All these choice options have a very long life span and lock-in effects. It is necessary to introduce these policy options early so as to influence the selection of an approriate future development path. The tax rate could start from a lower rate and generally increase, to avoid strong impact on public consumption and economic development.

Share of revenue from energy related taxes is small in total government tax revenue. According to energy tax rate used in the modelling study, total tax revenue will be around 500 billion RMB in 2030 with share of around 5% in total government tax revenue. As with other developed countries, energy activities will be a major source for economic growth. Therefore energy tax revenue should be properly used such as recycled into the budget for rational utilization of energy. Some energy tax revenue could be used to support energy conservation, new and renewable energy development, new technology development, etc. Energy industry and energy utilization are an important part of economic activities, proper use of tax revenue could contribute to economy development, enhance national competition and provide a foundation for long-term sustainable development.

8.4 Building Sector

8.4.1 Scenarios

In order to analyze future energy demand in the building sector of China, we consider two scenarios. The two scenarios are defined as follows: Baseline scenario: This scenario gives a basic trend to describe future energy use

Table 46: Policy options used in the modelling study

Area	Options, in 2030
Cooking	Natural gas cooking in urban, LPG and biogas in rural
Space heating	Central heating, energy saving building: 70% in urban, 65% in rural, use of heat pump
Space cooling	Ultra high efficiency air conditioner: 60%, energy efficiency building for cooling:80%
Electric appliance	Refrigerator: fully use of high efficiency refrigerator, washing machine: 45% higher efficiency
Lighting	Fully use of compact lighting with 80% higher efficiency
Hot water	Solar heater
Office electric equipment	30% higher efficiency higher computer, duplicator

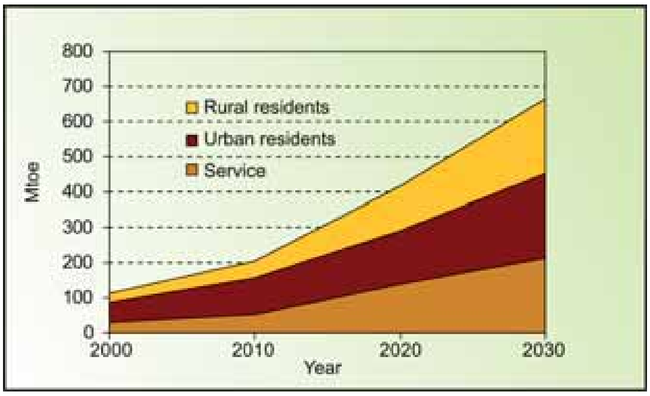


Figure 39: Final energy use in building by sectors, baseline scenario

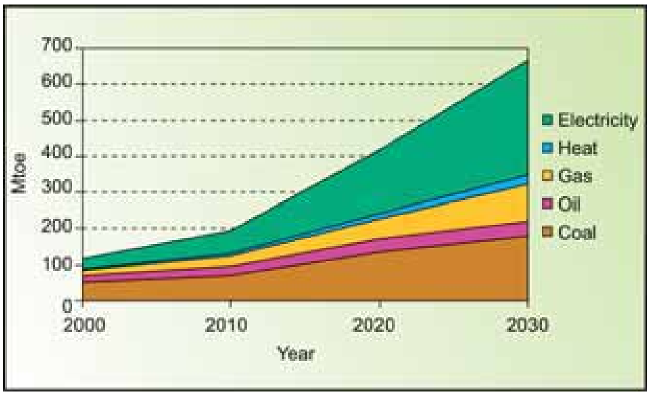


Figure 40: Final energy use in building by energy, baseline scenario

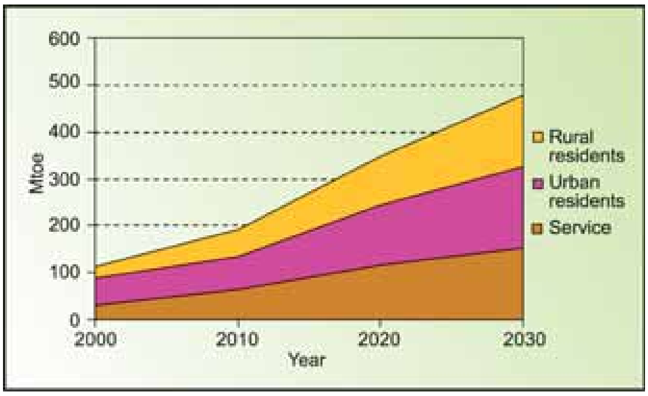


Figure 41: Final energy use in building by sectors, policy scenario

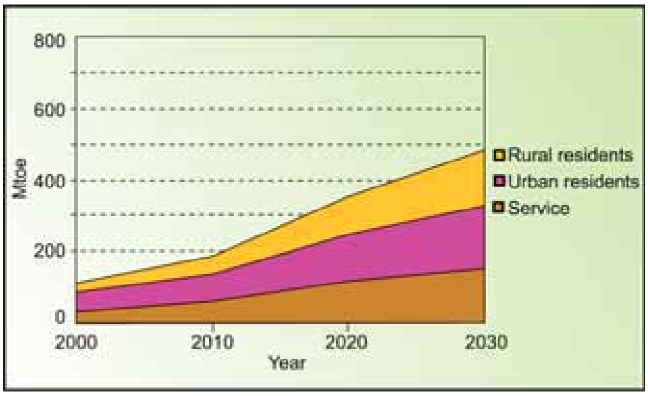


Figure 42 Final energy use in building by energy, policy scenario

based on moderate energy efficiency improvement. Policy scenario: mainly include higher efficiency building and equipment. Policy options to be considered in the policy scenario are given in Table 46.

8.4.2 Results

Energy demand is calculated using the IPAC-AIM/technology model, Baseline scenario results are given in Figures 39 to 41.

Final energy demand in building in the baseline scenario could go to 417 million toe in 2020 and 666 million toe in 2030. The annual growth rate from 2000 to 2030 is 6.2%. By 2020 share of urban resident, rural resident and service will be 39%, 27% and 34%, and 38%, 28%, 34% in 2020 respectively. Electricity will be the major energy used in building, taking share of 42% in 2020, 48% in 2030. Coal use also increases due to cooking and space heating demand (see Figures 39 and 40).

For the policy scenario, final energy demand in building could go to 347 million toe in 2020 and 479 million toe in 2030. The annual growth rate from 2000 to 2030 is 6.2%. By 2020 share of urban resident, rural resident and service will be 37%, 30% and 33%, and 36%, 32%, 32% in 2030 respectively (see Figure 41). Electricity will be the major energy used in building, taking share of 38% in 2020, 42% in 2030 (see Figures 41 and 42).

8.4.3 Conclusions

This scenarios study shows energy demand in building in China will have significant increase. The energy demand in building in 2020 could range from 347 and 417 million toe, 479 to 666 million toe in 2030. This depends on technology progress, and polices applied etc.

Policy orientation and wide use of new technology could considerably reduce energy demand in the building sector. Even with existing technology with lower cost, such energy efficient building, solar heater, high efficiency refrigerator and air conditioner, energy demand could be much lower. Energy saving in buildings have very good potential and low cost, only strong policies are urgently needed right now for further implementation of new energy saving technologies and change of consumption in building. Policies on regulation on energy efficient building with strong government enforcement, fiscal policies to reduce payment of space heating for users of energy efficient building, much higher energy efficiency standard for electric appliances, promotion of—solar heaters, geothermal for space heating, heat pumps etc., should be implemented as soon as possible, to avoid long time technology lock-in effects. There are already a lot of good practices for energy saving in building in other countries. Efforts should be made at an early time to reduce the rapid increase of energy use in buildings, in China, for the sake of energy security, local environment and global environment issues. Meanwhile, further studies by the IPAC modelling team also indicate that technological progress would also contribute to local economic development.

One more thing should be mentioned here. This study considered many technologies and policy options that could contribute to over 20% energy savings as compared with the baseline scenario for the building sector. However there are some advanced technologies available now which are not yet considered in this study, such as distribution heating, cooling and power generation system, super high energy saving building, and countermeasures such as energy saving campaign etc. If these technologies are also implemented, there will more energy saving potential.

8.5 Long-term Domestic and International Implications

China is in a stage of rapid urbanization and mass production. The current development pattern is driven by high natural resource and labour input and characterized by low efficiency of energy and other resource utilization and severe pollution. The Chinese government—at least some officials, begin to realize that its resources simply make it impossible to pursue the old development pattern of "pollution first, the cleaning up of pollution can wait till the country is richer".

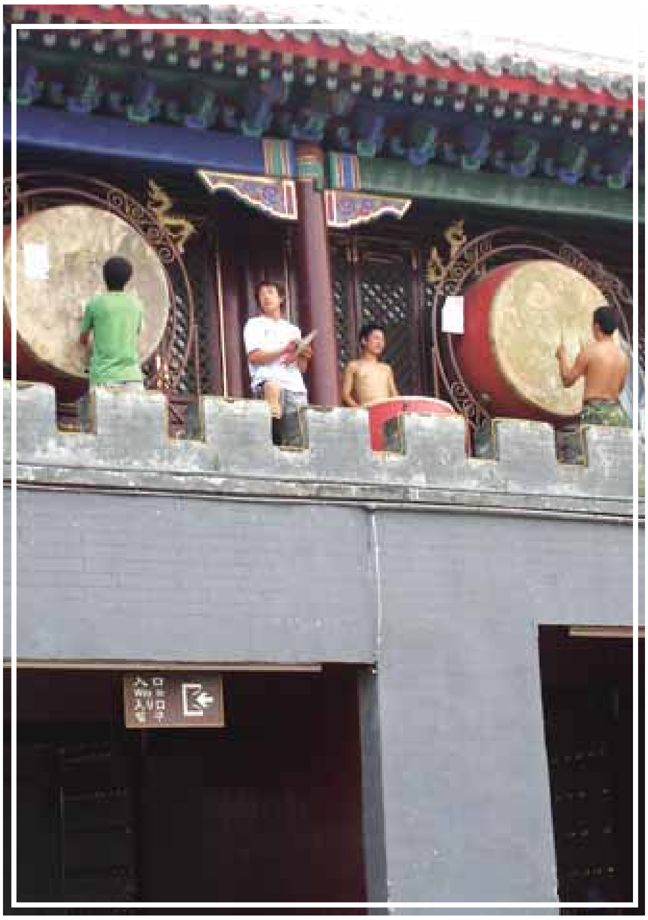
Due to globalization, China's economy is increasingly integrated into other parts of the world. Its GHG emissions and position is a major factor influencing the international efforts to address climate change. Its air pollution is influencing its neighbouring countries in the form of sandstorms, mist, and acid rains. And more importantly, China is both a major exporter and importer on the international market. The size and timing of its purchases is already influencing the world market price for oil, metals, and some key mineral resources.

As indicated in the previous sections of this chapter, China also faces rare opportunities of bending its resource consumption and pollutant emission curves and changing its development path towards higher sustainability.

The ongoing heavy investment for the construction of buildings, infrastructure facilities, power plants and ever increasing new cars will be there and significantly influence China's energy consumption and pollutant emission in the coming decades.

CHAPTER – 9

Cross-country Comparative Results and Conclusions



This chapter provides a cross-country overview of key assumptions and results in relation to economic growth, energy consumption, and local and global emissions. More detailed data is given on energy access and affordability in order to reflect the social aspects of the energy transition process that is underway in Brazil, China, India, South Africa, Bangladesh, and Senegal.

The chapter starts with an introduction of the general economic growth and population assumptions that have been used in the studies and with more in-depth discussions on development, energy, and the environment. These latter issues are dealt with in two separate clusters, where the results and conclusions are given separately for Brazil, China, India, and South Africa, and for Bangladesh and Senegal. The reasons for this division are that the development and energy issues that face the two country groups exhibit major differences. Countries like Brazil, China, India, and South Africa are large and relatively stable economies with high current energy investments, while Bangladesh and Senegal are in earlier stages of economic development and their energy systems are also in earlier phases of establishment.

9.1 Development Goals, Policies, and Model Assumptions

The approach of the country studies has been to use different national models and apply a consistent set of assumptions. Some countries have used long-term scenarios and models covering a period until 2100, while others have focused on the time-frame until 2030. The country summaries that are given in this report specifically focus on the time-frame until 2030. Another distinction in the studies is between macroeconomic modelling versus sector level models and project assessment.

Brazil has used the macroeconomic model, EMACLIM (Brazil, 2007), and has supplemented the model runs with more detailed assessments for specific policy cases, while South Africa has used the energy sector

MARKAL model (South Africa, 2007). China has used the IPAC-emission model and IPAC-AIM/ technology model which are components of the Integrated Policy Assessment Model for China for long term scenario development (Jiang and Hu, 2006). India has used a soft-linked model framework that employs bottom-up models like MARKAL and AIM, and top-down models like ERB, AIM/Material and SGM (India, 2007).

The Tables 47, 48 and 49 show the major economic growth and population assumptions that have been used in the national reference scenarios.

The economic growth and population assumptions that have been used in the country studies are reflecting official national development goals of the countries as well as expert judgments. Official projections typically are available for shorter time horizons such as up to 10 years, while 20-30 years and further ahead are only covered in specific energy sector planning activities. All the teams that are involved in this project are also partners in national energy planning efforts so the assumptions applied are close with those that have been used in official national planning.

The national reference scenarios by definition take policies and measures that are already under implementation into account, while policy scenarios include potential climate change policies. The annexure of this report includes tables with information about key national development goals and targets, and policies and measures under implementation in each country.

Table 47: Economic growth assumptions as applied in the development, energy and climate country studies (average annual GDP growth rates, %)

Country	1971-1990	1990-2004	2004-2015	2015-2030	2004-2030
Brazil	4.7	2.6	4.2	4.1	4.1
China	7.8	10.1	8	6.6	7.2
India	4.6	5.7	6.2	6	6.1
South Africa	2.1	2.2	2.4	2.8	2.6

Sources: for data up to 2004 (IEA, 2005a); for future projections (Brazil, 2007; India, 2007; South Africa, 2007)

Table 48: Population growth assumptions as applied in the development, energy and climate country studies (average annual population growth rates, %)

Country	1971-1990	1990-2004	2004-2015	2015-2030	2004-2030
Brazil	2.2	1.5	1.2	1.0	1.1
China	1.6	1.0	0.7	0.5	0.6
India	2.2	1.7	1.4	0.9	1.1
South Africa		1.8	0.5	0.3	0.4

Sources: Brazil, 2007; India, 2007; South Africa, 2007

Table 49 Resultant population projections (Millions)

Country	2000	2010	2020	2030
Brazil	171	198	221	241
China	1267	1380	1460	1530
India	997	1159	1290	1393
South Africa	44	48	47	49

Sources: Brazil, 2007; India, 2007; South Africa, 2007

9.2 Cross-cutting Assessment of the Studies for Brazil, China, India, and South Africa

9.2.1 General scenario indicators: Intensities and elasticities

The trend in energy intensity of the gross domestic product (GDP) and related CO_2 emissions from the energy sector are in the following illustrated for the period 1970 to 2030 for Brazil, China, India, and South Africa.

The data is based on IEA statistics for the period until 1999 and on national scenario projections from 2000 to 2030 which have been developed as part of the project. The scenarios are baselines where no specific climate policies are assumed to be implemented.

Figure 43 shows the trend in total primary energy supply (TPES) intensity of the GDP indexed from 1970 to 2030. As it can be seen the energy/GDP intensity is decreasing in the

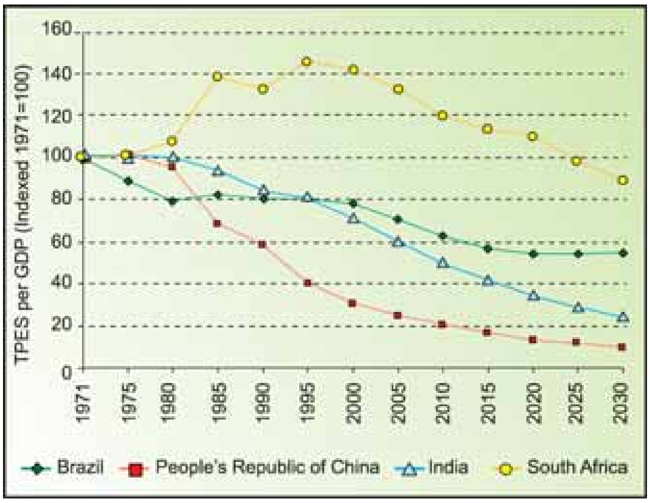


Figure 43: Total primary energy supply intensity of GDP indexed
Source: IEA, 2000a; IEA, 2000b; Brazil, 2007; India, 2007; South Africa, 2007

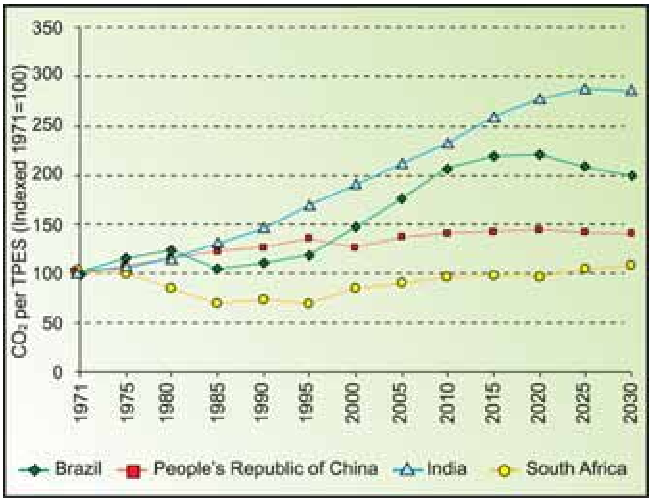


Figure 44: CO_2 intensity of TPES in Brazil, China, Denmark, India and South Africa 1970 to 2030
Source: IEA, 2000a; IEA, 2000b; Brazil, 2007; India, 2007; South Africa, 2007

whole period for China, India, and Brazil. The picture is a little bit different in South Africa, where the energy/GDP intensity increases with about 40% from 1970 to 1995, where after it decreases. Some of the countries such as China and India are expected to have a very large decrease in energy/GDP intensity from 1970 to 2030 of as more than 80% in the case of China, and about 70% in the case of India.

The trend in CO_2 intensity of energy is very different from the energy/GDP intensity as can be seen from Figure 44. An increase of almost 150% is expected for India and about 100% for Brazil from 1970 to 2030, and in China the expected increase is about 50%. The increases are predominantly a consequence of the increasing role of commercial fossil energy in the total primary energy supply of these countries. The trend for CO_2 intensity of commercial fossil energy is however declining for most countries after the late 1990s. The CO_2 intensity of energy supply is fairly constant over the period for South Africa, with a slight tendency to increase after 1995.

Finally, Figure 45 shows the resulting CO_2 intensity of GDP for the countries. For one country namely China, the energy/GDP intensity decrease in the whole period from 1970 to 2030 is large enough to offset the increase in CO_2/energy intensity, so the CO_2/GDP intensity is therefore decreasing.

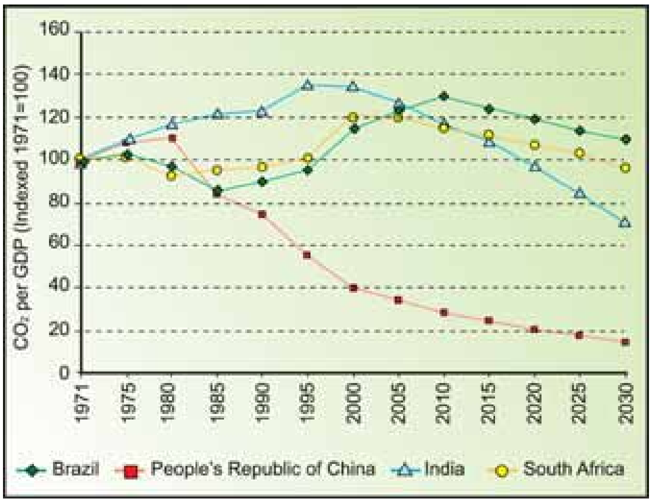


Figure 45: CO_2 intensity of GDP
Source: IEA, 2000a; IEA, 2000b; Brazil, 2007; India, 2007; South Africa, 2007

Differently Brazil, India, and South Africa first experience an increasing CO_2/GDP intensity, but expect a decrease over time in the scenario period from 2000 to 2030.

All together it can be concluded from Figures 43 to 45 that in the period from 1970 to 2030, where a very large GDP growth is expected in most of the countries, a large decrease in energy/GDP intensity is expected. However, the CO_2/GDP intensity will tend to be kept constant or will only decrease after some period. In relation to a GHG emissions reduction perspective a specific focus on climate change policy issues is therefore needed if GHG emissions are to be managed, since this goal is not automatically fulfilled by baseline energy policies as they are projected in the national scenarios that are shown in Figures 43 to 45. The relationship between the trend in GDP, energy, and CO_2 can also be illustrated by the corresponding elasticities, which are shown in Tables 50, 51 and 52.

The contribution of energy to economic growth can be examined in more detail by analyzing the role of energy as a production factor relative to other factors. A recent study (WEO, 2004) has, based on a standard Cobb-Douglas production function assessed the contribution of production factors to GDP growth for selected countries as shown in Table 53.

The conclusion that can be drawn from Table 53 is that productivity increases based on energy, labor and capital inputs are larger than for other factors, except in the case of China, where some uncertainty about GDP estimates according to IEA, 2004 can explain the difference to other countries in this regard.

Another lesson from Table 53 is that countries that are either highly industrialized, like the USA, or at earlier stages of development, tend to have energy as a less contributing factor to productivity increases than other middle income countries like Korea, Brazil and Mexico, where energy intensive industry plays a larger role in GDP.

Similar conclusions are drawn in the Special IPCC report on Emission Scenarios (IPCC, 2000). Based on data covering 1970 to 1990 from different regions of the world it is concluded that energy consumption and energy intensive industries share of GDP decrease with increasing GDP per capita (SRES, 2000, Figures 3-12, and 3-13).

Decreasing energy intensity with economic growth is a consequence of several factors including a tendency to a relative increase in service sectors and in energy extensive industries, technological change, and energy

Table 50: Energy (TPES) elasticity of GDP

Country	1971-1980	1981-1990	1991-2000	2001-2010	2011-2020	2021-2030
People's Republic of China	0.89	0.34	0.25	0.33	0.36	0.36
India	1.01	0.63	0.61	0.34	0.32	0.31
South Africa	1.33	2.90	1.67	0.35	0.66	0.21

Source: IEA, 2000a; IEA, 2000b; Brazil, 2007; India, 2007; South Africa, 2007

Table 51: CO_2 elasticity of energy (TPES)

Country	1971-1980	1981-1990	1991-2000	2001-2010	2011-2020	2021-2030
People's Republic of China	1.44	1.31	1.00	1.43	1.12	0.85
India	1.68	1.80	2.04	2.02	1.95	1.17
South Africa	0.53	0.47	2.16	2.29	1.06	2.86

Source: IEA, 2000a; IEA, 2000b; Brazil, 2007; India, 2007; South Africa, 2007

Table 52: CO_2 elasticity of GDP

Country	1971-1980	1981-1990	1991-2000	2001-2010	2011-2020	2021-2030
People's Republic of China	1.28	0.44	0.25	0.47	0.40	0.31
India	1.69	1.13	1.24	0.69	0.62	0.37
South Africa	0.70	1.37	3.59	0.81	0.71	0.60

Source: IEA, 2000a; IEA, 2000b; Brazil, 2007; India, 2007; South Africa, 2007

Table 53: Contribution of factors of production and productivity to GDP growth in selected countries, 1980-2001

Country	Average annual GDP growth %	Contribution of factors of production and productivity to GDP growth (% of GDP growth)			
		Energy	Labor	Capital	Total factor productivity
Brazil	2.4	77	20	11	-8
China	9.6	13	7	26	54
India	5.6	15	22	19	43
Indonesia	5.1	19	34	12	35
Korea	7.2	50	11	16	23
Mexico	2.2	30	60	6	4
Turkey	3.7	71	17	15	-3
USA	3.2	11	24	18	47

Source: IEA, 2005b Table 10.1

efficiency improvements This comes in addition to energy's role as a factor that can enhance the productivity of other inputs.

9.2.2 CO_2 and SO_2 emission projections

Figure 46 gives the CO_2 emissions for various countries under the reference scenario and their share of the global CO_2 emissions measured in relation to IEA's WEO 2005 (IEA, 2005a). During 2005-2030, India's emissions are projected to grow 3.6% per year, 2.8% per year in China, 2.7% per year in Brazil, and 2% per year in South Africa The countries cumulative CO_2 emissions are projected to increase from being 22% of global emissions in 2000 to 33% in 2030. Coal consumption in China, India and South Africa is the predominant driver of this emission growth, although the CO_2 intensity of coal use improves considerably in these countries due to efficiency improvements from 2005-2030. Figure 47 shows the corresponding SO_2 emission projections for the countries.

9. 2. 3 Issues related to CO_2 and SO_2 decoupling

A key issue related to integrated development, energy and climate policies is whether it is possible to combine local and global environmental policies in a way, where countries while pursuing high priority local environmental concerns, for example in

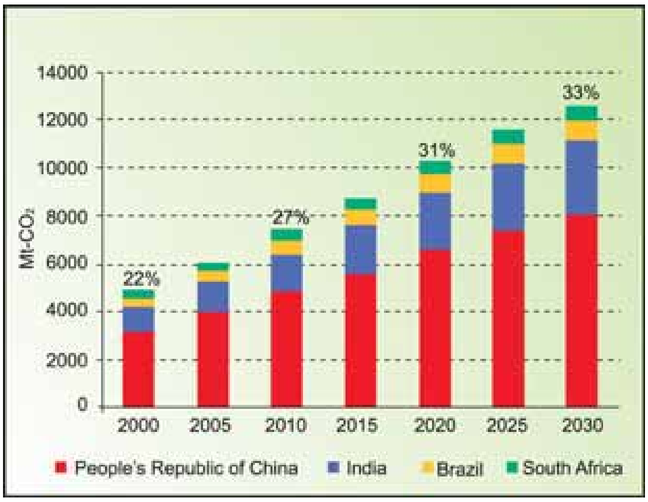


Figure 46: CO_2 emission projections under the reference scenario for Brazil, China, India and South Africa. The percentages above the bars are their cumulative share of the global CO_2 emissions (refer reference scenario in IEA, 2005b).
Source: Brazil, 2007; India, 2007; South Africa, 2007; IEA, 2005b.

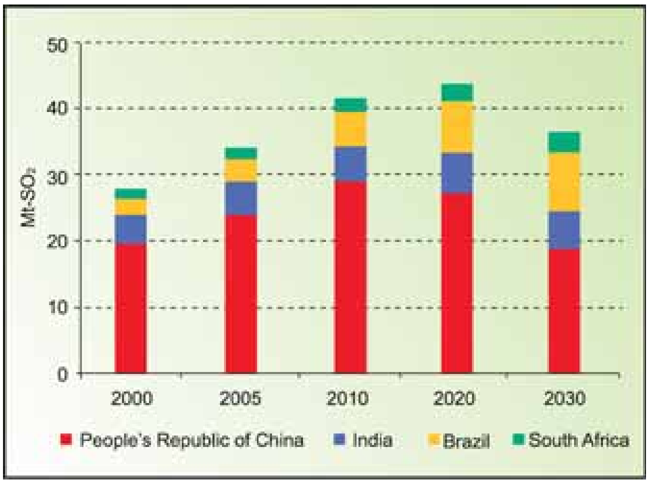


Figure 47: SO_2 emission projections under the reference scenario for Brazil, China, India and South Africa.
Source: Brazil, 2007; India, 2007; South Africa, 2007.

relation to local air quality, also can support CO_2 emission reduction policy objectives.

It should here be recognized that CO_2 and SO_2 emission control policies have various interesting links and disjoints. Starting from SO_2 emission control as the major policy priority, it can in many cases be cheaper to install various cleaning techniques that control SO_2 emissions rather than to implement general efficiency improvements or fuel switching that both reduce SO_2 and CO_2 emissions. On the contrary, starting with CO_2 emission reduction as the major policy priority will often suggest a number of cost-effective options that jointly reduce the two types of emissions. However, such policies seen from the SO_2 reduction perspective alone deliver more expensive local air pollution control than cleaning systems. The conclusion is that integrated local and global emission reduction policies in many cases will require special attention to the global aspects.

The relationship between CO_2 and SO_2 emission development is shown in Figure 48 below for Brazil, China, India and South Africa for 2000-2030 under the reference scenario.

Coal consumption for electricity generation is the major source of CO_2 and SO_2 emissions in

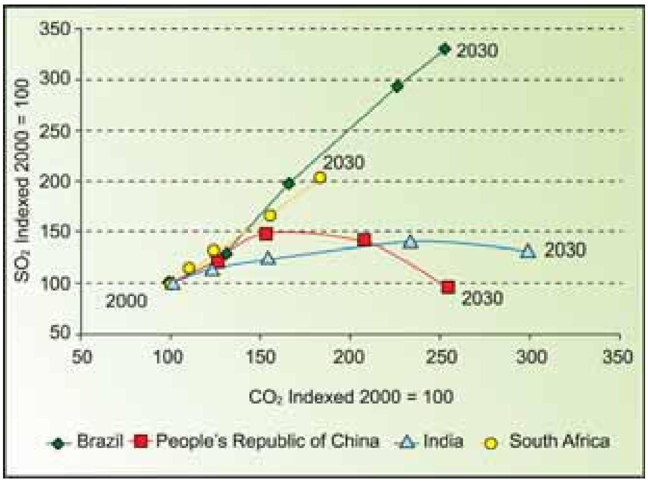


Figure 48: Links and disjoints in CO_2 and SO_2 emissions in Brazil, China, India and South Africa 2000 to 2030 (The emissions are indexed separately for each country to maintain comparability; and dots show the time namely, 2000, 2005, 2010, 2020 and 2030)
Source: Brazil, 2007; India, 2007; South Africa, 2007

China, India, and South Africa and coal also is expected to play a major role in the future (India, 2007; South Africa, 2007). However, domestic pressures in the countries have implied increasing efforts over time to introduce various local air pollution control measures such as flue gas desulphurization (FGD), fluidized bed combustion (FBC) and integrated gasification combined cycle (IGCC) that can curb SO_2 and suspended particulate matter (SPM). CO_2 emissions, however, continue to rise but the growth tends to slow down over time. Road transport emissions are a major source of local air pollution and cleaner road transport technologies, although based on fossil-fuels, contribute to reduce SO_2, SPM, NO_x and CO emissions. CO_2 emissions again continue to rise since fossil-fuel based road transport continues to have a major share in all these countries. This also promotes local-GHG emission decoupling.

The air pollution control policies in China and India initiate a decoupling of global and local emissions from around 2010-2020. The tendency emerges in South Africa around 2025, but is at this time a small effort that is not visible in the aggregate national SO_2 emission data that is shown in Figure 40. This tendency is also confirmed by a steady decline in the growth rate of SO_2 emission from 2000-2030 while CO_2 emissions rise more steeply. All new coal plants in South Africa have FGD, and a vehicle emissions strategy (DME and DEAT policy) mandates the phase-in of lower-sulfur fuels in transport.

The Brazilian case is slightly different mainly due to a different energy mix. Hydro power, which is CO_2 and SO_2 emission free, dominates Brazil's electricity production, so local and global emissions come from other sources as for example transportation. The high growth in SO_2 emissions from Brazil that are projected for the future is derived from a large increase in biofuel production, that has SO_2 emissions but is CO_2 neutral, and from coal consumption. Overall SO_2 emissions are projected to rise by 3.3 times over 2000-2030 while CO_2 emissions will rise by 2.5 times.

9.2.4 Social aspects of energy development

Energy access is a key dimension of sustainable development, and is also indirectly linked to many of the MDGs as outlined previously. This section will provide a short overview of present and expected energy access. As a reflection of this, increasing energy access actually is a key policy priority that is an integral part of baseline scenarios for these countries. Figures 49 and 50 provide scenarios for household electricity access for the period 2000-2030 in various countries.

As it can be seen from Figure 45, almost 97% of Chinese households and 95% of Brazilian households had electricity access in 2000, while the levels were down to 55% in India and 63% for South Africa in this year. By the end of the period in 2030, it is expected that more than 95% of the households have electricity access in the countries.

When national electricity consumption data is studied in more detail it shows up that there are striking differences in per capita electricity consumption in rural and urban areas (Figure 50). Electricity access in 2000 were respectively 45% and 82% for rural and urban households in India, and 45% and 75% for rural and urban households in South Africa.

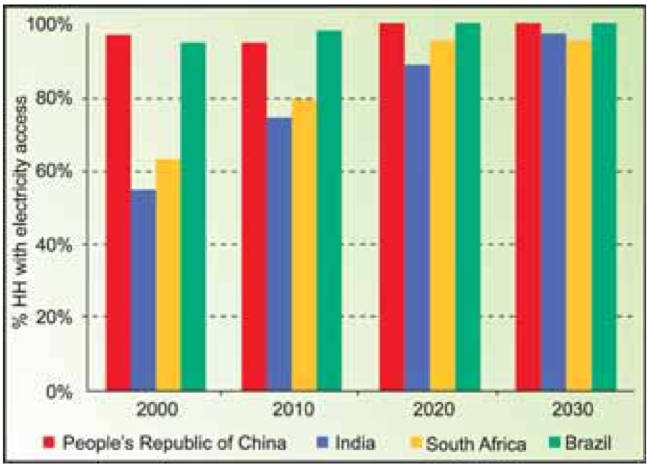


Figure 49: Households with electricity access for reference scenario for 2000 to 2030

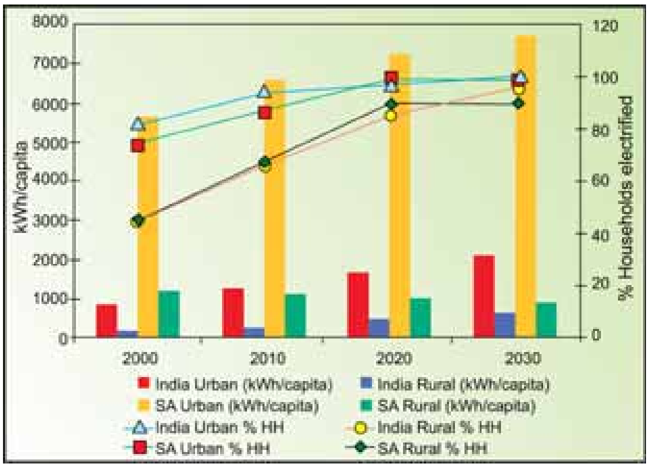


Figure 50: Electricity access and consumption in rural and urban households for 2000-2030 for India and South Africa

The average per capita consumption also varies considerably for rural and urban areas. Urban areas consumed about 4.7 times more electricity per capita in 2000 for India than rural areas, and 3.8 times in South Africa. This ratio is projected to decline to 3.6 times in 2030 for India, indicating a more equitable electricity distribution and regional development patterns in future. The long-term Indian policies have a decentralization thrust, including constitutional provisions of a federal structure and power to the people through Panchayati Raj (local governance) institutions, and equitable availability of social infrastructure (Shukla et al., 2006). However for South Africa the urban/rural electricity per capita ratio is projected to worsen in future and the per capita electricity consumption declines in rural areas during 2000-2030. The main reason is gradual and continuous re-classification of many rural areas as urban areas over 2000-2030, leaving areas with very low electrification rates under rural areas. This lowers the actual electrification rates under the revised rural areas. Although their electrification rates also improve over 2000-2030, they effectively become lower than those of the previous years.

Electricity consumption is strongly correlated with economic output. Figure 51 shows GDP per capita and electricity consumption per capita for China, India, and South Africa in the period 1990 to 2030. It can here be seen that the countries expect to move upwards almost along a common line, where increases in income per capita is followed by a very similar increase in electricity consumption across the countries.

Energy access also differs significantly across income groups. Tables 54 and 55 show the household expenditures on energy consumption for different income groups.

The share of the household budget that is spent on energy shows a number of similarities in India and China (see Table 54). Energy expenditures decrease with increasing income and the share of the household budget spent in India and China for urban households similarly vary between more than 10% for the poorest incomes down to around 5% for highest income households.

It should be noted that even the poorest households spend as much as 10% of their income on energy. Despite the fact that they must also be using non-commercial fuels in addition. This points to the key role of energy as a basic need.

Similarly Table 55 summarizes the different residential fuel shares in Bangladesh, Brazil and South Africa. It shows that the expenditure on electricity consumption in South African households is much higher than in Brazil. Despite Brazil's much higher level of electrification, the largest cost burden still derives from wood, and another large share from LPG. In Bangladesh, wood or biomass accounts for a similar share of expenditures as in Brazil, but the electricity expenditures are lower due to low access rates and incomes. The estimates for biomass use in South Africa suffer from data uncertainty and the costs of biomass are also not well known (Winkler et al. 2005).

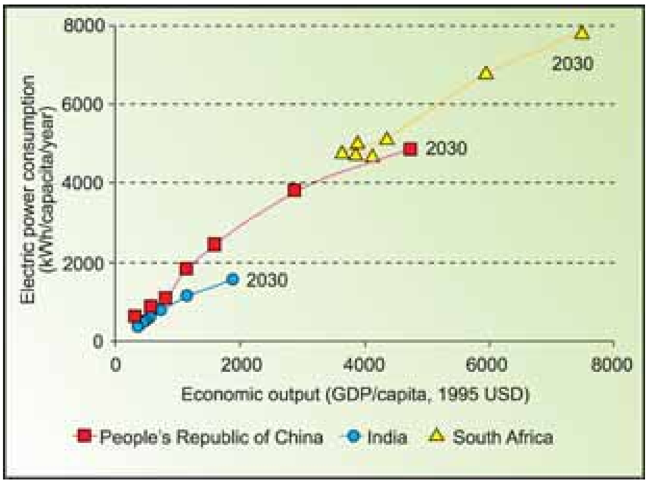


Figure 51: Relationship between GDP per capita and electricity consumption per capita for 1990-2030 for China, India and South Africa (dots show the time namely, 1990, 1995, 2000, 2005, 2010, 2020 and 2030)

Table 54: Household expenditure on energy for Indian households in 2000 and Chinese households in 2004

HH income category	India rural, 2000		India urban, 2000		China urban, 2004	
	Absolute expenditure (USD, 2000 prices)	% share of total HH expen-diture	Absolute expenditure (USD, 2000 prices)	% share of total HH expen-diture	Absolute expenditure (USD, 2000 prices)	% share of total HH expen-diture
Poorest 0-5%	0.46	10.2%	0.65	10.9%	3.00	10.3%
0-10%	0.51	10.1%	0.80	10.7%	3.33	9.8%
10-20%	0.62	9.0%	1.04	10.5%	4.10	8.7%
20-40%	0.73	8.7%	1.46	10.1%	4.79	7.9%
40-60%	0.97	8.9%	1.73	9.6%	5.57	7.2%
60-80%	1.15	8.6%	2.13	8.9%	6.55	6.6%
80-90%	1.44	8.1%	2.67	7.8%	7.67	6.0%
Top 90-100%	1.79	7.2%	4.01	5.7%	10.10	5.0%

Note: Fuel and light expenditure for India**,** Water, oil and electricity expenditure for China
Sources: NSSO, 2001 (India); China Statistics Yearbook 2005 (visit www.stats.gov.cn)

Table 55: Residential fuel shares in households in Bangladesh, Brazil and South Africa

Fuel shares (%) Country	Electricity	Coal	Gas	Paraffin	LPG	Wood	Candles	Other
Bangladesh (expenditure share)	18%	0.3%	5%	12%		33%		32%
Brazil	30%	2%	1%	0.3%	30%	37%	-	
South Africa	62%	9%		12%	2%	12%	2%	

Sources: BBS, 2000; MME, 2003; MME, 2004; DME, 2003; ERI, 2001

9.3 Sustainable Development (SD) Indicators

Chapter 2 of this report introduces an analytical approach that can be used to assess sustainable development dimensions of energy and GHG emission reduction policies. In a pragmatic way, it is proposed to use indicators of economic, social, and environmental SD dimensions such as costs, employment generation, energy access, local and global emissions, income distribution, and local participation in the evaluation of specific policies. See a more detailed discussion about SD indicators in Halsnæs and Verhagen (2006) and Halsnæs et al. (2006).

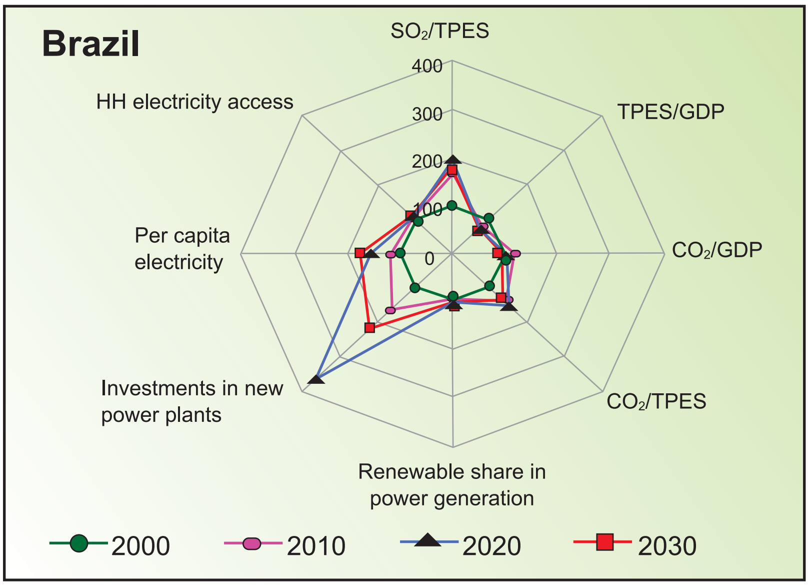


Figure 52: Sustainable development indicator projections for Brazil (Indexed for year 2000 = 100, for all indicators)

Based on this approach, SD indicators have been applied to the country study results for Brazil, China, India and South Africa in order to reflect energy efficiency, supply structure, per capita electricity consumptions, and local and global pollution. The results of this assessment are shown in Figures 52-55 for 2000-2030 for Brazil, China, India and South Africa.

Figures 52-55 are structured as "web-diagrams", where the development trends for the chosen SD indicators are shown for the period 2000-2030 (defined as index values with 2000=100). The SD indicators include variables where low index values are considered to be supporting SD, and other variables, where high index values support SD[19].

Variables that are considered to have a positive impact on SD if the index value is **low** are:

- SO_2 intensity of energy consumptions (SO_2/TPES).
- Energy intensity of GDP (TPES/GDP).
- CO_2 intensity of GDP (CO_2/GDP).
  CO_2 intensity of energy (CO_2/TPES).

While variables that are considered to have a positive impact on SD if the index value is **high** are:

- HH electricity access
- Per capita electricity consumption.
- Efficiency of electricity generation (fossil).

[19] A low index value for the period 2000 to 2030 implies that the variable is decreasing or only slowly increasing, which for example is positive for CO2 emission. On the contrary a high index value shows a large increase over time, which for example can be positive in terms of per capita electricity consumption.

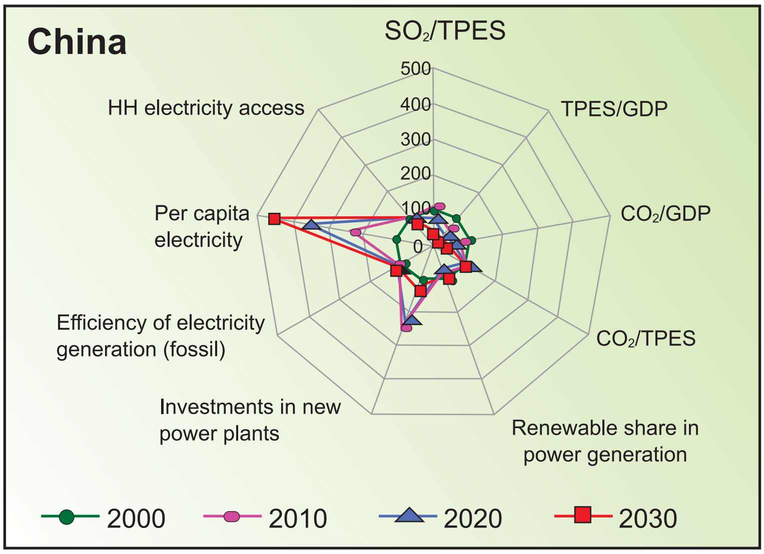


Figure 53: Sustainable development indicator projections for China (Indexed for year 2000 = 100, for all indicators)

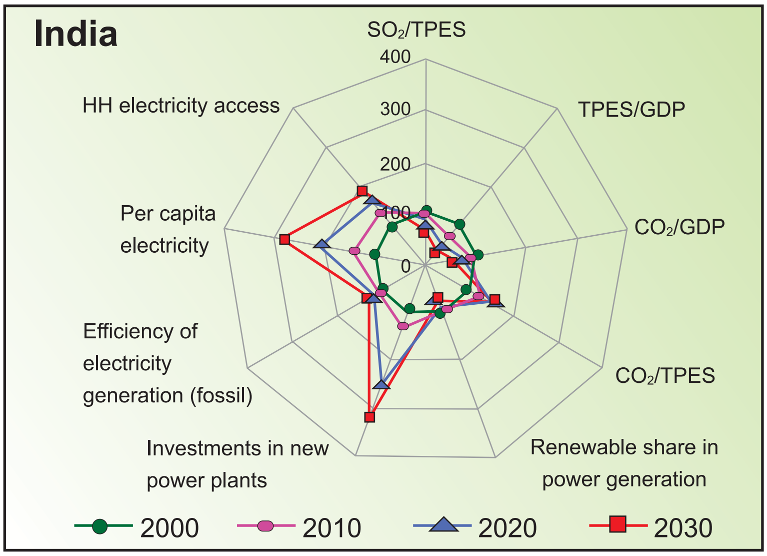


Figure 54: Sustainable development indicator projections for India (Indexed for year 2000 = 100, for all indicators)

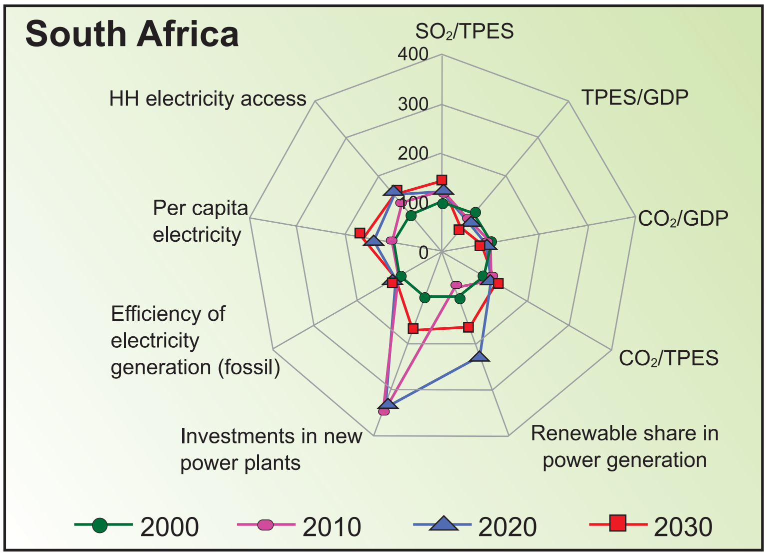


Figure 55: Sustainable development indicator projections for South Africa (Indexed for year 2000 = 100, for all indicators)

- Investments in new power plants.
- Renewable share in power production.

The Brazilian baseline development trends from 2000 to 2030 that are shown in Figure 52 are characterized by a large increase in power sector investments and increasing CO_2 and SO_2 intensity of energy consumption. The share of renewable energy increases slightly and there is a relatively small increase in per capita electricity consumption.

The baseline scenario for China for 2000 to 2030 implies an increasing share of renewable energy and a very large increase in per capita electricity, while the CO_2 and SO_2 emission intensities of energy are kept very close to the 2000 levels (Figure 53). There is also a high growth in power plant investments, and the efficiency of power production increases by about 20%.

In India, there is a growth in the CO_2 emission intensity of energy consumption, while the SO_2 intensity is decreasing from the 2000 level (Figure 54). The energy intensity of GDP is also decreasing in the period. The per capita electricity consumption is increasing about three times, and this is also the case for power sector investments.

Finally, South Africa in particular has a high growth in power sector investments from 2000 to 2030 and also some growth in the share of renewable energy in power generation (Figure 55). The CO_2 intensity of GDP is almost constant in the period, while the energy GDP intensity is decreasing slightly. Per capita electricity consumption is expected to have a relatively modest increase like the case of Brazil.

The common conclusions that can be drawn from Figures 52-55 are that there generally is a tendency for CO_2 and SO_2 emission intensities of energy and GDP to develop slowly in the countries in their 2000 to 2030 baseline cases. Investments in the power sector are expected to grow fast in the period, and particularly in China and India this implies a large growth in per capita electricity consumption. It is worth recognizing that none of the countries expect very large increases in the renewable share of electricity production in the period, however the absolute levels of renewable energy is projected to increase considerably in all the countries.

9.4 Conclusions on Development, Energy and Climate Synergies and Trade-offs

The 1970 to 2030 time-frame studies for Brazil, China, India, and South Africa show that there is a tendency to decouple economic growth and energy consumption over time. Energy consumption, however seems to have a stable or increasing CO_2 intensity, so all together CO_2 emissions tend to grow with about the same or a lower rate than GDP in most countries.

The power systems of all the countries except Brazil are dominated by coal and this supply structure will continue in the future. This also implies high growth rates in CO_2 emissions of between 3.6% and 2% per year from 2005 to 2030. As a result of this, the four countries are expected to contribute as much as one third of total global CO_2 emissions in 2030.

Local air pollution in terms of SO_2 emissions will also grow in the period, but there is a tendency to introduce significant control measures 10 to 15 years from now, which implies much smaller growth in this area in the future. However, CO_2 emissions do not automatically drop as a consequence of these local air pollution control measures.

Energy access is a major priority in all the countries studied, and the official development and energy policies assume almost full household access to electricity in 2030. More detailed studies of income levels and energy expenditures however show that energy is a relatively high budget burden for the poorest households. Energy expenditures contribute more than 10% of the household budget for poor households in China and India today, while the level is between 5% and 7% for high income families.

The application of SD indicators to the Brazilian, Chinese, Indian, and South African studies point to the conclusion that the countries all expect significant improvements in energy sector investment and per capita electricity consumption. This is maintained while the future growth of not only SO_2 emissions but also CO_2 emissions are kept relatively low. However, the baseline scenarios that have been examined do not deliver high GHG emission reductions and is also only contribute small increases in renewable energy. So it is clear that a promotion of specific policy objectives in these areas requires special attention and policy options beyond baseline scenario perspectives.

References

Arrow, K., P. Dasgupta, L. Goulder, G. Daily, P. Ehrlich, G. Heal, S. Levin, K.-G. Mäler, S. Schneider, D. Starret, and B. Walker, 2004. *Are We Consuming Too Much?* Journal of Economic Perspectives, 18(3), pp. 147-172.

Brazil, 2007, *Development, Energy and Climate Change: Brazil Country Report*. By Emilio et al.. UNEP Risoe Centre, Denmark, ISBN 978-87-550-3630-7

Chen, Jining, Can Wang, Ke Wang, Wenjia Cai, Ying Zhang, Yuan Cao, 2006. *Greenhouse Gas Emission Mitigation in China – Scenarios and Opportunities through 2030*, Tsinghua University of China and the Centre for Clean Air Policy (CCAP), pp168

China Cement Industrial Association, 2006. *Developments of China's Cement Industry during the 10th Five-Year Period and Prospects for the 11th Five-year Period*.

China Statistical Yearbook, 2006. China National Statistical Bureau, China Statistical Press, Beijing www.stats.gov.cn

China Statistical Communiqué, 2007. China National Statistical Bureau, March 2007, www.statst.gov.cn

Edmonds J, Reilly J., 1983. *A long-term energy-economic model of carbon dioxide release from fossil fuel use*. Energy Economics 5:74–88

Edmonds, J. A., Pitcher, H. M., Barns, D., Baron, R., & Wise, M. A, 1993. *Modeling Future Greenhouse Gas Emissions: The Second Generation Model Description*. In L. R. Klein, & F.-c. Lo (Eds.), Modeling Global Change. New York: United Nations University Press.

Financial Times, 2007. *Coal imports become China's burning issue*. By Richard McGregorin, Beijing, Published: April 24 2007

Halsnæs, K., Garg, A., Denton F. and Olhoff, A., 2006. *Practical Guidance Material for the Development, Energy and Climate Country Studies*. A publication of UNEP Risoe Centre, Denmark

Halsnæs, K., and J. Verhagen, 2006. *Development Based Climate Change Adaptation and Mitigation - Conceptual Issues and Lessons Learned in Studies in Developing Countries*. Mitigation and Adaptation Journal, Forthcoming

HE Jiankun, LIU Bin, CHEN Ying, XU Huaqing, GUO Yuan, HU Xiulian, ZHANG Xiliang, LI Yu'e, ZHANG Aling, CHEN Wenying, WEI Zhihong, DUAN Maosheng, ZHANG Xiaohua, LU Yingyun, 2006. *National Assessment Report on Climate Change (III): Integrated evaluation of strategies on response to climate change in China.* Advances in Climate Change Research, 2006, 2 (4): 147-153

IEA, 2000a. *Energy Statistics for OECD Countries.* International Energy Agency, OECD/IEA, Paris.

IEA, 2000b. *Energy Statistics for Non-OECD Countries*. International Energy Agency, OECD/IEA, Paris.

IEA, 2005a. *Energy Statistics for Non-OECD Countries*. International Energy Agency, OECD/IEA, Paris.

IEA, 2005b. *World Energy Outlook 2004*. International Energy Agency, OECD/IEA, Paris.

IEA, 2006. *CO2 Emissions from Fuel Combustion: 1971 / 2004*: 2006 Edition)

India, 2007. *Development, Energy and Climate Change: India Country Report*. By P.R. Shukla et al.. UNEP Risoe Centre, Denmark, ISBN 978-87-550-3627-7

IPCC, 2000. *Special Report on Emission Scenarios.* Cambridge University Press.

IPCC, 2001a. *Climate Change 2001: Mitigation*, Working Group III, Cambridge University Press, Cambridge.

IPCC, 2001b. *IPCC Special Report on Emission Scenario*, Cambridge University Press, UK.

IPCC, 2002. *Synthesize Report of TAR*, Cambridge University Press, Cambridge.

Jiang, Kejun, 2005. *Management of Energy Resources in China*, Energy Research Institute of the National Development and Reform Commission, China

Jiang, Kejun, Xiulian Hu, 2006. *Energy Demand and Emissions in 2030 in China: Scenarios and Policy Options*, Energy Research Institute

Jiang K, Morita T, Masui T, and Matsuoka Y, 1999. *Long-Term Emission Scenarios for China*£¬Environment Economics and Policy Studies Vol.2:267-287, 1999.

Jiang K, Morita T, Masui T, and Matsuoka Y, 2000a. *Global Long-Term GHG Mitigation Emission Scenarios based on AIM*¬Environment Economics and Policy Studies Vol.3, 2000.

Jiang K, Masui T, Morita T, and Matsuoka Y, 2000b. *Long-term GHG Emission Scenarios of Asia-Pacific and the World.* Technological Forecasting & Social Change 61(2-3).

Jiang, Kejun, , Dadi Zhou, Ju Hui, Erda Lin, 2003. *The Development and Climate – Country Study: China, case study report under the Development First Project*, www.developmentfirst.org

Kevin A. Baumert, Rob Bradley, Navroz K. Dubash, Jose Roberto Moreira, Stanford Mwakasonda, Wei-Shiuen Ng, Luiz Augusto Horta Nogueira, Virginia Parente, Jonathan Pershing, Lee Schipper, Harald Winkler, 2005. *Growing in the Greenhouse Protecting the Climate by Putting Development First*, World Resource Institute, Washington DC

Klein RJT, Schipper ELF, Dessai S, 2005. *Integrating mitigation and adaptation into climate and development policy: three research questions, ENVIRONMENTAL SCIENCE & POLICY*, 8 (6): 579-588

Liu J, Ma F, Fang L, 2002. *China Sustainable Development Strategy*, Beijing: China Agriculture Publishing House. (in Chinese)

Modi, V., McDade, S., Lallement, D., and Saghir, J., 2004. *Energy services for the Millennium Development Goals.* Commissioned paper for the Millennium Project Task Force 1. http://www.unmillenniumproject.org/documents/MP_Energy_Low_Res.pdf

NDRC, 2006. (China National Development and Reform Commission), 2006, *Notice about Issues on Speeding Up Electricity Industry Restructuring and Promoting Orderly and Healthy Development.* 18 April 2006, www.ndrc.gov.cn

NDRC, 2007, *China's National Climate Change Programme*, June 2007, China National Development and Reform Commission

NSSO, 2001. *Differences in Level of Consumption among Socio-Economic Groups 1999-2000.* National Sample Survey Organization, Ministry of Statistics and Programme Implementation, Government of India, New Delhi. Report No. 472 (55/1.0/10).

OECD, 2005, *China in the Global Economy,* Governance in China, ISBN92-64-00842-X, 578 pages.

QU K, 2003. *Energy, Environment Sustainable Development Study*, Beijing: China Environment Science Publishing House.

Schurr, S. H., 1982. *Energy Efficiency and Productive Efficiency: Some Thoughts Based on American Experience*. Energy Journal 3(3):3-14.

SEPA, 2007. *2006 China Environmental Pollution Communique*', available at www.sepa.gov.cn, June 2007, China State Environmental Protection Administration,

SEPA, 2004. China State Environmental Protection Administration) and CNBS (China National Bureau of Statistics of China), '*China Green National Accounting Study Report 2004*',

SERC, 2006. *SERC and China Electricity Association Release Data about Electricity Supply Reliability for 2006*', 14 May 2007, China State Electricity Regulatory Commission.

Shell, 2005. *Shell Global Scenarios to 2025. The future business environment: trends, trade-offs and choices*, Shell International Limited, London.

Shukla P. R., Rana, A., Garg A, Kapshe M and Nair R., 2006. *Global climate change stabilization regimes and Indian emission scenarios: Lessons for modelling of developing country transitions.* Environmental Economics and Policy Studies, 7(3), 205-231.

South Africa, 2007, *Development, Energy and Climate Change: South Africa Country* Report. By H. Winkler et al.. UNEP Risoe Centre, Denmark, ISBN 978-87-550-3629-1

Tan S., Wang Y, Jiang S, 2002. *Economy Globalization and Developing Countries,* Beijing: Social Science Documentation Publishing House. (in Chinese)

Toman, M. and Jemelkova, B., 2002. *Energy and Economic Development: An Assessment of the State of Knowledge*. Resources for the Future. Discussion Paper Series DP 03-13

UNDP, 2003: *Human Development Report.* Oxford University Press, New York.

UNDP, 2006. *Human development report: 2006.* United Nations Development Programme, Oxford University Press, New York

UNESC Asia Pacific, UNDP, ADB, '*Millennium Development Goals: Progress in Asia and the Pacific 2006*, avaiable at http://www.mdgasiapacific.org.

WBCSD, 2005, '*The Cement Sustainability UNDP, Human Development Report 2006 - Beyond scarcity: Power, poverty and the global water crisis Initiative – Progress Report*', June 2005, World Business Council for Sustainable Development.

Winkler, H, Howells, M & Alfstad, T 2005. *South African energy policies for sustainable development*. Report for the International Atomic Energy Agency. Cape Town, Energy Research Centre.

Xinhua News Agency, 2004. *Acid Rain Pollution Costs China RMB 110 Billion A Year*', 23 April, 2004, available at www.xinhuanet.com

Zheng Y, Zhang X, Xu S, 1999. *China Environment and Development Review*, Beijing: Social Science Documentation Publishing House.

Zhou, Dadi et al., 2003. *China's Sustainable Energy Scenarios in 2020*, China Environmental Sciences Press.

Project Partners

The Balancing Energy, Sustainable Development and Climate Change Project is coordinated by the UNEP Risø Centre, Denmark. Our country partners are;

FUNDACAO COPPETEC, Rio de Janeiro, Brazil
Centro de Tecnologia, Bloco H sala 203
Cidade Universitari – Ilha do Fundao
Rio de Janeiro CEP 21945-970, Brazil
Tel: +55 21 2560 8995, +55 21 2562 8805
Fax: +55 21 2562 8777
Prof. Emilio Lebre La Rovere (emilio@ppe.ufrj.br)
André Santos Pereira
André Felipe Simões
Amaro Olimpio Pereira
Carolina Burle Schmidt Dubeux
Ricardo Cunha da Costa

Energy Research Institute (ERI), Beijing, P.R. China
State Development Planning
B – 1515, Jia No. 11, Muxidibeili, Xicheng Dist.
Beijing 100038, P.R. China
Tel: +86 10 6390 8576
Fax: +86 10 6390 8568
Dr. Kejun Jiang (kjiang@eri.org.cn)
Xiulian Hu
Qiang Liu

Indian Institute of Management, Ahmedabad (IIMA), India
Vastrapur, Ahmedabad- 380015, INDIA
Tel: +91 79 2632 4827
Fax: +91 79 2630 6896
Prof. P.R. Shukla (shukla@iimahd.ernet.in)
Subash Dhar

Energy Research Centre (ERC), Cape Town, South Africa
University of Cape Town
Private Bag, Rondebosch
Cape Town 7700, South Africa
Tel: +27 21 650 3892, +27 21 650 3355
Fax: +27 21 686 4838
Dr. Harald Winkler (harald@erc.uct.ac.za)
Stanford Mwakasonda
Pierre Mukheibir

Contact Us

UNEP Risø Centre on Energy, Climate
and Sustainable Development (URC)

Risø National Laboratory
Technical University of Denmark – DTU
Building 142, Frederiksborgvej 399, P.O. Box 49
DK-4000, Roskilde, Denmark

Phone : +45 4677 5169, +45 4677 5170, +45 4677 5112
Fax : +45 4632 1999

Dr. Amit Garg, Dr. Xianli Zhu and Dr. Kirsten Halsnæs
Email : amit.garg@risoe.dk, xianli.zhu@risoe.dk,
kirsten.halsnaes@risoe.dk
Website : http://developmentfirst.org/