Understanding China's Energy Policy

Economic Growth and Energy Use, Fuel Diversity, Energy/Carbon Intensity, and International Cooperation

Background Paper Prepared

for

Stern Review on the Economics of Climate Change

By

Research Centre for Sustainable Development, Chinese Academy of Social Sciences

Acronyms, Abbreviations, and Chemical Compounds

ADB: Asian Development Bank.

AIM/EMF: Asia Integrated Modeling/Energy Modeling Forum

AM0001: Approved baseline methodology of "Incineration of HFC 23 waste streams"

APP: Asia-Pacific Partnership on Clean Development and Climate

BASIC: EU founded Project entitled for "Linking National and International Climate Policy: Capacity Building for Challenges ahead for Brazil, China, India and South Africa"

CBM: Coal-bed Methane

CDM: Clean Development Mechanism

CECA: China Energy Conservation Association

CER: Certified emission reduction

CHP: Combined Heat and Power

CMM: Coal Mine Methane

CNIGC: China National Investment & Guaranty Co., LTD

CNPC: China National Petroleum Corp.

CO_2: Carbon dioxide

COP/MOP: Conference of the Parties/Meeting of the Parties

CPA: Centrally planning Asia

CREIA: Chinese Renewable Energy Industries Association

CSEP: China Sustainable Energy Program

DNE21: Dynamic New Earth 21 model.

DRC: Development Research Centre, China

DSM: Demand Side Management

EBRD: European Bank for Reconstruction and Development

EF: Energy Foundation, US

EIA: Energy Information Agency

EMCA: Energy Management Company Association

EMCO: Energy Management Company

ERI: Energy Research Institute

ESCO: Energy-saving Services Company

ESD: Emission Scenarios Database

EU: European Union

FDI: Foreign Direct Investments

G20: Group of 20 largest GHGs emission nations in the world

G8＋5: Group of 8 industrialised countries plus large five developing countries

GDP: Gross Domestic product

GEF: Global Environmental Facility

GHGs: Greenhouse gases

GtC: giga (10^9) tons of carbon

GW: giga(10^9) W

ICC: International Carbon Cooperation

IIASA: International Institute for Applied System analysis;

IMF: International Monetary Foundation

IPCC: Intergovernmental Panel on Climate Change

L20: Leadership of 20 Countries Conference on Climate Change

MtC: Million tons of Carbon

Mtce: Million tons of coal equivalent

Mtoe: Million tons of coal equivalent

MW: Megawatt

NBS: National Bureau of Statistics of China

NDRC: National Development and Reform Commission

NGOs: Non-governmental Organisations

NIES: National Institute of Environmental Sciences, Japan

NOx: Nitrogen oxides

ODA: Official Development Assistance

OECD: Organization for Economic Co-operation and Development

PDD: Project design document

PE: Primary energy

PV: Photo Voltaic

R&D: Research and development

RICE: Regional Integrated Computable Equilibrium;

RMB: Renminbi

SDPC: State Development and Planning Commission.

SETC: National Economic and Trade Commission

SGM: The Second Generation Model

SO_2: Sulphur dioxide

SUVs: Sport Utility Vehicles

SWH: Software HOLDRs

TNC: Transnational Corporation

UK: United Kingdom

UNDP: United Nations Development Program

UNFCCC: United Nations Framework Convention on Climate Change

US: Unites States

WB: World Bank

WEC: World Energy Council.

WHO: World Health Organisation

WTO: World Trade Organisation

Contents

1. Introduction

As a developing and a large economy, China has to consider and make its energy policies in a comprehensive and strategic way, so as to meet its increasing energy demand and reduce its impact on the world energy market while fulfilling wider social objectives for equitable and sustainable development The significance of the role by China with respect to energy policy is further amplified by domestic and global environmental concerns.

Energy consumption in China increased from 1.3 billion tce in 2000 to 2.2 billion tce in 2005. Industrialisation and urbanisation are still in the stage of acceleration. Double-digit growth in the industrial sectors is likely to continue in the next 5 or 10 years. Each year, over 11 million residents are to be added to the urban sector over the next 10 to 20 years. In terms of energy consumption and greenhouse emissions, China is second largest in the world. Sulphur dioxide emissions in 2005 amounted 25 million tons, absolute world number position. As such, energy policy in China is not merely a domestic issue, but has a significant impact on the world energy market and overall pattern.

Commissioned as part of the Stern Review, this background report looks at the economic and environmental aspects of energy policies in China and at the future prospects for energy consumption growth and the potential for greenhouse gas emission reductions through fuel diversification and demand side strategies. Key issues to be covered include analysis of: medium and long term growth and greenhouse gas emissions projections, the drivers of emissions growth,, current domestic policies for energy saving and their impacts on greenhouse gas emissions reductions, energy diversification and its major barriers, and potential for international cooperation between China and the outside world to secure domestic energy supplies and reduce greenhouse gas emissions.

This review exercise does not engage in any new research. Instead, it is based on existing literature and communication with researchers in related areas in China. The Review team has made a comprehensive survey of literature on energy policy, economic modeling of energy demand and emissions scenarios, climate change mitigation, environmental pollution control, international climate cooperation, and recent policy developments in China such as the 11th five year (2006-2010), National medium and long term Plan for Scientific and Technological Development, National Environmental Protection, as well as energy and climate related legislations and policies. Some of the studies are taken in China while many others are undertaken by international researchers from different perspectives. A comparative approach is taken to understand the differences between the Chinese and international literature and to evaluate the projections against recent observed patterns. As an illustration, we construct scenarios to look at the possible approaches and impacts resulting from implementation of the 11th five-year plan.

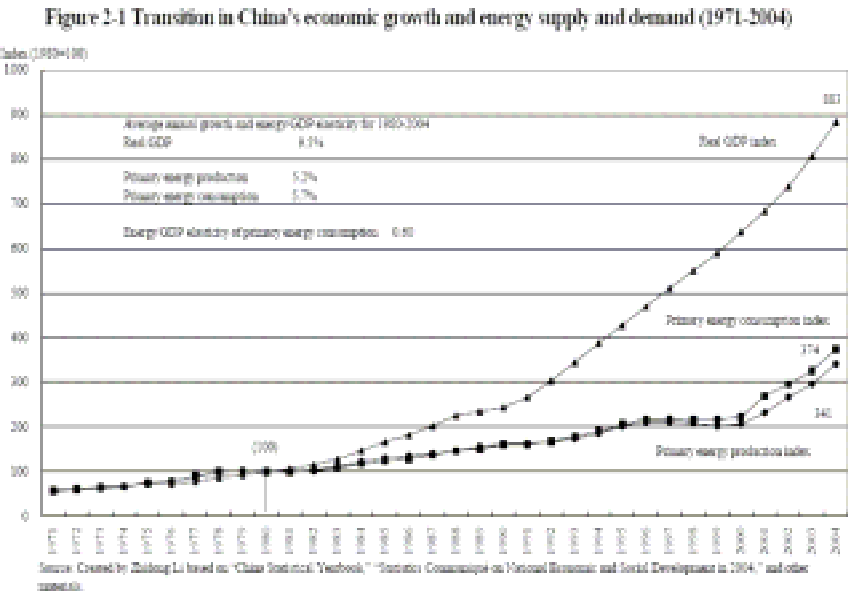
This background report is organised as follows. Section 2 examines medium and long-term growth and greenhouse gas emissions. Section 3 examines energy intensity reduction targets under the 11th five-year plan together with the key drivers and barriers for their fulfillment (evaluated in context and illustrated through a few key industrial sectors). Energy diversification had long been pursued in China but was not very successful in the past. This is treated at length in Section 4. The potential scope for and approaches to cooperation between China and the international community is presented in Section 5. The last section provides a few conclusions and discussion on some of the issues is made.

2. Growth and greenhouse gas emissions to 2020 / 2030/ 2050

2.1 Pathways and key drivers for China's energy use and greenhouse gas emissions

China entered a high economic growth phase around the end of the 1970s, and the momentum has been kept up to now. Compared to 1980 level, its real GDP expanded by 9.7 times in 2005，with an average annual economic growth rate of 9.5%. In contrast, the growth of energy demand was far slower than the GDP growth due to energy saving, efficiency improvement and conservation. Nevertheless, energy consumption in 2005 was 4.3 times the 1980 level and average annual growth rate was 5.7% (see Figure 2-1). This is in sharp contrast to the increase in total global energy demand which grew only 1.4 times from 1980 to 2001 with average annual growth rate of 1.6%.

Figure 2-1 Transition in China's economic growth and energy supply and demand (1971-2004)

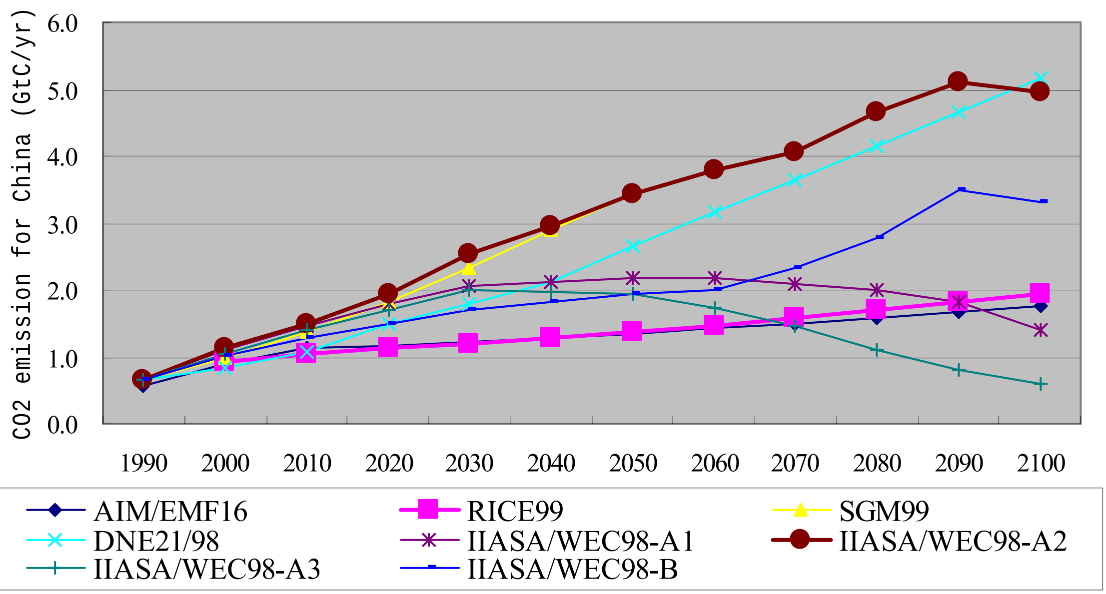


With rapid increase in energy demand, China is facing a series of great challenges such as: energy security, air pollution, acid rain, ecological degradation and climate change. According to the Energy Information Agency (EIA), China's CO2 emission from fossil fuels combustion increased from 394 to 966 million tons of carbon from 1980 to 2003, (an annual average growth rate of3.98%). In 2003, China contributed about 14.1% of world total carbon dioxide[1] emissions, ranking second to the United States.

The national plan is to quadruple the 2000 GDP level by 2020. What would be the environmental consequences? Different scenarios have been developed for understanding energy demand and emissions in China. Some are relatively long-term with 50-100 years horizons but others tend to be short to medium terms, up to 2020, 2030 or 2050. Figure 2-2 shows the results, in which China is included, from a few long-term emission scenarios from Emission Scenarios Database (ESD) compiled by NIES (National Institute of Environmental Sciences, Japan)[2]. In total, there are 8 modeling groups that produce scenario results that contain information on future emissions by China. Some of them include China as an independent entity in the modeling exercise while others put China in a country group such as centrally planning Asia (CPA). Where appropriate, we have made adjustment to exclude other countries in a country group to enable comparisons with data for China only.

[1] This number considers carbon emissions from fossil fuel combustions only, without taking into account other greenhouse sources (see EIA, 2005).
[2] The database can be accessed at http:/www.nies.go.jp.

Figure 2-2 Long-term emission scenarios from ESD compiled by NIES



The projections are highly diverse, as shown in Table 2.1. In general, the longer the time horizon is, the larger the gap between the high and low scenario results. In 2020, the ratio between the extremely high and extremely low scenarios is less then 2 but is close to 3 by 2050.

Table 2-1 wide ranges of projections from selected emission scenarios of ESD/NIES

		2020	2030	2050
IIASA/WEC98-A2	CO_2 (GtC)	2.1	2.7	3.6
	PE(EJ)	106	136	188
	PE(Mtce)	3623	4648	6425
RICE99 & AIM/EMF16	CO_2 (GtC)	1.1	1.2	1.4
	PE(EJ)	55	58	65
	PE(Mtce)	1880	1982	2221

Note: PE: primary energy; EJ: 10^{18} Joules; GtC: giga (10^9) tons of carbon; Mtce: million tons of coal equivalent; AIM/EMF: Asia Integrated Modeling/Energy Modeling Forum, representing modeling teams from Japan and a modeling consortium coordinated in the US; RICE: Regional Integrated Computable Equilibrium; IIASA: International Institute for Applied System analysis; WEC: World Energy Council. Details are reported in Chen Ying et al, BASIC Project Report, 2006.

Chinese literature also reports scenario results, but normally for a much shorter time horizon. Some of the analyses are made by national organisations that represent the best estimate of the picture for China[3]. One such study conducted by Zhou Dadi and his colleagues was published in 2003 under the title of "*China's Sustainable Energy Scenarios in 2020*". The reference scenario projected that total annual primary energy demand would increase from 1368 Mtce in 1998 to 3100 Mtce by 2020. The share of coal in the energy mix is projected to decline from 75.4% in 1998 to 64.8% by 2020. CO_2 emission will reach 1899MtC in 2020. Development Research Centre (DRC) under the State Council, a policy oriented think tank of the Chinese government, produced a very similar report shortly after Zhou's study. The reference scenario projected that total annual primary energy demand would increase from 1297Mtce in 2000 to 3280Mtce by 2020; the share of coal in energy mix would decline from 69.9% in 2000 to 63.2% by 2020; CO_2 emission would reach 1940MtC by 2020.

Table 2-2 Comparison of total demand for primary energy and its composition

Reference Scenarios	Type	Total Demand for Energy （Mtce）			Annual Growth Rate (%)	Composition (%)		
		Base year	2010	2020	1998~2020	Base year	2010	2020
Zhou et al, 2003	Coal	1030.9	1509.4	2007.9	3.1	75.4	69.6	64.8
	Oil	281.4	471.5	752.4	4.6	20.6	21.7	24.3
	Gas	19	80.4	155.4	10.0	1.4	3.7	5.0
	Primary power[4]	36.6	107.8	184.6	7.6	2.7	5.0	6.0
	Total	1368	2169.1	3100	3.8	100	100	100
EF-DRC, 2004	Coal	907	1425	2074	4.22%	69.9%	66.7	63.2
	Oil	324	538	877	5.10	25.0	25.2	26.7
	Gas	36	112	220	9.44	2.8	5.2	6.7
	Primary power	29	63	109	6.77	2.3	2.9	3.3
	Total	1297	2137	3280	4.75	100.0	100.0	100.0

Note: the base year from Zhou et al is 1998 where the other used 2000 as the base year. Source: Zhou Dadi ed., "*China's Sustainable Energy Scenarios in 2020*", China Environmental Sciences Press, Aug. 2003; EF-DRC, "China's National Comprehensive Energy Strategy and Policy", project report for t**he China Sustainable Energy Program (CSEP)** of Energy Foundation, 2004 (http://www.efchina.org/).

[3] These studies are considered authoritative for several reasons, including (1) they are directly under or part of the central government agency meaning that the reasults are somewhat semi-official; (2) they have close cooperatin with their international counterparts meaning that methods are well grounded; (3) they have access to data which are often not available to purely academic researchers.

[4] In China's statistics, primary power includes hydro, nuclear, wind, solar, geothermer. Although new and renewable power from wind, solar, landfill methane and geothermer grow at a relaively fsster rate thaan conventionalo sources, their share in the primary power is small even in the future. In China, the major part is from hydro and nuclear.

Some scenarios give projections to 2030 or 2050. For example, Mr. Zhidong Li, a visiting researcher at the Institute of Energy Economics, Japan (IEEJ), projected that primary energy demand in China would be 2947 Mtce by 2020 and 4249 Mtce by 2030, CO_2 emission will go up to 2575MtC by 2030 in the reference scenario. A researcher at the Energy Research Institute (Hu, 2005) did a similar study but the projections were extended to 2050. The results from these two studies are presented in Table 2-3. The base year data are roughly the same though there exist slightly differences between the two studies. Also the projections for 2020 are rather close as well for reference scenarios. It is interesting to note that the numbers between the two studies diverge for 2030, with a difference of roughly 550 million tons of coal equivalent. Afterwards, the energy demand continues to grow at a linear rate to 2050 in Hu's projection.

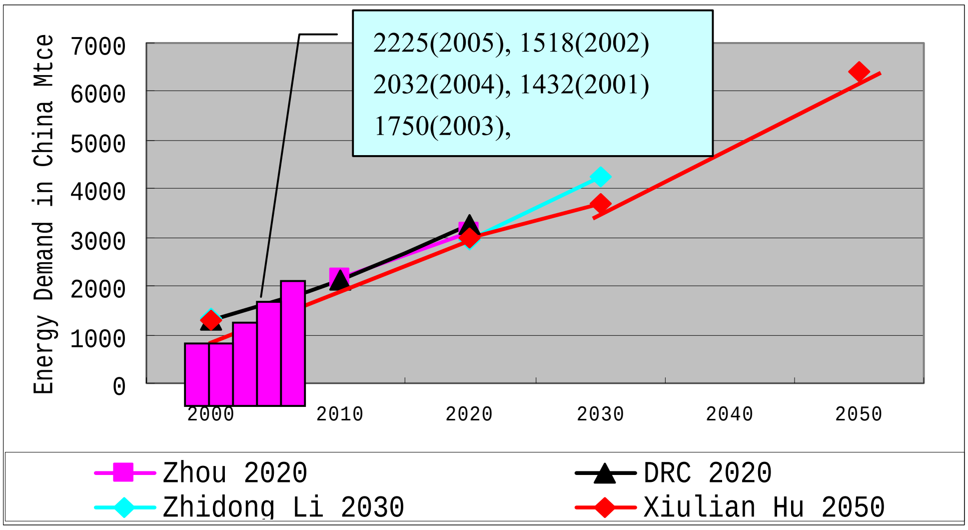
Table 2-3 reference energy and emission scenario to 2030, 2050

Reference Scenarios		2000	2020	2030	2050
Li, 2005	PE(Mtce)	1327	2947	4249	—
	CO_2(MtC)	900	n.a.	2575	—
Hu, 2005	GDP index	1	5.1	9.14	20.9
	PE (Mtce)	1303	~3000	~3700	6405
	CO_2(Mtc)	900	~2000	~2400	3263

Note: The data in 2020 and 2030 for Hu's scenarios are read from the curve and are not wholely accurate.

Source: Zhidong Li: "Energy Demand and Supply Outlook in China for 2030 and a Northeast Asian Energy Community- the Automobile strategy and nuclear power strategy for China"; Xiulian Hu, "Development of China Carbon Emission Scenarios towards 2050", presentation at COP11 and COP/MOP1 side event "Global Challenges Towards Low-Carbon Economy-Focus on Country-Specific Scenario Analysis", held in Montreal, Dec.3, 2005.

Fig 2-3 Comprehensive comparisons among projections and actual data



In comparison with the actual consumption record in China, all projections appear rather conservative than the reality. In year 2005, total energy consumption reached 2,225 Mtce. From figure 2-3, it is clear that 2005 energy consumption turned out to be higher than all the scenario projections for 2010. For the 11th five-year plan, the Chinese government is determined to reduce energy intensity by 20% in 2010 as compared to 2005. Even if this target is realised, total energy consumption is likely to be close to, or even higher than, all the scenario projections for 2020. The underlying reason lies in the speed and nature of the growth of the economy. As economic expansion continues, moderate increase in energy consumption would mean substantial growth in aggregate numbers. The drivers are discussed below for a better understanding of the process.

All these studies assume a continued decrease in the share of coal in the energy mix, and most of the scenarios suggest that share by coal would be reduced from current level at above 2/3 to about 2/5 by 2020 and further down to 1/2 by 2030 and onwards. If we look at the recent developments in the change of energy structure, coal has been even more dominant than these projections. This is rather difficult to shift from coal to other energies in China due to constraints of resource endowments and relatively high cost. Here are some examples:

- The price of oil in international market has doubled within the past several years, leading to rising prices of related energy products in domestic market, such as petrol and LPG. Some middle and low income households have to shift back from LPG to coal for cooking.
- A few gas turbine power generators have been installed in Shanghai and Beijing, but these are not in operation due to lack of natural gas and high price.
- China is now investing in conversion of coal to oil because of oil shortage. This could help with oil security but might have serious environmental impacts in terms of both air pollution and climate change.
- SO_2 emissions control is now more stringently implemented to protect environment (and these controls could go further). However, the problem is that

desulpherisation would require more energy further impacting on a critical demand-supply balance.

- China has made quite ambitious plans for development of nuclear power but the potential to substitute coal with nuclear is also quite limited due to huge initial investment, safety consideration and shortage of uranium reserve inside China.

In a parallel issue, the likely lower operating efficiency of the developmental technology carbon capture and storage may impact on its future uptake to reduce carbon dioxide emission. Given the above complications, emissions paths in the scenario analyses might be an underestimate for China if no carbon capture and storage projects are involved or without significant new policies, investment and greater cooperation to promote fuel diversification and energy efficiency.

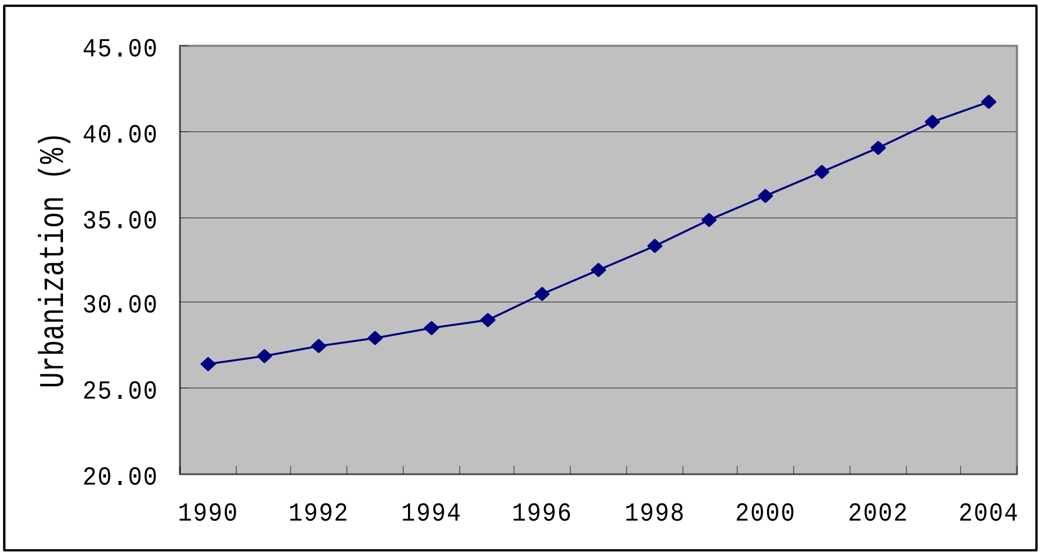
2.2 Analysis of Key Drivers

Generally, the key drivers of energy and emissions scenarios include: population, social and economic development, technological advancement, and constraints of natural resources and environment protection, etc. As such, the pathways of China's energy and emissions scenarios will be determined by assumptions on a group of indicators, such as population growth, urbanisation, GDP growth, economic structure, energy efficiency, environmental policy and foreign trade, etc.

China is the most populous country in the world. With great efforts by government to implement family planning policy since the 1980s, population growth has been is kept relatively low, but it is unlikely that this trend will reverse until it reaches 1.5 billion around 2050. More importantly, as shown in Fig2-4, urbanisation process is accelerating in China. China's urbanisation level has increased from 26.41% in 1990 to 41.76% in 2004. It is expected to reach about 55%-60% by 2020. Even if the urbanisation level increases by only 1 percent every year in the first twenty years of the new century, China will still see its urban population increase by about 13 million every year. Accelerated urbanisation accompanied with a series of significant changes, for example, employment pressure[5], consumption patterns and large scale of infrastructure construction, will lead to great challenges for China in the coming decades.

Fig2-4 Accelerated urbanisation trend in China (1990-2004)

[5] Normally every two urban people requires at least one job position. This would mean that each year 6.5 million new jobs have to be created to accommodate the increase in urban population.



Accelerated urbanisation means expansion of existing cities and creation of new towns and cities. Both require large-scale construction of infrastructure and buildings. As shown in Table 2-4, by the end of 2003, per capita urban road area, drainpipe density and per capita floor space of residential building are 3, 1.6 and 1.7 times of the levels in 1990 respectively. From 2002, the floor spaces of buildings completed have exceeded 1 billion m^2 per year. In 2004, this number reached 1.28 billion m^2 and the total floor spaces of buildings under construction was 2.9 billion m^2. Infrastructure and buildings need a great amount of energy intensive materials such as steel, cement and chemicals, etc. The likely continued growth of these energy intensive industries will have significant impacts on China's energy demand and emissions in the future.[6]

Table2-4 China's infrastructure and residential building construction in urban area (1990-2003)

Year	1990	1995	2000	2002	2003
Per capita road area (m^2)	3.1	4.4	6.1	7.9	9.3
Drainpipe density (km/km^2)	4.5	5.7	6.3	6.7	7.0
Per capita floor space of residential buildings (m^2)	13.7	16.3	20.3	22.8	23.7

Note: Data in this table is calculated with society-wide figures.
Source: China Statistics Yearbook, various years.

Residential energy consumption now contributes to over 11% of China's total energy consumption and is the second biggest energy consumption sector following the industrial sector. Empirical analysis indicates that currently, annual per capita commercial energy consumption of urban Chinese residents is 3.5 times that of the rural due to changes of their living style, for example, using more electronic

6 There is a particularly significant path dependency arising from the development strategies of buildings and urban infrastructures due the low turnover of capital)..

appliances and substituting biomass with commercial energy, will drive up a great deal of residential energy consumption. For example, in 2004, in contrast to 90.15 refrigerators and 95.9 washing machines owned by urban Chinese residents per 100 households on average, only 17.75 refrigerators and 37.3 washing machines are owned by rural Chinese residents.

It is estimated that the total amount of biomass available is about 500 million tce per year in China. Half of them, about 250 million tons are used as raw material for industry, such as paper making and organic fertilisers, and the rest are mainly used as energy in rural area for cooking and heating. Assuming that only 30% of the traditional energy (about 60 million tce) is shifted to commercial energy, particularly coal due to reasonable price, it will lead to extra 44.8 million MtC GHG emission per year.

Almost all the scenarios assume that China assume a high level of economic growth. Realisation of the national plan to quadruple 2000 GDP levels by 2020 requires that the average GDP growth rate be about 7.2% annually. As previously outlined, the growth rate has been over 9% in recent years. It is also interesting to see changes of economic structure. China's economy seemed to enter into a new phase. Since 2002, the ratio of heavy industries[7] has been growing over 60% (this figure reached 60.9% and 64.3% in the years 2002 and 2003, respectively). Evolution of consumption patterns and the process of urbanisation and infrastructure construction would mean that this new phase of industrialisation can be expected to continue for quite a long period. Currently, the industrial sector consumes almost 70% of total primary energy in China. However, structure changes and improvement of energy efficiency in energy intensive industries have great potentials to contribute to energy conservation.

In a globalised world, China is increasing integrated into the world economy and is highly dependent on international trade. Total imports and exports amounted to 14 trillion in 2005(accounting for 77% China's total GDP). China is becoming a major manufacturing base for the world. Since China is at the lower end of the international division of labor, the majority of the country's imports are high value-added products and services, while exports are mostly products from energy intensive manufacturing industries. As such the intensity of the embedded energy of its imports is generally lower than that of its exports causes an international mismatch of energy demand (and supply in the case of certain fuels). Under such an import and export structure and given the expectation of inevitable growth in import and export volumes, it would be difficult to buck the trend of energy demand transfer from other countries to China in short and medium term.

China's energy strategy is subject to constraints of natural resources and environment. With high dependence on imported oil and recent increases in gas and oil prices, energy security, especially oil security has become a serious problem in China. In

[7] The ratio of output value from heavy industries (mainly metals, electricity, paper making, machinery, heavy chemicals, etc) over that from ligh industries (mainly food processing, textiles, clothing, stationeries, etc.).

term of the environmental impacts of energy use, direct coal burning is one of the main sources of air pollution in urban area, especially for Northern China in winter heating period. China is the world's largest SO2 emitter with 25.49 million tons as of 2005, 27% higher that that in 2000[8]. Of the urban population, 64% or more than 200 million people are exposed to some form of air pollution. Acid rain pollutes more than 30% of Chinese territories and long distance flow of pollutants leads to international concern in East Asian.

Between 1980 and2000, China's energy intensity fell by 64 percent with an average annual conservation rate of 4.6 percent in China. Besides structure changes, technological advancement played an important role. As shown in Table 2-6, from 1990 to 2004, comparable energy consumption of main energy intensive products has deceased and the disparities between China and developed countries have also been reduced considerably. It is estimated that energy consumption for coal-burning power generation, steel and cement production are still 22%, 20% and 45% higher than those of advanced levels in developed countries. Although technological improvement can be expected to continue to contribute to the reduction of future energy and emissions, additional policies are needed to facilitate faster technology innovation and deployment..

Table2-5 Energy Intensity of Selected Energy-Intensive Products (1990-2004)

	Unit	1990	2004	Reduced (%)	Gap narrowed % between China and developed countries
Coal burned for power generation	g/kwh	427	376	11.9	8.1
Comprehensive energy consumption of Steel	kgce/t	997	702	29.6	43.4
Comparable energy consumption of cement	kgce/t	201	157	21.9	40.4
Comprehensive energy consumption of ethene	kgce/t	1580	1004	36.5	20.8
Comprehensive energy consumption of ammonia synthesis (large scale)	kgce/t	1343	1184	11.8	14.7

8 Zhou shengxian, 2006. Speech made at National Conference on Atmospheric Pollution Control. 30 May, 2006. But the national target set in 2001 for 2005 was reducdtion of SO2 emission by 10% relative to 2000 level.

2.3 Impacts of energy diversification and reduction in energy intensity on emissions pathways

Against their reference scenarios, many studies on energy and GHGs emissions have developed different policy scenarios for understanding of possible impacts of energy diversification and reduction in energy intensity on emissions pathways. Decrease of coal share and increase of renewables in energy mix are the most common characteristics of energy diversification

As shown in Table 2-6, Zhou et al (2003) developed two policy scenarios (S2 and S3). As compared to reference scenario S1, CO_2 emissions from energy use will be reduced by 13% and 33% respectively by 2020. How could these policy goals of emissions reduction be achieved? Part of the explanation lies in energy intensity reduction, by 11% and 25% respectively. Energy diversification is a other key contributor to emission reductions. The shares of coal in energy mix are assumed to decrease from 64.8% to 59.7% (S2) and 54.4% (S3) by 2020. In the meantime, shares of primary power will increase from 6.0% to 7.2% (S2) and 10.2% (S3).

Table2-6 Comparison of energy demand and CO_2 emissions (MtC)

Scenarios	Variables	1998	2010	2020	annual growth rate (%) (1998-2020)	Changes based on S1 (%) in 2020
S1 Reference	PE（Mtce）	1368	2169.1	3100	3.8	-
	Coal （%）	75.4	69.6	64.8		-
	CO_2 (MtC)	871.7	~1350	1899.9	3.6	-
	Primary power(%)	2.7	5.0	6.0		-
S2 Policy Scenario	PE（Mtce）	1368	2033.5	2761.8	3.2	-11%
	Coal （%）	75.4	67.3	59.7		-4.9%
	Primary power(%)	2.7	5.4	7.2		+1.2%
	CO2 (MtC)	871.7	~1250	1659.0	2.97	-13%
S3 Enhanced Policy Scenario	PE（Mtce）	1368.0	1860.3	2318.7	2.4	-25%
	Coal （%）	75.4	64.1	54.4		10.4%
	Primary power(%)	2.7	6.3	10.2		4.2%
	CO2 (MtC)	871.7	~1100	1265.3	1.71	33%

Source: Zhou Dadi ed., "*China's Sustainable Energy Scenarios in 2020*", China Environmental Sciences Press, Aug. 2003

Similar analysis could be done for scenarios developed by EF-DRC as shown in Table 2-7. In general, energy diversification and reduction of energy intensity will continue in the future. In addition, sectoral composition of CO_2 emissions will experience considerable changes along time, with decrease for industry and agriculture sectors and substantial increase from commercial and residential sectors.

Table 2-7 Comparison of total demand for primary energy and its composition

		2000	2010	2020	Annual Growth Rate (%) (2000-2020)	Changes based on S1（%） in 2020
A Reference Scenario	PE（Mtce）	1297	2137	3280	4.75	
	Coal （%）	69.9%	66.7	63.2		
	Primary power(%)	2.3	2.9	3.3		
	Total CO_2 (MtC)	801	1288	1940	4.5	
	Industry and agriculture (%)	73.2	67.4	59.1		
	Transportation (%)	10.7	12.8	16.1		
	Commercial/residential (%)	16.1	19.8	24.7		
B Policy Scenario	PE（Mtce）	1297	2068	2896	4.10	-12%
	Coal （%）	69.9	66.0	61.7		-1.5%
	Primary power(%)	2.3	3.4	4.1		0.8%
	Total CO_2 (MtC)	801	1234	1716	3.9	-12%
	Industry and agriculture (%)	73.2	67.4	57.9		
	Transportation (%)	10.7	13.0	16.8		
	Commercial/residential (%)	16.1	19.6	25.2		
C Enhanced Policy Scenario	PE（Mtce）	1297	1859	2466	3.26	25%
	Coal （%）	69.9	64.8	59.4		-2.8%
	Primary power (%)	2.3	4.3	5.8		2.8%
	Total CO_2 (MtC)	801	1111	1437	3.0	26%
	Industry and agriculture (%)	73.2	67.1	57.1		
	Transportation (%)	10.7	13.0	16.6		
	Commercial/residential (%)	16.1	19.9	26.3		

Source: main report of EF-DRC project, Overview of National Energy Strategy, 2005； Huaqing Xu, report on climate change attached to EF-DRC project, 2005

2.4 Assessment of the capabilities for China's choice of less energy intensive, lower carbon pathways

China needs to further build and enhance her mitigative capacity to choose less energy intensive and low carbon pathways in the future. Although mitigative capacity has not been well defined, technological, financial and institutional capacities are key elements.

Technologies in the energy sector in China are highly heterogeneous, from advance solar PV and zero energy buildings at one end of the spectrum to very primitive technologies such as outdated small scale coal fired power plant and traditional wood and mud houses with no insulation element. From the positive side, China has the technological capacities to develop super-critical power plant, solar, wind, hydro and renewable energy sources. Most importantly, China is able to develop its own technologies in energy use and conservation. For instance, automobiles by Chinese design are as efficient as the advanced OECD models. On the negative side, the pace in technological development and diffusion has been rather uneven. Many of the outdated inefficient technologies are still in use. However, primitive and outdated technologies continue to take a large share of the total investment. This would mean that these technologies would be locked in for another 20-50 years. The government has published a medium and long science and technological development plan, giving emphasis on energy development, efficiency improvement, and energy saving. However, investment in R&D by the government is considered insufficient and the private sector investment has been rather limited. Regional disparities also exist in diffusion of technologies. In general, coastal regions are more advanced in technologies with insufficient capacities in inland and poverty striven remote areas.

As for financial capacity, by tradition and culture, Chinese have a tendency of high rate of saving. Bank savings in China has been increasing steadily, from a few billion in the 1980s to 14 trillion RMB in 2005. Also, china has been a favorable destination of foreign direct investment. From the end of 1990s, government revenue in china has been growing at a much faster rate then that of GDP, being above 25% annually. Both the central and local governments are in a strong position to influence decision making in the industrial sectors. Therefore, theoretically, financial resources are available. Furthermore, international cooperation on energy, environment and climate issues is also a major source of funding. Nevertheless, there is a lack of financial mechanism to channel the money to the energy and climate mitigation sectors. Many of energy efficiency and energy development technologies are long term and uncertain with respect to returns. As the income in China is in general low, there is a lack of market for high energy efficient and new and renewable energy sources. In shanghai for example, local governments encourage consumers to buy “ green power” at higher prices to support renewable energy development, which is so called

"Shanghai Green Power Programme"[9]. In 2005, green power generated was 20 million kWh, accounting for only 0.02% of total amount of power generated in Shanghai. Currently, the price of green power is 0.53yuan/kwh higher than that of coal-burned (about 0.60yuan/kWh for households users). Till now, only 8.5million kWh have been purchased by companies and residents. Even in Shanghai, the most developed region in China, the campaign does not seem to have enthusiastic support from the public, let alone other relatively less developed regions in remote areas.. In many poor areas, residents cannot afford to buy fluorescent lamps. The reason is the price is too high also it is a no-regret choice in the longer run. The market for venture capital is yet to be developed for attracting long term and risky investment in the energy and climate change mitigation sector. Therefore, the existence of financial resources does not mean financial capability. Financial capability is highly dependent on two factors: commercial viability of the investment for security of returns for the investors in the short run and public support for long term and strategic venture capital investment. For the first one, general level of low income restricts the development of market. For the other, there is a need for the government to have a consistent policy for support. Therefore, for China as a developing country, there exists financial potential. But enhancement of financial capacity requires efforts from all the stakeholders, including the government, the private sector and the general public at large.

As for institutional capacity, being a top-down society by culture and society, Chinese government has a very strong administrative power over the planning and operation of the economy. Against this institutional background, China has been in a position to opt for low energy intensive and low carbon development path. In social policy sector, family planning and poverty alleviation have positive impact on energy consumption and emissions. For instance, 300 million births were avoided for the last 30 years owing to the compulsory family planning policy. Afforestation and natural conservation policies also contribute to enhancement and enlargement of sinks. A series of laws have been passed to promote energy conservation and development of renewable energy sources, including energy saving, renewable energy, clean production, and the like. Industrial policies also play an important role. Chinese government periodically makes sectoral policies, including energy intensive sectors such as steel, automobile, and chemicals. In all these documents, energy saving is included as a key indicator. Financial incentives have also been widely employed in promoting low energy intensity and low emissions activities. For instance, small hydropower enjoys a 6% value tax rate as compared to a normal rate of 17%. For biogas utilisation, a subsidy is provided to rural households for the construction of a biological digester. In the 11th five-year plan, 20% energy intensity reduction is made as a compulsory target for all the regions and industries. While these top-down policies are effective on the on hand, they also have negative impacts on reduction of energy intensity and low emissions development. Government failures can lead to waste in energy and emissions. Government cars can be an example for illustration.

---

9 http://www.crea.org.cn/greenpower/

Government cars are large in size and do not respond to increase in oil prices as the pay is from tax-payers. With a strong government, grassroots innovation is normally depressed.

In general China has developed a certain capacity of technologies, financing and institutions for promotion of low energy intensity and low emission paths. However, barriers also exist preventing these capacities from taking effects.

3 Targets for Reducing Energy Intensity in 11th Five-Year Plan

3.1 Energy Intensity in Retrospect (1980-2005)

Energy intensity is the ratio of energy consumption and GDP for a given year. It is thus a measure of energy efficiency within an economy. Energy intensity reduces from the progress and application of energy saving technology, improvements and innovations in the management of energy systems. Therefore, energy intensity can be said to be an exogenous variable relative to GDP and energy consumption. In another words, GDP and energy intensity determine energy consumption. For example, an increase in energy prices would make consumers reduce energy consumption or change their energy consumption mix, leading to a decrease in energy intensity.

Overall, energy intensity in China has reduced over the past two decades however there have been fluctuations in this underlying trend. From 1980 to 2001, China's energy intensity dropped substantially and continuously from 13.34 tce per 10000yuan to 4.21 tce per 10000yuan, a 68.4% reduction in total during the 21 years and 5.4% reduction annually (See Figure 3.1). However, the rate of decrease slowed down after 1988. The major reason lies in the lower growth rate, in particular as a result of the drop in the growth rate in industrial output. After 1996, the rate of energy intensity reductions accelerated as a result of the closure of small coalmines and in-efficient energy intensive state owned enterprises. The rate of economic growth decreased slightly at that time, but the major factor contributing to change of energy intensity is attributable to a decrease in energy consumption arising from economic restructuring. The decreasing trend in energy consumption has gradually disappeared since 1999. According to Han and Wei (2004), the decrease in energy intensity from 1998 to 2000 was mainly due to an increase in energy utilising efficiency of the primary, secondary and tertiary industries but improved efficiency in secondary industry predominantly led the fall of the overall energy intensity ratio.

From 1980 to 2000, China managed to sustain spectacular economic growth, with an average growth rate of GDP of over 9% per year. Even more impressive but less known is the fact that such economic performance was accompanied with an energy growth of about 40% of the rate of GDP growth, averaging 3.9% per year. This is remarkable since prior to the Chinese success, it has been long thought that energy growth was likely to outpace economic growth in the early stage of industrialisation. Japan's energy consumption increased 7.4 times from 1953 to 1980, with annually 6.4% growth. Electricity consumption per capita in Korea was 627 KWh when its GDP per capita reached 1000 dollars in 1977. Ten years later in 1988 this figure reached 1525 KWh. Energy consumption per capita in Thailand was 618 kg oil equivalent when its GDP per capita reached 1000 dollars in 1988. Ten years later in 1998 this figure reached 1112 kg oil equivalent. Data from Asia developing countries in their golden period (1990-1997) showed that energy consumption per capita in rapidly industrialising countries increased 5.6% annually while the world average level was only 1.1%. From the Table 3-1 we can see that energy consumption elasticity in developing countries such as Brazil and India are much higher than that of developed countries.[10] While such a decoupling of energy and economic growth has been observed in advanced economies, no other developing country has managed to achieve such a success yet.

Table 3-1 Energy Consumption Elasticity in Selected Countries (1981-2002)

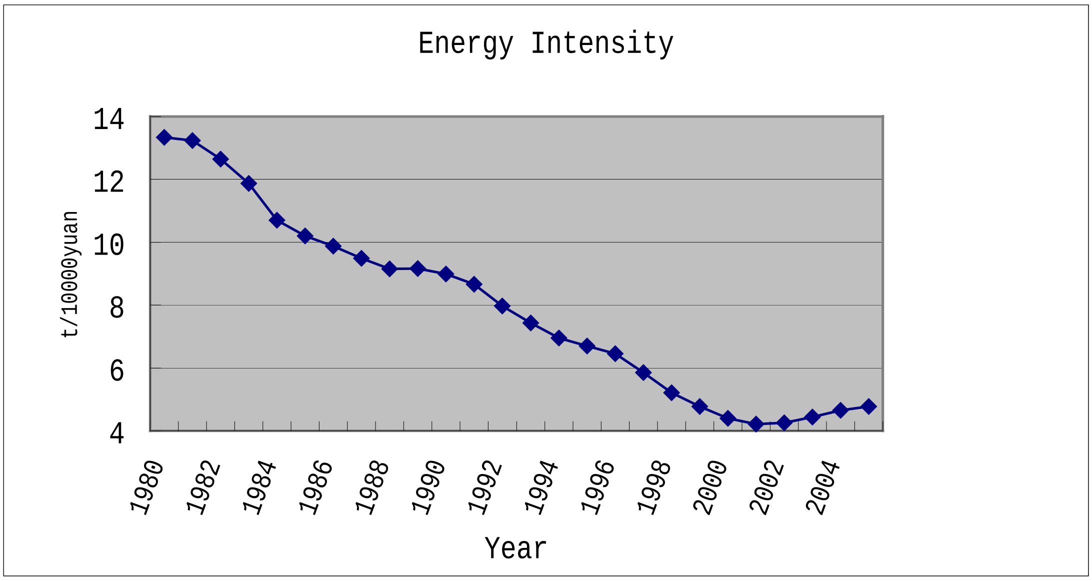
Country	Energy consumption growth（%）	GDP growth based on comparable price（%）	Energy consumption elasticity
Australia	1.83	3.30	0.55
Brazil	2.99	2.05	1.45
Canada	0.92	2.82	0.33
France	0.73	2.12	0.34
India	4.66	5.57	0.84
Japan	1.98	2.53	0.78
UK	0.72	2.46	0.29
US	0.76	3.03	0.25
China	4.17	9.53	0.44

Source: Shi Faqi (2006)

[10] Shi Faqi, 2005. Preparatory analysis on the change of China's energy consumption elasticity and reasons. China Center for National Accounting and Economic Growth, Peking University. Available at: http://www.nepku.com/index.asp.

However, energy demand in China has surged since the arrival of the new millennium. Since 2002, China's energy consumption has been growing at a faster rate than its GDP growth, when a new round of investment-driven economic growth began. During the 10th five-year plan, total investment in fixed assets reached 295.3 trillion yuan, 112.4% increase than that of 9th five-year plan period. The growth rates were 13%, 16.9%, 27.7%, 26.6% and 25.7% respectively in the five years, and average growth was 20.2% annually. For example, the investment of real estate during the 10th five-year period reached 532 billion yuan, 178.6% increase than that of 9th five-year period, which meant 26.5% growth rate every year. A number of key infrastructure projects such as South-North Water Diversion Project, West-East Gas Pipeline Project, West-East Power Transmission Project, Qingzang Railway Project and Three Gorge Dam Project began to be completed. In the subsequent 4 years, China's GDP growth at 2000 price was respectively 9.1%, 10.0%, 10.1% and 9.9%, but the annual growth rate of its total primary energy consumption stood at 9.9%, 15.3%, 15.2% and 12.7% respectively. The energy elasticity of demand (the growth rate of energy consumption divided by that of GDP) exceeded 1 in these 4 years. This shift reverses China's recent historical trend of maintaining energy elasticity below 1.0. From 2001 to 2005, energy intensity in China increased from 4.21 tce per 10000 Yuan to 4.77 tce per 10000 Yuan。

Figure 3-1 Change in Energy Intensity (in 1980 price) in China (1980-2005)



Calculated by author, based on data from China Statistic Yearbook, various years.

The recent change in the trend in the Chinese energy intensity ratio stems at least in part from high economic growth, which drives demand for energy-intensive materials. According to He Jiankun and Zhang Xiliang (2005), the reason of energy intensity increase in recent years is mainly due to the change of industrial structure. It is the sharp change of industrial structure that has resulted in an increase in energy intensity.

In particular, accelerating development of the industrial sector especially heavy-chemical industry and the construction sector to support the demand for infrastructure development (which is closely linked to the process of urbanisation), as well as growth in urban residents consumption patterns for housing and automobiles which are also significant drivers of change in the industrial sector. However, technology efficiency of energy conversion and utilisation continues to improve. For example, energy consumption of major energy-intensive products decreases gradually in recent years (see Table 2-5)

Structural factors are the major determinants of increases in energy intensity per unit of GDP. China now consumes two-fifths, one quarter, and one-fifth of the world's cement, aluminum, and steel, respectively. Chinese car production and sales were up 69 percent between 2002 and 2003, yet automobile ownership remains low, with only 20 cars per 1,000 people. As a result, electricity, coal, and oil shortage are expected to become a prominent problem. In 2005, China's dependency on oil imports increased from negative in 1992 to 42.9%, contributing to wide concerns about the country's capability to be resilient to world oil price fluctuations and supply interruptions. China has become the second largest importer of oil in the world since it became an oil importer for the first time in 1993. By 2020, China's oil consumption is projected to reach 11.7 million barrels a day under reference case, and 13.1 million barrels a day under high growth scenario (IEA, 2006), being half the US level under both scenarios. According to recent data available[11], total oil reserve in China is 18.3 billion barrels. Assuming that this reserve was kept to 2020, the total domestic reserve would meet the demand for oil by China for 4 years and 104 days under the reference case consumption level and 3 years and 302 days. No matter how large the scale of coal conversion to oil and bio-diesels, large quantity of oil import will have to be necessary. Moreover, the Chinese government has set the target of quadrupling its GDP at doubling energy consumption during the first two decades of the 21st century. Such a rapid increase in energy consumption threatens the realisation of the government targets.

Two issues are worth considering in depth when reviewing the observed patterns in the Chinese energy intensity from 1980 to 2005. Why were energy saving policies successful during 1980-2000 and why this success did not continue after 2001. It is important to understand the reform process and its implication for the implementation of energy saving policies. In the 1980s, the Chinese economy was mainly a planned system. As such, industrial outputs were mainly from state-owned sectors. Central government place a priority on energy conservation and implemented this policy through the relevant administrative departments and State-owned enterprises. At that time, the government, industrial and economic structures, were well suited to the

[11] "Worldwide Look at Reserves and Production," Oil & Gas Journal, Vol. 103, No. 47 (December 19, 2005), pp. 24-25.

effective imposition of energy saving policies and measures. Moreover, some local governments took guiding measures to support energy conservation.

The success of energy conservation policies can also be attributed to other factors. In the 1980s, energy resources were extremely scarce, so it was easy for the energy sector to support energy conservation through constraints on internal distribution. At the same time, energy conservation policies received much financial support and were carried out strictly in many economic sectors.

During the 1990s, China underwent great transformations, which weakened the effectiveness of administrative energy conservation policies. First of all, administrative planning measures have been gradually replaced by market functions. Secondly, the role of state-owned enterprises has decreased gradually. Finally, the authority of the central government in dictating local government and enterprise is not as marked as before. With the Chinese economy largely transformed from a planned to a market based structure, old administrative measures become ineffective. Although, the *Energy Conservation Law* passed in 1997 was filled with all kinds of good intention, in fact few meaningful actions have been taken to support its implementation. This results from two key system-related issues. The first is that there is no special institution to coordinate the establishment and implementation of energy policy. The second is attributed to the fact that energy-producing sectors such as coal, oil, gas and electricity have important political and economic power in central and local government. In addition, some key industries such as steel and iron, chemicals are controlled by state. As such they are not subject to hard budget constraints, which means that higher energy prices have little impact on their energy using strategies. Although China has established energy saving targets and huge benefits would be brought out, the government continues to pay more attention to energy supply (not energy conservation) than demand side management. Consequently, capital investment is mainly made in expanding energy supply rather than on energy efficiency programmes.

There is no doubt that China will push energy conservation action vigorously in order to meet its target of reducing energy intensity by 20% during 11^{th} five- year plan period. However, the effectiveness of energy conservation policies could be ensured only through continuing to develop the domestic energy market, thus exposing energy users to stronger incentives to improve energy efficiency. New energy conservation policies can be established and carried out in the nation-wide only when all level governments are committed to energy conservation. As such it is necessary to establish a system to coordinate the inherent competitiveness issues and institutional conflicts arising from energy conservation policy by constructing a stringent legal and supervisory framework, supported by appropriate market incentives achievable through further restructured energy markets..

3.2 Impact of Intensity Reductions on demand for Energy and GHG Emissions

The reduction of energy intensity is unlikely to mean an absolute reduction of energy consumption (rather a reduction in energy demand growth). Given the energy supply and security issues outlined so far, it is likely that (increased) energy pricing will be a necessary instrument in order to shift behavior and promote investment necessary to reduce consumption growth and thus the energy intensity ratio.

China is short of energy resources, in particular oil and natural gas. The proven reserves per capita of coal, oil and natural gas are only 60%, 10% and 5% of world average level, with poor exploitation conditions. However in recent years, China has been the second one in the world after the United States in terms of total energy consumption. Energy consumption of major energy intense products is up to 40% higher than that of advanced world. The contradiction among resource, supply and demand is rather prominent. Up to 2010, China is expected to import 50% of oil and 40% of natural gas from abroad. In the meantime, price liberalisation will accelerate in a globalised world. Therefore it is necessary to take all kinds of measures such as legal economic and administrative instruments to promote energy conservation, renewable energy development and utilisation, and energy price reform.

During the 10th five-year period (20001 – 2005), domestic energy market was impacted by both soaring international oil price and large demand-pulled increase of domestic coal price. In general, the level of energy price reflected market change of supply and demand and promoted the development of energy industry. The achievement of energy price reform during this period established a good foundation for further energy price reform in the 11th five-year period (2006-2010).

At present, there still exist many problems with respect to price mechanisms, constituting barriers to comprehensive, harmonious and sustainable development of national economy. Firstly, energy price is in general lower than their social and scarcity costs. Low energy price is not in favor of environmental protection, energy conservation and reasonable utilisation, and sustainable energy development. Therefore, taking into account the factors of scarce situation of energy resources, requirement to establish an energy-saving society, as well as the trend of international energy prices, it is necessary to liberalise energy prices gradually in China. Low energy prices do not give the right signal for enterprises and consumers to take actions for energy saving.

Secondly, unreasonable price relations among all kinds of energy do not benefit optimisation of energy structure. According to the international standard of price relations calculated on caloric values of different energy, the price relations of coal, oil and natural gas is about 1 to 1.5 to 1.35, while the real price relations in China is approximately 1 to 4 to 3. Seen from the relations among the prices change of coal, oil and electricity, change range of coal price is comparatively low. For example, if the price index of coal, oil and electricity are 100 respectively in 1992, then the figure in 2003 are 267 to 556 to 303. this means that for the same amount of caloric values, coal price is comparatively lower than that of other energy prices. Internationally, average price relations between natural gas and crude oil calculated on caloric value is 1.05 to 1, while in China the price relations is 0.4 to 1. This means that in China natural gas price is rather low compared with substitutable oil price. In addition, transport cost of coal is rather high as much as about 50% of arrived price at factory, which means final price at power station is twice that of coal mine gate price. Similar situation exists for electricity pricing, too, as price ratio of price sold to power grid over retail price is disproportionately low.

Finally, dual pricing systems played a negative role in price reform. There is a difference in price regulation mechanism. Although the price of coal for power was deregulated on paper in 2002, coal price for power in practice has been hardly determined by supply and demand in the market. National authority releases reference price every year in coal trade conference in order to promote market deals between coal and electricity corporations, but the gap between coal price for power and market price is still large. Therefore it is necessary to establish linking mechanism between coal and electricity to reflect market supply and demand. In term of oil price formation mechanism, although marketisation degree is higher as domestic crude oil market price has already linked with international market, petrol price has yet been decided by market competition, with national authority supervised by adopting price guidance. Natural gas (at factory gate) at present still goes with two-track prices: one is planned price and another is self-sale price, leaving space for interruption by non-market factors.

Energy is the driving force of economic development. In general there is causality between energy use and economic growth although decoupling of growth with energy has been recorded in the literature. The energy sector - given its importance for the economy as a whole - has traditionally been a sector in which there has been strong government involvement. Many of the instruments of government intervention affect the final prices of energy paid by the producer and consumer. Whatever form energy subsidies take, the result is that prices fail to reflect the true economic costs of supply. Low consumer prices result in overuse, inefficient use, and waste of energy. According to the World Bank's study on 2500 companies, 55% of energy use reduction is from the effect of price regulation or adjustment, 17% from R&D.[12] In conclusion, price rationalisation and the imposition of hard budget constraints have formed the foundation of successful energy reform in China.

[12] China Price Association team: "Study on key issues related to future energy price reform". Price Theory and Practice, 2005,Vol.10.

Since the 1980s, the Chinese government has carried out a series of innovations and policy measures to reform energy markets and industrial systems. The overall direction has been to relax state control, that is, to push energy enterprises into market, and to reform the energy price system gradually, enabling the market based adjustment of the supply and demand relationships etc. In early 2006, NDRC (National Development and Reform Commission) required that price reform of the resource products go further. As price control over resource products has restricted the role of market to guide demand growth, a few negative impacts are not avoidable. First, relatively low prices do not reflect the relationship between supply and demand in the market and the scarcity of the resource. Secondly the price does not represent full costs such as resource damage and environment pollution (which remain external). Thirdly, price relations of resource products do not seem to reflect relative cost. From the price relations between electricity and substitute fuel we can see that electricity price is relatively low, as electricity price per unit Mega Joule is only equal to 70% the price of oil and natural gas, 67% the price of liquefied gas, and 56% the price of coal gas. Fourthly, imperfect market system reduces China's market power in the price formation of resource products in the international market. Therefore China must push price reform of resource product, putting prices reform of water, electricity, oil and natural gas, coal and land as start point.

3.3 Drivers for 20% Energy Intensity Reduction in the 11th Five-year Plan

The emergence of China as a major economic power has important implications for energy use and environmental outcomes at the local, regional and global level. China is currently the world's third largest energy producer and the second largest energy consumer. In 2002, China accounted for 10% of total world energy use and is projected to account for 15% of global energy use by 2025. China is the world's largest coal producer accounting for 28% of world coal production and 26% of total consumption. China is the third largest consumer of oil and is estimated to have the world's sixth largest proven reserves of oil. China has roughly 9.4% of the world's installed electricity generation capacity (second only to the United States) and over the next three decades is predicted to be responsible for up to 25% of the increase in global electricity generation. China emitted 10.6% of global carbon emission from fossil fuels in 1990 (second only to the United States) and 14.2% in 2003. This share is projected to rise to 22.2% by 2020 IEA, 2006).

China is becoming a global manufacturing base. The process of urbanisation is closely linked with that of industrialisation. Accelerated urbanisation requires large-scale construction of infrastructure and buildings, which need a great amount of energy intense materials such as steel, cement and chemicals, etc. The likely continued growth of these energy intensive industries will have significant impacts on China's energy demand and emissions in the future. Total constructed areas of buildings has been over 1 billion m2 a year in the past five years, increasing steadily from 1 billion m2 in 2001 to 1.6 billion in 2005. On the one hand, the role of being a major global producer provides an opportunity for China to achieve high-speed economic growth and increased welfare. On the other hand, China is consuming more and more energy resource.

China suffered heavily from high oil prices in the international market. Crude oil prices in the international market have risen steadily since 2003. The futures price has hit 70 dollar per barrel. According to the results of a quantitative exercise carried out by the IEA in collaboration with the OECD Economics Department and with the assistance of the International Monetary Fund Research Department, a sustained $10 per barrel increase in oil prices would result in the OECD as a whole losing 0.4% of GDP in the first two years of higher prices (2004 to 2005). Euro-zone countries, which are highly dependent on oil imports, would suffer most in the short term, their GDP dropping by 0.5% and inflation rising by 0.5% in 2004. The United States would suffer the least, with GDP falling by only 0.3%, largely because indigenous production meets a bigger share of its oil needs. Japan's GDP would fall 0.4%, with its relatively low oil intensity compensating to some extent for its almost total dependence on imported oil. It is estimated that the loss of GDP averages 0.8% in Asia and 1.6% in very poor highly indebted countries in the year following a $10 oil price increase. The loss of GDP in the Sub-Saharan African countries would be more than 3%.[13] The direct cost of crude oil price increases to China is estimated at 13.6 billion dollar in 2004, (7.5 billion dollar increase from crude oil imports and 6.1 billion dollars from oil and chemical products), equal 0.9% of GDP in 2003. If indirect costs are included, the economic lose are likely to be much larger.[14]

In an attempt to reduce fossil fuel reliance, China has made great efforts to develop renewable energy.[15] China enacted its *Renewable Energy Law* early in 2005 and it entered into effect on 1 January 2006. According to the draft *Medium and Long term National Planning of Renewable Energy Development under discussion*, the installation capacity of renewable energy generation is targeted to reach 30% of total generation capacity by 2020. Renewable energy supply will be 400-500 million ton coal equivalent, accounting for about 1/7th of primary energy consumption assuming that total primary energy consumption will be around 3.5 billion tons of coal equivalent. Although impressive in scale, the emergence of renewable energy will only slightly dent the overall dominance of coal in the foreseeable future in China. This means that China will need to respond to a range of environmental problems resulting from burning fossil fuels, including air quality (including black carbon

---

[13] Fatih Birol (Chief Economist and Head of Economic Analysis Division, International Energy Agency), 2004. "Analysis of the impact of high oil prices on the global economy".

Available at: http://www.iea.org/textbase/work/2004/cambodia/bj_session1.3.pdf.

[14] http:www.finance.sina.com.cn (August 24, 2005).

[15] Renewable energy has the impact on carbon intensity but not on energy intensity.

emissions), acid rain (from sulphur dioxide and nitrogen oxides emissions) and climate change (from carbon dioxide emissions and other greenhouse gases).

At local level, a number of studies have explored air pollution caused by energy use in China. The term “air pollution” covers a wide range of problems including emissions of particulates, sulphur dioxide, nitrous oxides and carbon dioxide. According to statistics, 70% of soot emission, 90% of sulphur dioxide, 67% of nitrogen oxides, and 70% of carbon dioxide are from burning coal, which is dominant within the energy mix. The estimated costs of air pollution, largely due to the burning of fossil fuels vary in size. A study based on data from shanghai shows that health loss arising from air pollution equal to 1.6% of GDP in 2000.[16] A study by the World Bank (1997) valued health damages from air pollution at 5% of GDP in 1995 although other studies such as Yang and Schreifels (2003) suggest this is closer to 2% of GDP.[17] A study by Garbaccio et al (1999) found that a reduction in carbon emissions of 5% every year would reduce local health costs by 0.2% of GDP annually. Health impacts account for a large proportion over pollutant’s economic loss, but findings of domestic studies varied greatly from that of World Bank. World Bank estimated the proportion of health loss to economic loss is about 80% while domestic studies found that it should be 10-20%. The major reason behind lies in the use of different methods: World Bank adopted WTP (Willing To Pay) method to assess life risk while domestic studies used human capital method which usually leads to a lower value.

According to the World Bank in 2001, 16 of the 20 most serious air polluted cities in the world are situated in China. The World Health Organisation notes that only 31% of Chinese cities met the WHO standards for air quality in 2004. Among the 11 biggest cities, soot and fine particulate in the air are estimated to kill half a million people every year and leave 400,000 people with chronic bronchus inflammation. Projection made by World Bank based on current trend indicates that China will pay 390 billion dollars as a result of diseases caused by pollution of burning coal, accounting for 13% of GDP in 2020.

One of the worst pollutants from burning fossil fuels is sulphur dioxide (SO2). This has local (health and acid rain) as well as regional (acid rain) implications. The WHO estimated that more than 600 million people are exposed to SO_2 levels above the WHO standards. SO_2 mixing with nitrogen oxides (NOX) causes acid rain. The WHO (2004) estimated that acid rain seriously affects 30% of China.[18]

[16] Kan Haidong et al. “Impact Assement of Energy Efficiency Improvement and Structure Adjustment on Inhabitant Health”. *Shanghai Environmental Science*, 2002, 21(9):520-524.
[17] Warwick J. Mckibbin. 2005. Environmental Consequences of Rising Energy use in China.
[18] World Health Organisation. 2004. Environmental health Country profile—China, WHO: Geneva.

3.4 Fulfillment of the 20% Reduction Goal and Its Implication for GHG Avoidance

During the 10th five-year plan period, the Chinese economy experienced an average growth rate of 9.48%. In 2005, GDP reached 18232.1 billion Yuan. At the same time energy consumption increased and will continue to increase as a result of sustained high-speed economic growth, rapid industrialisation and urbanisation, and upgrading of industrial capital and infrastructure structure. China consumed 2.22 billion tce in 2005. From Table 3.2 we can see that energy consumption elasticity averaged 1.165 during 10th five-year plan period.

Table 3-2. Economic Growth and Energy Consumption during the 10th five-year plan Period

	2001	2002	2003	2004	2005	Average
GDP (2000 price，10^8yuan)	107449.8	117227.7	128950.6	141974.6	156030.0	
Energy consumption (10^8 tce)	13.49	14.82	17.09	19.70	22.20	
Energy Intensity (kgce/yuan)	0.1255	0.1264	0.1325	0.1388	0.1423	
GDP growth rate (%)	8.3	9.1	10.0	10.1	9.9	9.48
Energy Consumption growth rate (%)	3.53	9.86	15.31	15.27	12.69	11.26
Energy Consumption Elasticity	0.425	1.08	1.53	1.51	1.28	1.165

Table 3-3. Future Energy Consumption Scenario (BAU)

	Unit	2000	2005	2010	2020
Coal	10^8ton	14.5	19.2	22.8	31.8
Oil	10^8ton	2.3	3.1	4.1	6.5
Natural gas	10^8 m3	239	483	863	1701
Hydro, Nuclear	10^8 KWh	3930	7575	9227	15858

etc. primary electricity					
Energy Consumption (Equivalent calorific value)	10^8tce	14.4	19.6	24.4	36.2

Source: Zhou Dadi ed., "*China's Sustainable Energy Scenarios in 2020*", China Environmental Sciences Press, Aug. 2003.

Compared to the figures in Table 3.2 and Table 3.3, it is clear that energy actual consumption during 10th five-year plan turned out to be substantially higher than the base case scenario. According to the business as usual (BAU) scenario made by ERI, energy consumption would be 1.96 billion tce in 2005 and 2.44 billion tce in 2010 (see Table 3.3). Actual energy consumption in 2004 had reached the highest projection scenario by the end of 10th five-year plan. Actual consumption in 2005 was 260 million tce higher than projected. Thus it can be concluded that if economy sustains the current level of growth, energy consumption under the period of the 11th five-year plan will exceed current expectations. This means that energy consumption in 2010 will certainly surpass 2.44 billion tce, the expected highest value.

Industrial energy consumption usually accounts for about 1/3rd of total energy consumption in the world, but in China it is nearly 70%. Energy consumption of steel, chemicals, building materials, oil refining and coking, electricity generation and heat supply sectors account for 63% of the total industrial energy consumption, 43.9% of total national energy consumption in 2004. From 2001 to 2004, total energy consumption grew at a speed of 10.1% every year, industrial energy consumption increased 12.8% annually. Total electricity consumption increased 13% every year, industrial electricity consumption increased 18% annually. The ratio of industrial energy consumption to total consumption increased from 66.6% in 2000 to 68.4 in 2004, industrial electricity consumption from 64.7% in 2000 to 77% in 2004. Elasticity of major energy consuming product production to GDP growth increased greatly from 0.89 during 6th –9th five years to 1.38 in the 10th five-year period, among these GDP elasticity of steel production was as high as 2.36, electricity consumption elasticity reached the highest value 1.77 in 2003. The figure above showed that the trend of dependency of economic growth on energy-intense products during in the 10th five-year period was increasing clear, which led to more energy consumption than expected.[19]

We consider two scenarios in order to estimate the energy demand in the event that energy intensity reduction target set in 11th five-year plan is realised:

---

[19] Zhou Dadi, 2006. " Making efforts to realise energy intensity reduction target and to establish a resource-saving society " , lecture for 21th speical seminar for the standing committee of the 10^{th} People ' s Congress of China.

Scenario 1: If annual population growth rate is set 0.7% from 2000 to 2010, in order to double GDP per capita, it is necessary to realise 7.93% GDP growth rate every year. As average GDP growth rate was 9.48% during the 10th five-year plan period, so it needs merely 6.38% to reach for annual GDP growth rate during the 11th five-year plan.

Scenario 2: Based on current trend, it is likely that China will keep at least 9% rate of economic growth. This is another scenario for discussion on energy demand.

In order to analyze the relationship between energy intensity reduction (λ) and energy consumption elasticity(ε), we can arrive at the formula $\lambda = \frac{\beta}{1+\beta}(1-\varepsilon)$, where β refers to annual growth rate of GDP.

In order to reduce energy intensity by 20% during the 11th five-year plan, annual reduction rate should need to be 4.36%. If the average annual growth rate of GDP were 6.38%, average energy consumption elasticity during the period would need to be 0.27. If the average annual growth rate of GDP is 9%, average energy consumption elasticity during the period would need to be 0.47. Thus a higher GDP growth rate would allow a higher energy consumption elasticity. As the average energy consumption elasticity was 1.165 during the period of 10th five-year plan, it would appear to be highly challenging to reduce the elasticity to under 0.5 during the 11th five-year plan (See Table 3-4).

Table 3-4. Scenarios Design of the 11th five-year plan period for 20% intensity reduction

	10th five-year plan period	11th five-year plan period	
		Scenario 1	Scenario 2
Annual Growth Rate of GDP（%)	9.48	6.38	9.0
Annual Reduction Rate of Energy Intensity (%)	(+) 5.5	4.36	4.36
Energy Consumption elasticity	1.165	0.27	0.47
Increase Rate of Energy Consumption（%)	11.26	1.72	4.23

Table 3-5. Economic Growth and Energy Consumption during the 11th five-year plan period (2000 price), with two scenarios to reach 20% intensity reduction

	2000	2005	2010		
			Scenario 1	Scenario2	Reference

GDP (10^8 Yuan)	99215	156030	212573.0	240071.5	245404.2
Energy Consumption (10^8tce)	13.0	22.2	26.36	29.77	37.85
Energy Consumption intensity (tce/10000 Yuan)	1.30	1.55	1.24	1.24	1.54

Note: The result of reference scenario was calculated using average value of 10th five-year plan period. GDP growth rate: 9.48%; energy consumption growth rate: 11.26%.

Table 3-5 shows energy demand under the two scenarios in 2010. In scenario 1, with an annual GDP growth rate of 6.38%, total GDP in 2010 reaches 21257.3 billion Yuan (based on 2000 prices). If energy intensity is 1.24tce/10^8yuan, i.e. the reduction target is realised, energy demand would be 2.636 billion tce. Under scenario 2, energy consumption demand would reach 2.977 billion tce. Therefore, it can be concluded that, based on these scenarios, even if the target to reduce 20% energy intensity in 2010 compared 2005 is realised, the total energy consumption would increase to from 2.636 billion tce to 2.977 billion tce. The realisation of this target would mean that 0.8-1.15 billion tce are saved compared to 3.785 billion tce of energy demand in the reference scenario. According to IPCC (1996) guidelines on emissions inventory, the emissions coefficients of coal, oil and natural gas are 0.7476, 0.5825 and 0.4435 respectively. This means 510-740 millions tons of carbon equivalent emission avoidance if energy mix keeps constant. Nevertheless, an additional supply of 410 to 750 million tce of energy will have to be needed. As such, it is clear that China will encounter serious challenges to the achievement of a secure sustainable energy supply.

In June 2006, NBS (the National Bureau of Statistics of China) released provincial data of energy consumption in 2005. This could be as baseline for calculating provincial energy consumption reduction rate per unit of GDP during the 11th five-year period. From Table 3-6 we can see that national energy consumption per 10000yuan is 1.22 tons coal equivalent in 2005, which means national target of energy consumption per 10000yuan GDP will be 0.976 tons after 5 years. Ningxia, Guizhou and Qinghai recorded the top three of the most energy-consuming provinces while Guangdong, Zhejiang and Jiangsu listed top 3 of the least energy-consuming provinces.

Table 3-6 Provincial Level of Energy Consumption in 2005

Region	Energy Consumption per Unit of GDP （tce/10000yuan）	Electricity Consumption per Unit of GDP （kwh/10000yuan）	Energy Consumption per Unit of Added Industrial Value （tce/1000yuan）

National Average	1.22	1358.5	2.59
Beijing	0.80	828.5	1.50
Tianjin	1.11	1040.8	1.45
Hebei	1.96	1487.6	4.41
Shanxi	2.95	2264.2	6.57
Neimenggu	2.48	1714.1	5.67
Liaoning	1.83	1386.6	3.11
Jilin	1.65	1044.7	3.25
Heilongjiang	1.46	1008.5	2.34
Shanghai	0.88	1007.2	1.18
Jiangsu	0.92	1198.2	1.67
Zhejiang	0.90	1222.2	1.49
Anhui	1.21	1082.9	3.13
Fujian	0.94	1151.8	1.45
Jiangxi	1.06	966.3	3.11
Shandong	1.28	1032.4	2.15
Henan	1.38	1277.7	4.02
Hubei	1.51	1210.0	3.50
Hunan	1.40	1035.8	2.88
Guangdong	0.79	1195.3	1.08
Guangxi	1.22	1251.7	3.19
Hainan	0.92	912.3	3.65
Chongqi	1.42	1132.3	2.75
Sichuan	1.53	1276.3	3.52
Guizhou	3.25	2460.6	5.38
Yunnan	1.73	1604.6	3.55
Tibet			
Shaanxi	1.48	1405.0	2.62
Ganus	2.26	2531.0	4.99
Qinghai	3.07	3801.8	3.44
Ningxia	4.14	4997.7	9.03
Xinjiang	2.11	1190.9	3.00

3.5 Effective Policy Instruments

From the above scenarios based illustrations, China might be expected to consume 2.636 –2.977 billion tce in 2010, even if it realises its energy intensity reduction target set as pat of 11th five-year plan. Objectively speaking, this target is ambitious and as such it will not be easy to realise. It could be achieved only through effective policies mechanisms coordinating administration, regulation and incentives, collective efforts from governments, enterprises and the public.

Energy conservation is a long-term strategic policy in China's economic and social development. For a long time, Chinese government keeps to the principle of "energy exploitation and energy saving simultaneously but energy saving in the first place". In China, energy efficiency promotion is carried out in a top-down approach and a national target is set first, and the various policies and measures are identified toward realising the target. In November 25, 2004, China released *Medium- and Long-Term Special Planning for Energy Conservation,* which put forward key fields, key projects of energy conservation and related safeguarding measures.

◆ **Industrial restructuring.** The rebound in the energy intensity ratio observed since 2001 was been mainly attributed to changes in industrial structure. Therefore, in order to realise the energy intensity reduction target it is necessary to deliver efficiency improvements by optimising and upgrading the industrial structure in the first place. Theoretically, upgrading industrial structure is a long-term factor affecting energy consumption. The industrial structure is determined by the stage of economic and social development of an economy. In developing countries, rapid industrialisation is likely to ensure a relatively high share of industrial sector within the overall economy for a relatively long time. It can be a lengthy process of economic development to optimise and upgrade industrial structure, but government can speed up the process through policy initiatives. Beginning from the late 1980s, the Chinese government started paying increased attention to the transformation of the economic growth pattern and the adjustment of the economic structure. A key component of China's industrial policies is to reduce consumption of energy and other resources, improve the comprehensive utilisation efficiency of resources and energy, promote cleaner production and prevent and control industrial pollution. China has promulgated laws and regulations in energy efficiency, energy saving, promotion of renewable energy and the like. In all the five-year plans, goals are set to reduce energy intensity and development of new and renewable energy.

◆ **Command and control.** Command and control policies will continue to play a role in improving energy efficiency. According to *Notification of the State Council on Inspection and Punishment of Environmental Pollution Cases* (2003), to shut down all enterprises belonging to fifteen small category[20], new five small category[21] and listed in catalog of product and technologies to be eliminated; to stop and neaten those enterprises which have no reasonable management measures and cannot realise emission criteria; to stop and treat those which have not finished their treatment task and are still discharging emission above criteria; to stop the production of those factories that do not implement environmental impact assessment and environmental three simultaneous systems[22] and thus could not reach environmental requirement; to

---

[20] These enterprises include small paper mills, small leather making, small dyeing matter, small homemade coke, small galvanisation, small fulling and dyeing, small pesticide, small gold filtration, small oil refinery, small plumbum refining, small asbestos, small radialisation, small hydrardyrum refining, small arsenic refinery.

[21] The new five small includes small caol fired power, small glass making, small paper mills, small oil refinery, small steel mills.

[22] The three simultaneous system of construction project refers to all infrastructure projects, technological

take compulsory measures to those that refusing termination of production. In later 2005, the State Council released *Temporary Regulation on Promoting Industrial Structure Adjustment* and guidance contents. In March 2006, the State Council issued a *Notification on Promoting Structure Adjustment of Industries with Surplus Energy Production*. Since April 2006, NDRC together with relative ministries issued guidance to expedite structural adjustment of aluminum, coal, cement, calcium carbide, coke, ferroalloy and textile industries. Some provinces attached importance and worked out detailed measures.

◆ **Standards and regulation of buildings.** In 2005, the Ministry of Construction undertook an investigation on implementation effects of buildings energy conservation around the country since energy-saving designing codes wwer issued in 2000. The findings showed that 58.53% of building designs and only 23.25% of buildings followed codes from 2000 to 2004 for the all country. China has about 40 billions square meters buildings areas in total which consume about 25% of total national energy consumption including heating, cooling, ventilation, lighting. It is worth noticing that public buildings consume 10 times energy as many as that of other housing. *Energy-saving designing standard for public buildings* entered into force since July 1, 2005. During the 11^{th} five-year period, desig standard of saving 50% energy must be implemented in new buildings strictly and some big cities such as Beijing and Tianjin should take lead to implement 65% energy-saving standard. At present, 300 millions m^2 new public building areas were completed every year. If every square meter reduce 50% energy consumption, then one year one square meter would save 30 kg coal equivalent. These new public buildings would save 9 million tons of coal equivalent every year. Currently, there are about 4.5 billions m^2 public buildings areas all the country, if reconstructed according to saving 50% energy standard, then total energy saving potential would be 135 millions tons of coal equivalent.

◆ **Economic incentives.** Firstly, to establish catalog of energy-saving equipment (products), whose keys are final energy use equipment including high efficient electromotor, wind engine, water pump, transformer, family electric facilities, lighting products and building products for energy-saving; to provide incentives for producers or consumers who produce or use energy-saving products listed in catalog; to bring energy-saving products into catalog of governmental procurement. Secondly, the government will provide subsidies of investment and capital or support of reduced interest loans to some key energy-saving projects, energy-saving technological development and demonstration projects. Expenditure needed for governmental energy-saving management and energy-saving reconstruction of governmental institutions will be brought into financial budgets of same level government. The ten key projects of energy conservation include: oil conservation and substitution, coal-firing boiler reconstruction, regional CHP, excess heat and pressure utilisation,

---

innovation projects, natural resource developing projects, and probaly environment harming engineerings that are being constructed, rebuilt and enlarged must design, construct and put establishments into use simultaneously with principal part to prevent pollution and other hazards to environment.

electrical and mechanical system energy saving, energy system optimising, energy saving building, green lighting, energy saving in governmental buildings, energy saving monitoring and technology service construction. The target is to save 240 million tce during the 11th five-year plan period through the ten key projects. Thirdly, energy pricing can be critical. Low prices result in wastage of energy and discouragement of investment and innovations to deliver energy efficiencies. Full cost pricing of energy use (social, economic and environmental) becomes a necessary solution to adjust energy consumption. Increase in energy price leads to two positive effects: (1) energy saving for the sake of cost saving; (2) investment in renewable energy as higher energy price makes such investment commercially viable. As energy is a basic input in production and consumption, change of energy price ultimately leads to adjustment of price system of the whole economy, creating favorable conditions for transforming economic structure and pattern of production and consumption. Finally, to study on financial and revenue policies which encourage to develop energy-saving vehicle and eliminate high oil-consuming vehicle; to implement fuel tax reform scheme at right time; to cancel all unreasonable provisions on restricting use and operation of low oil consuming and small emission automobiles; to study on policies that encourage to produce or consume hybrid fuel and simply electric automobiles.

From the analysis above, government plays a key role to adjust economic structure, facilitate energy saving and develop renewable energy through effective policy design and coordination among administration, law and incentives. In a top down society like China, government acts as a choice editor through relationship with retailers and suppliers and catalyses action on energy conservation. In late 2004, the Ministry of Finance and NDRC jointly issued *Implementation Notion on Governmental Procurement for Energy-saving Products* and governmental procurement bill of energy-saving products requiring governmental sectors to take energy-saving products first in procurement, which indicated that Chinese government began to lead energy-saving consumption. However, there is large room to resolve problems encountered in practice. For example, preference of energy-saving products is not of obligation. As a large energy consumer, governmental institutions taking the lead to save energy will not only reduce energy consumption of governmental institutions and save administrative expenditure, but also boost and drive energy conservation in all society. During the 11th five-year period, 20% of governmental building areas will be rebuilt according to energy-saving standards of buildings and high efficient energy-saving products will be brought into governmental procurement bill. Meanwhile, government will reform government automobiles use system and takes the lead to procure low oil consuming cars. All these measures will be implemented first in central governmental institutions, with target to reducing 10% energy consumption per building space area and per capita compared with 2002 level.

Enterprises are not only the major players of sustainable development, but also the key to realising energy intensity reduction target. In 2005, the State Council attached great importance to improve the energy use efficiency of 1000 enterprises with more than 10 thousands tce consumption each year. These enterprises are mainly in the iron and steel, non-ferrous metal, coal, power, petroleum and petrochemical, construction materials sectors. In China, manufacturing sectors consume 2/3 of the total energy. This group of top 1000 large energy industrial consumers accounts for 48% of the total industrial energy consumption, and 34% of national total energy consumption. These top 1000 energy consumers demanded 0.67 billion tce in 2004. After a five-year effort, comprehensive energy consumption of these enterprises should reach the advanced domestic level and selected enterprises should reach an advanced international level. Within five years, unit energy consumption of major products in all enterprises should be reduced by at least 5 percent. In total, energy saving shall reach 0.1 billion tce. Under the market system, energy saving will not carry through automatically. For government, its responsibility is to make feasible policies that encourage enterprises to take actions for their own benefits. Practices of SO2 pilot emissions trading prove that it is easy to say but not easy to do. China is the number one SO2 emitter in the world, and emissions increased 27% during the 10^{th} five-year plan period. Why is it not successful for SO2 pilot emission trading system with good intention? Which gave us many useful insights.

Essentially, SO2 emission trading is a good market-based mechanism first used in US. However, SO2 emission trading in China has not been a market behavior. There is no buyer but seller. On the whole, existing SO2 emission trading was carried out among power sectors while they are not willing to sell excess emission right, as with large gap of electricity demand, new construction or enlargement of power corporation is inevitable. Shortage of supply is the biggest barrier to SO2 emission trading. Of course, legislative, technological, economic and administrative factors together constitute the implementation barriers.

The public is also a key player to energy conservation. In fact, from 1999 to 2002, about 26% of energy consumption, 30% of CO2 emissions were from individual consumers' behaviors and activities. There is considerable scope to save energy in daily life. Estimates suggests, in the household sector alone, that 21.76 million tce could be saved merely from housing, automobile, motorcycle and housing electric appliances, accounting for 11% of households' energy consumption in 2002.[23] However, it is more difficult to change consumer behavior and lifestyle than to establish energy saving production pattern. Energy endowment is not rich in China and energy mix is not environmental friendly. Basic needs are yet to be met effectively but both waste and luxurious consumption can be observed. Therefore, one effective solution is to discourage luxurious consumption and to reduce wasteful consumptions. Ethical and cultural elements are involved in shaping consumers' behavior. Therefore, simple awareness raising can be slow and insufficient. Economic instrument is necessary, as rational consumers would adjust their behavior based on their budget constraints. Therefore, during the 11^{th} five-year plan, efforts must be made to improve public

[23] Wei Yiming et al. 2005. Suggestions and Solutions to Carbon Emissions in China. *Advance in Climate Change Research*. 2006. 2(1): 15-20.

energy saving awareness through financial support for public campaigns, education and training, sustainable consumption, and environment friendly consumer behavior. Taking information policies for example, a series of activities were carried out during the 16th national energy-saving publicity week (from June 11-17, 2006), including special reports, large exhibitions, introductory meetings, communications, and high-level fora, seminars and colloquium. The emphasis this year is to publicise strategic significance of energy-saving, targets of the 11th five-year plan and national energy conservation this year, key energy-saving projects and related policies and measures, law and rules, standards and criterion.

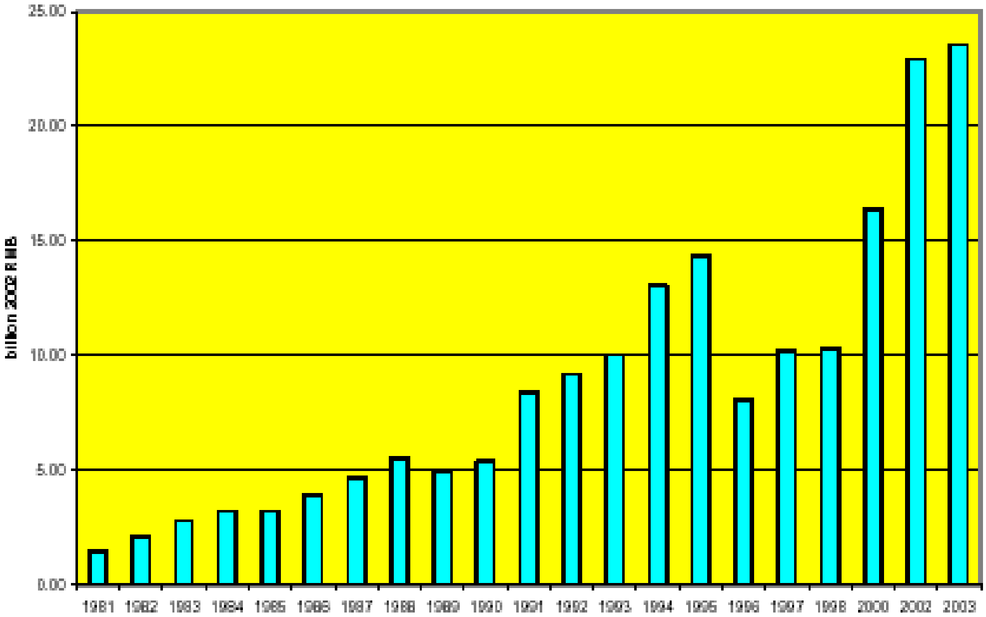
3.6 Scale of Investment and the Role of China's Domestic Capital Markets

Undoubtedly, investment plays a significant role in energy security. Despite China's long-standing efforts on both energy supply and energy conservation, investment in energy efficiency has fallen substantially, compared with that in energy supply security during the past several years. The fact is that many policies successful in the 1980s and 1990s have been significantly weakened when China begins to accelerate its step into a market-based economy.

The role of investment in energy conservation can be examined from two sides. The first is in terms of absolute scale. Figure 3.2 shows the investment in energy conservation projects in China since 1981. It is obvious that the overall investment of energy conservation has been increasing. Total investment grew from 1 billion RMB in 1981 to 14 billion RMB in 1995 (all in 2002 RMB) and then dropped due to the SDPC's determination to phase out the investment program implemented by SETC[24]. Fortunately, investment has rebounded since 1996 and grew to 23.5 billion RMB in 2003.

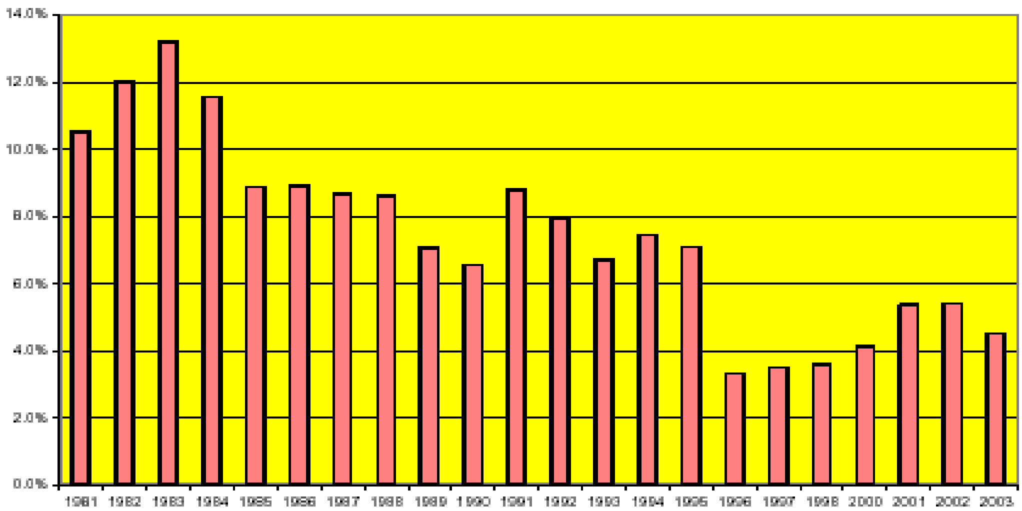
[24] SDPC: State Development and Planning Commission. SETC: National Economic and Trade Commission. In 1998, SETC was merged with SDPC to form NDRC (National Development and Reform Commission).

Figure 3-2. Investment in energy conservation projects, China



The other is from a relative perspective. Owing to the fact that total investment in energy infrastructure has increased sharply over the same period, the share of investment in energy in total energy investment has reduced. Figure 3-3 shows that the share of energy conservation investment reaches its highest level in 1983, about 13%. Since then the share has been declining and drops to only 4% in 2003.

Figure 3-3. Share of Energy Investment for Energy Conservation Projects



Experience has demonstrated that investment in energy efficiency can be far more cost-effective than that in enlarging energy supply. Given the lower level of energy efficiency in transportation, buildings and industries, China has a huge potential to save energy or reduce energy demand. Furthermore, investment in energy efficiency would also bring additional environmental benefits through reducing local air-pollution and GHG emissions. In order to significantly reduce energy intensity of China, a large volume of investment in energy efficiency will be required over the next two decades. If great efforts such as the institutional reform are initiated effectively and public and private resources are efficiently mobilised, China will definitely witness a long-term prosperous prospect, and even the global economy and environment will also enjoy its outcome.

To achieve the objective of energy intensity reduction by 20% during "11th Five Year", two aspects need to be considered when calculating the required investment. One is investment in energy supply to ensure economic growth; the other is in energy conservation. It is proven that 1.145 billion tce were saved from 1980 to 2000, equivalent to the necessary investment of 327 billion RMB in energy supply systems otherwise. While 152 billion RMB (2002 RMB) have been invested in energy conservation during the same period (Figure 3.2). Based on the data above, we can roughly estimate the amount of investment required for energy conservation and additional energy supply. Scenario analysis indicates that about 2.636 billion--2.977 billion tce will be required even if energy intensity target of "20%" reduction is achieved. This means that 0.426 billion--0.757 billion tce more than the quantity in 2005 will be needed in 2010. Compared with the reference scenario, 1.049 billion--0.806 billion tce will be saved. Therefore, it is not difficult to make a rough estimation that total investment will be 652.5 billion--806 billion RMB during "11th Five year" period, and the investment in energy conservation will account for 27%--32%.

It is obvious that investment in energy conservation will play an important role in achieving "20%" reduction in energy intensity. Unfortunately, compared with energy conservation, energy supply has been given more attention to by the government. Take electricity shortage for example, China has responded to electricity shortage by building more new power plants with billions of dollars investments. In 2004, China averagely built one giant power plant (1000 MW) per week, almost equal to California or Spain's entire generation capacity during one single year. In contrast, investment in energy conservation has fallen proportionally to about 4% of the supply investment. Experience in utility Demand Side Management (DSM) programs in the US has demonstrated that cost of energy conserved is much lower than the marginal cost of supply (Kushler et al 2004). Not only could investment in energy efficiency in China defer supply investment in the future with much lower cost, it also brings considerable economic and environmental benefits. Therefore, it is necessary for China to boost substantially and quickly its investment in energy efficiency.

Besides inducement by the government's inputs, the fundamental way is to mobilise resources of the whole society for energy conservation. In recent years, enterprises have more initiatives in energy saving due to rapid increase in energy prices. Enterprises lower the cost of production through developing high-efficiency energy-saving equipment, eliminating low-efficiency product, and strengthening energy conservation capacity. Some enterprises worry that efforts in energy conservation will deteriorate their financial situation. Some still have doubt on the effectiveness of energy conservation, which certainly hampers enterprises' implementation of energy improvement plan.

Foreign experience shows that energy service companies which provide feasible and cost-effective energy services for customers through energy management contract can overcome many obstacles in energy saving, such as enterprises' weak consciousness in energy-saving investment, inadequate funds for energy conservation projects, low-efficiency energy conservation projects and inefficient energy-saving services. In November 2004, "energy-saving strategy for mid-and long-term" by NDRC encouraged introduction of "energy management contract" by which building a resource-saving society will be safeguarded. It is also stated in the strategy for “11th Five Year” that "energy management contract" has enormous potential in changing the pattern of economic growth and improving the efficiency of resource use in order to achieve " 20%" reduction in energy intensity.

From above study in this section we know that total scale of energy-saving investment in the 11th five-year period is about 180-250 billions. In fact, the target of Energy Management Company Association (EMCA) of China Energy Conservation Association is to invest 50 billions for energy conservation and gain 32 billions benefit during the 11th five-year period. The 18 billions capital gap may need energy-saving services company to play a role. Governmental institution, marketplace, hotel, school and hospital are the best client of EMCO.

Started in the 1970s, energy-saving services company (ESCO abroad while EMCO at home) delivers energy-saving services by means of "energy management contract" which is a new market-based mechanism. Concretely, the specific contract is signed between the energy-saving services company and the customer enterprise. The contract stipulates that benefits originate from energy-saving projects and the cost of projects be covered by part of energy-saving benefits. Generally speaking, energy-saving services companies are responsible for investment required for projects and also have full ownership of energy-saving equipments. This kind of energy conservation focuses on upgrading existing equipments by using the future proceeds from energy saving, which contributes a lot to lowering the operating costs of enterprises.

As an emerging industry, however, at present, most energy-saving services companies are private enterprises with prevailing problems such as the shortage of financial strength, the scarcity of financial knowledge, the irregularity of financial management and the lower reputation in the bank records, which become obstacles to obtain enough financial supports through various financing channels including bank loans, equity financing, venture capital (investment funds), offshore financing, project financing and etc. Undoubtedly, the development of China's energy-saving industry is impeded seriously.

International organisations have a big role to play in the promotion of China's energy industry. For example, WB/GEF's energy conservation project in China can be thought as the incubator for Chinese energy efficiency industries. With the "WB / GEF project launched in 1997, three demonstration companies for the energy-saving services have been operating successfully, and have conducted 304 energy-saving projects by means of "energy management contract" with 0.78 billion RMB of the total investment, about 973,300 tce per year of the energy conservation. Currently, WB/GEF's energy conservation project has entered the second phase whose goal is to facilitate the industrialisation of energy saving services company. To achieve this goal, a special commercial-loan guarantee scheme has been established with the grant by GEF targeting at enriching financing opportunities for EMCO. Actually, commercial-loan guarantee schemes, operating since 2004, have covered 23 energy-saving services companies, 16 provinces, municipalities and autonomous regions, and 52 energy-saving projects. All these promote energy-saving investment by 295.0554 million RMB, about 3.31 times that of the first fund for guarantee purpose by WB (11 million U.S. dollars).

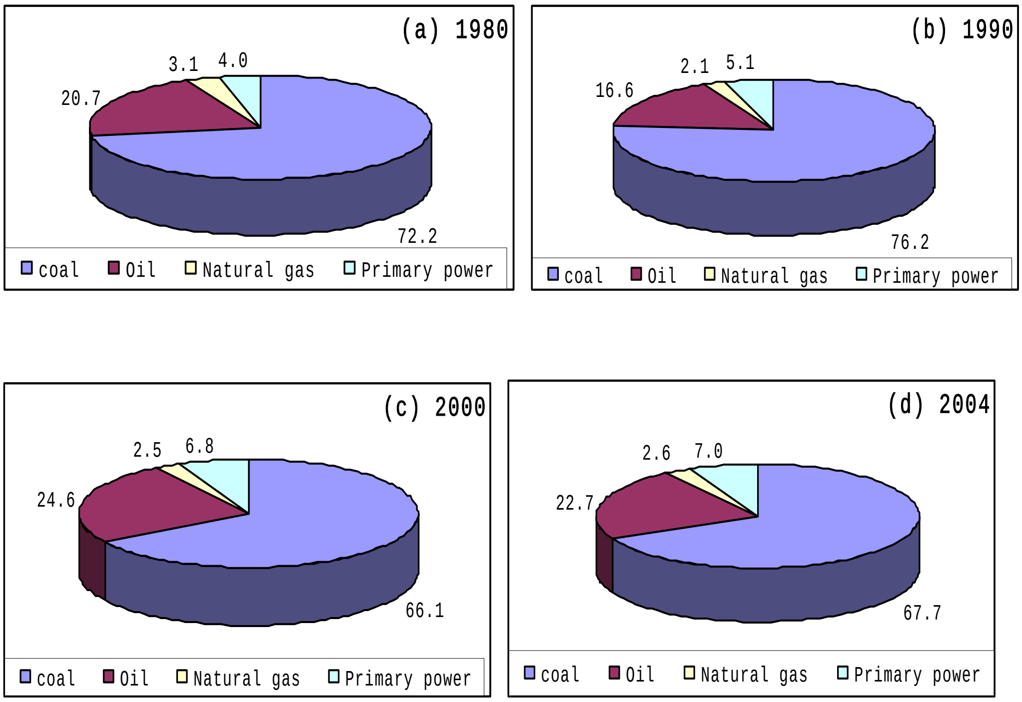
Besides improved financing in quantity, overall financing environment has also been enhanced substantially. For instance, China National Investment & Guaranty Co., LTD (CNIGC) is responsible for the implementation of WB/GEF's second-phase energy conservation project by throwing actively itself into extensive cooperation with banks. July 2004, CNIGC and Beijing Bank signed the "Cooperation agreement on loan guarantees for energy saving service companies", providing favorable interest rate by Beijing Bank to energy-saving service companies supported by CNIGC. Since then CNIGC has been dedicated to enlarging collaboration with other banks such as Bank of China, China Merchants Bank and so on. Moreover, CNIGC also pays more attention to cooperate with local guarantee agencies. Till 2004, 16 local guarantee agencies have signed "Cooperation agreement on loan guarantees for energy saving service companies" with CNIGC, and 7 among 16 agencies have conducted business cooperation.

4. National objectives for energy diversification

4.1 Past experiences with change in fuel mix

Despite efforts made to diversify energy sources during the past two decades, the dominant status of coal is unchallengeable. As shown in Fig 4-1(a-d), the share of coal in primary energy consumption decreased from 72.2% in 1980 to 66.1% in 2000 and 65.3% in 2001. It is worth noting that the share of coal was slightly increased since 2001 (reaching 67.7% in 2004) as a result of rapid economic development and high international oil and gas prices. However, at the same time, the share of primary power including hydropower and new renewable energy such as solar, wind power etc. has increased from 4.0% in 1980 to 7.0 % in 2004, peaking at 7.8% in 2002.

Fig4-1 (a)-(d) Changes of energy mix during 1980-2004



Source: China Statistical Yearbook 2005.

Oil is the second largest part of the energy mix in China. China became a net oil importer in1993 and since then oil consumption and importation has increased steadily. The share of oil peaked at 24.6% in 2000. As domestic oil production is unable to meet the increasing demand, the gap has to be in filled with oil imports from international market. In 2005, oil consumption reached 350 million tons, with about 40% being imported from international market.

4.2 Medium and long term objectives and reasons behind

4.2.1Considerations on promoting energy diversification

Energy diversification in order to optimise the energy mix is one of the central objectives of Chinese energy strategy. The main considerations in promoting energy diversification lie in energy security, environmental protection and sustainable development.

As discussed in section 2, with rapid growth of energy demand and high dependence on imported oil, energy security has become one of the greatest challenges for China in the 21st century. Oil supply lies at the heart of energy security. Oil insecurity could result from a series of risks, such as:

- Increasing oil price: China spent $43 billion on importing oil in 2004. The expenditure went up to $50 billion in 2005. China suffered heavily from the fluctuant high price
- Resources shortage: Currently, world oil production is about 3.8 billion tons, of which only 2.2 billion tons enter the international market. The US and Japan are the two largest importers whose annual imports are about 700 and 260 million tons respectively. Other big importers include South Korea, Germany and France which each import over 100 million tons per year. As a new comer, China has begun to influence patterns of international resources allocation.
- Marine transport security: 70% of China's oil imports pass through the Malacca Channel. However, China does not have the capacity to protect this (and other) marine transport routes. Marine transport security is thus becoming an increasing concern, as larger and larger volumes of oil have to be shipped by sea.
- Political risks: Oil has become an important strategic resources rather than an ordinary good. International political relations directly influence the international oil market.

In addition to the security issues relating to oil products as well as pollution and sustainable development constraints on the use of coal, energy diversification can potentially contribute greatly to increasing the quantity and scale of production by expanding the supply of energy. Renewable energy sources are not only clean, but also secure and sustainable (whereas fossil fuels are exhaustible resources). Although renewables are not currently commercially competitive compared to conventional fossil fuels, they do represent an important source of energy now and are expected to play a far greater role in securing future energy supply, environmental quality and sustainable development. As such, the promotion of these sources should be (and is) high on the government agenda.

Environmental protection is another important reason to promote energy diversification. As discussed in section 2, over dependence on coal will result in low efficiency of energy utilisation and serious environmental impacts. Experts estimate that 90 percent of the sulfur and 70 percent of the smoke and dust in the atmosphere come from coal combustion. Although the dominance of coal seems unchangeable in the foreseeable future due to constraints on natural resources and the existence of cost effective substitutes, energy diversification does help to improve air pollution and environmental degradation.

Furthermore, renewable energy development will also play an important role in the provision of energy services in remote areas, where centralised power networks cannot reach economically. China is geographically large with uneven development levels among different regions. By 2001, 30 million residents of more than 20,000 villages were without access to electricity. Some of them are without the guarantee of basic energy consumption. Combustion of traditional biomass energy is the primary method of consuming energy in most areas, especially in areas where energy supply is short and utilisation efficiency is low. Most of them live in Western China, where renewable energy resources are relatively rich. Government has made great efforts to promote electrification in rural area and integrate it into poverty alleviation and sustainable development. During the period of the "Tenth Five Year Plan", 400 counties have achieved electrification by small hydropower development. In 2004, the power generated was equivalent to 23.4 Mtc, reducing 35MtC CO_2 emission and other pollutants. Further more, 3.58 million tons of biomass was substituted by electricity, which is equivalent to save 2.53 million ha forests. By the end of 2004, hydropower capacity in rural areas has reached 38.75GW, which occupies 37% of the total hydropower capacity in China. Over 1600 counties have established hydropower stations, with 800 mainly relying on hydro-electricity (Pan et all, 2006) Renewable energy development is an efficient way to solve the problem as demonstrated by several projects that deliver power to rural areas.

4.2.2 Targets of energy diversification by 2020

Medium and long-term objectives for energy diversification have been discussed intensively over a long period. For example, according to the scenario of the sustainable energy strategy developed by EF-DRC, the target of energy diversification by 2020 was to:

- Reduce the share of coal to around 60%,
- Control the dependence on imported oil to less than 60%,
- Ensure renewable energy utilisation of over 525Mtce and electricity generation from renewable energy over 100 GW,

In this case, the primary energy consumption could be below 2500Mtce and 45%-60% emission of major pollutants could be reduced. Unfortunately, all these projections seem out of date and the above targets are impossibe to be achievable.

With social and economic development and advancement of sciences and technology, the national objectives for energy diversification have been adjusted accordingly.

China enacted its *Renewable Energy Law* early in 2005 and it entered into effect on 1 January 2006. A new *Medium and Long term National Planning of Renewable Development* has been ratified by the National Congress and will be issued soon. According to the new plans, the installation capacity of renewable energy generation is targeted to reach 30% of total generation capacity by 2020, of which hydro, wind, solar, and biomass generation should account for 300GW, 30GW, 1.8GW and 30GW respectively. Renewable energy supply will be 400-500 Mtce, accounting for about 1/7th of primary energy consumption assuming the total primary energy consumption will be around 3.5 billion tons of coal equivalent. This target is more ambitious than that of the " Outline of New and Renewable Energy Development (1996-2010) " published in 1996.

On Nov.6, 2005, the first assessment report on the status and outlook of wind power generation development in China was published. The projections of this report were even more ambitious. It is declared that China will be able to realise 40 GW of installed capacity by 2020. Under this proposal, wind power would generate 80 billion kWh annually to meet the demand of 80 million people thereby avoiding 48 million tons CO2 emission   If these goals could be achieved, wind power would assume a greater share of be total electricity generation than nuclear power.

China's nuclear power development is drawing the attention of the international community. Today when the world's nuclear power development is slowing down, nuclear power companies throughout the world, mainly in developed countries, expect that China will be the largest nuclear power market in the 21st century. As at the end of April 2005, the installed capacity totaled 8.7 million kW with 11 reactors (including the 2 million kW of the two reactors under construction). However, the current share of nuclear power in total installed capacity is small, only 1.5% (as at the end of 2004), and the share in total power generation is also low 2.3% (again, as at the end of 2004). As part of the national objective for energy diversification, nuclear power could also play an important role, although there exists controversies around this role both domestically and internationally. According to official planning, by 2020, installed capacity will reach 40 GW supplying 4% of total installation capacity for power generation in China. Electricity production is expected to reach 6% of total volume. In this case, in the coming 15 years, about 30 reactors will need to be constructed (each having a 1 million kW capacity).

Besides renewable energy and nuclear power, natural gas may offer another option for energy diversification. Production and consumption of natural gas reached 40.8 and 39.0 billion m^3 respectively in 2004 but accounting for only 2.6% of the overall energy mix in 2004. In recent years, consumption of natural gas has increased rapidly. It is estimated that the demand will go up to 200 billion m^3 by 2020 with estimates for further growth in the medium and long-term. This consumption growth would largely need to be met by importation.

4.3 Barriers, policy instruments and keys risks

The following discussions are made on development of renewable energy, nuclear power and natural gas utilisation.

4.3.1 Renewable Energy

The main barriers for the development of renewable energy in China are linked to costs, market share, and policy related issues.

Firstly, Renewable energy has a higher cost than traditional energy sources. This is the biggest obstacle to its wider scale commercialisation and distribution. It is estimated that the cost of small-scale hydropower is 1.2 times, biogas 1.5 times, wind power 1.7 times, and PV 11 to 18 times the cost of coal–burning power[25].

Secondly, the current market for renewable energy in China is small and full of uncertainty. Reducing production costs and improving technological reliability are crucial to cultivating and expanding the market further. Appropriate institutional arrangements would also be helpful in supporting these needs.

Finally, as stated at the Beijing Renewable Energy Conference held in 2005, there are a number of significant policy challenges to wider use of renewable energy. Government policies have a significant impact on attracting private sector investment and determining the pace of expansion of renewable energy (as demonstrated in several developed and developing countries). Experiences show that successful actions for scaling up the use of renewable energy include:

- Creating supportive policy, legal, and institutional frameworks;
- Securing public sector commitment, including for R&D and procurement policies;
- Promoting private sector involvement and stronger alignment between policy timeframes and timelines for investment;
- Supporting the establishment of national renewable energy industries including small and medium enterprises; and
- Providing access to affordable finance, including micro-finance, and consumer credit mechanisms.

In order to promote the development of renewable energy, Chinese government has consistently pursued a positive approach through the making of a series of laws, regulations and industrial policies. China Renewable Energy Law that was enacted on Feb. 28th, 2005 and entered into force on 1st of January, 2006, reconfirm the important role of renewable energy in China's national energy strategy and sets several basic principles. . The Medium and Long-term Energy Development Strategy and Plan to 2020 are under formulation and will be finalised soon. Economic incentives, particularly subsides, are provided by the central and local governments for R&D on key technologies, investment in renewable village power systems in remote rural areas, exemptions on VAT or custom duties and pricing policy in favor of renewable energy. For example, the normal VAT (value added tax) is 17%. But, favorite tax rates applied to some renewable energy have been reduced to 8.5% for wind power, 13% for biomass and 6% for small hydropower and 0 for Landfill gas utilisation.

[25] Renewable Energy Strategy and Policy, one of sectoral reports of China National Energy Strategy and Policy 2020, EF-DRC project, 2003.

However, some policies have not been well implemented and need to be reformed to create a positive investment climate to attract private capital for renewable energy and to expand international cooperation in this field. Currently, the government encourages CDM project of renewable energy as an effective way to attract international advanced technologies and investment. In the long term, if domestic SO_2 emission trading system could be extended to carbon, it would provide extra incentives to enhance the competitiveness of renewables.

4.3.2 Nuclear power

As for nuclear power, though hardly any official documents are quoted as opposing its development, there are views suggesting that nuclear power be considered carefully. Here are some typical arguments, such as:

Firstly, China has extremely high potential for energy conservation and renewable energy development, so efforts should be made in these areas as priority.

Secondly, nuclear power safety issues, particularly the problem of the disposal of highly radioactive nuclear waste, remain unsolved.

Thirdly, there is a need to reconsider whether or not nuclear power generation will contribute to energy security. It cannot be denied that accidents and incidents could induce movements against nuclear power and bring about an electric power supply crisis.

Fourthly, pricing mechanisms in the power generation system need to be reformed based on comprehensive comparison on economic, social and environmental costs and benefits of different resources of power generation.

Last but not the least, uranium reserves in China are limited and nuclear power potentially raising security of supply issues.

Besides public awareness on security, huge initial investment of nuclear power construction could be one of main barriers for future development. Currently, nuclear investment completely relies on public finance, even state-owned large energy companies are not allowed to hold the shares. Owing to the high risk, uncertainty and strong government regulation in the nuclear sector, private capital can hardly get involved in the process. If the investment is mainly from the public sources, the potential for rapid expansion can be limited.

4.3.3 Natural gas utilisation

An effective risk management system is needed to avoid the potential for adverse impacts arising from energy diversification. Natural gas provides a good illustrative example: China has been promoting the utilisation of natural gas as a substitute to coal and oil in the past decade. However, with increasing oil and gas prices in recent years, China has had to change its mind and adjust its policies to avoid economic risks despite the fact that gas-based power generation have a much higher efficiency and better environmental performance than coal-based alternatives. Within 18 months before July 2005, the Chinese government approved the building of 168 new power stations, most of them are coal-based power ones. At present, only 2.1% of power stations are gas-based, of which about 40% of this installed capacity have been shut down due to a shortage of gas supplies and high fuel costs.

Similar stories are also reported in the UK. Great emission reductions were achieved from fuel shift from coal to gas, but with gas price surging, companies opted for shifting back to coal for cost reasons. This could partly explain the upward trend of GHG emissions in the UK in the past several years.

Up to now, there are no specific law and regulations such as taxation to internalise the environmental cost of coal burning. Thus natural gas does not seem to have comparative advantages for its good environmental performance. 4.4 Implications for GHG avoidance

Reducing the share of coal in the energy mix has clear implications for GHG emissions avoidance. Table 4-1 shows the changes of primary energy consumption and energy mix in China. Scenario S2 from Zhou et al China's Sustainable Energy Scenarios in 2020 is used for illustration.

Table 4-1 Changes of Primary Energy Consumption and Energy Mix in China

	1990 (Mtce)	Energy mix (%)	2000 (Mtce)	Energy mix (%)	2020-S2 Scenario * (Mtce)	Energy mix (%)
Primary energy consumption	987	100	1303	100	2762	100
Coal	752	76.2	861	66.1	1648	59.7
Oil	164	16.6	321	24.6	690	25.0
Natural gas	21	2.1	33	2.5	225	8.2
Primary power**	50	5.1	89	6.8	198	7.2

Note: *Scenario S2 is from Zhou Dadi et al: China's Sustainable Energy Scenarios in 2020, China Environmental Sciences Press, 2003. ** Nuclear is included in primary energy.

Energy diversification has great potential for GHG avoidance due to energy substitution of carbon intensive coal. Energy efficiency of oil and gas utilisation is estimated to be 30% and 23% higher than coal use. According to IPCC guidelines on emissions inventory, the emissions coefficients of coal, oil and natural gas are 0.7476, 0.5825 and 0.4435 respectively[26]. The details of calculation are shown in Table 4-2.

For example, comparing energy mix in 2000 to 1990, the share of oil increases considerably. Assuming the share of oil remained as same as in 1990, 1303 Mtce times 16.6% would be 215.8 Mtce. The difference between the actual oil consumption in 2000 and this number, 321 minus 215.8, is 104.2 Mtce, which is the amount of coal substituted by oil due to changes of energy mix. Since the emission coefficient of oil is less than that of coal, 17.21 MtC could be reduced from substitution. Further more, in terminal energy consumption, is equivalent to 23.97 Mtce more than same amount of coal due to 23% higher energy efficiency for oil use. In other words, 23.97 Mtce of coal saved leads to avoidance of 17.92 MtC CO2 emissions. The calculation for natural gas is similar to oil. As for primary power, the data in Table 4-1 has been shifted with average coal consumption of coal-burned power generation. Thus, no energy saved by substitution could be displayed but increased share of primary power did lead to certain amount of emission avoidance.

Similar calculation has been done to compare energy mix in 2020-S2 scenario to 2000, but things seem quite different to analysis above. In Scenario S2, the share of oil in the energy mix has changed only a little. An increased share of natural gas and primary power are the main drivers to reduce the share of coal. The analysis seems optimistic for fuel shifting from coal to natural gas. High efficiency and low emissions of natural gas would significantly contribute to climate change mitigation if China had sufficient natural gas supply as the scenarios projected. Renewable energy development could also be promising options to control GHG emissions in the future.

Table 4-2 Estimated Implications of Energy Diversification on GHG avoidance

2000 compared to 1990	Coal equivalent (Mtce)	Difference of emissions coefficient	GHG avoidance (MtC)
Substituted by oil	104.24	0.1651	17.21
Saved by oil use	23.97	0.7476	17.92
Substituted by natural gas	5.21	0.3041	1.58
Saved by natural gas use	1.56	0.7476	1.17
Substituted by primary power	22.15	0.7476	0.17
In total	157	-	38.06
2020 compared to 2000	Coal equivalent (Mtce)	Difference of emissions coefficient	GHG avoidance (MtC)

26 The number may vary due to carbon contents. However, coal equivalent is measured in standard terms and this coefficient is in general applicable.

Substituted by oil	11.05	0.1651	1.82
Saved by oil use	2.54	0.7476	1.90
Substituted by natural gas	157.43	0.3041	47.87
Saved natural gas use	47.23	0.7476	35.31
Primary power	11.05	0.7476	8.26
In total		-	95.16

Source: calculated by author

5 International Cooperation for Reduction of Carbon Intensity

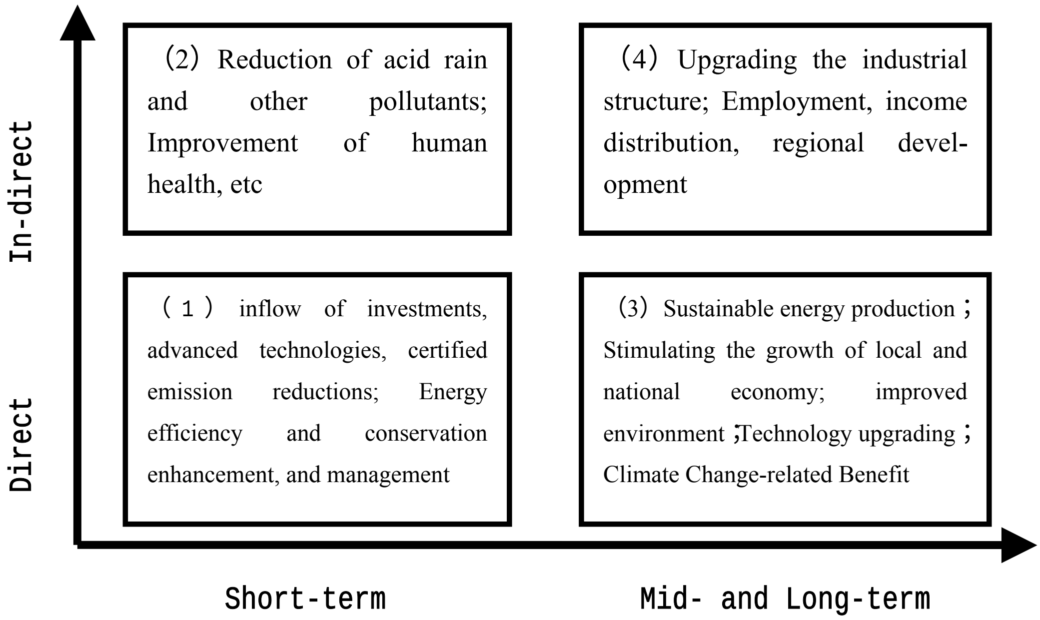
5.1 Introduction

China's participation in international regimes on all issues has increased dramatically during the past two and half decades of the 'reform and open-door policy'. China's accession to the WTO has in turn contributed substantially to technological progress and economic growth. Similar to many other areas in international cooperation, climate change mitigation is taken into also account China's sustainable development strategy as part of international cooperation to reduce the carbon intensity. In this section, we first look at the impacts of the existing international cooperation with China in the short and long term. Next, we examine the key factors for widening and deepening international cooperation. Finally, we consider options for the potential evolution of international cooperation mechanisms to reduce carbon intensity target.

5.2 Role of International Cooperation on Technology Transfer

Generally, the impact study should focus mainly on two dimensions --direct/indirect and short term/long term----on potential impacts of China's participation in the international cooperation. Figure 5-1 summarises all the possible benefits that international cooperation may bring to China. With regard to climate change, the short-term goal of the international cooperation is to cope with climate change through enhancing carbon management and improving energy efficiency, while the long-term goal is to reduce GHGs and accordingly to mitigate future climate change through financing the development of low carbon technologies.

Figure 5-1 Two-Dimensional Impacts for China's Participation in International Cooperation



5.2.1 Short-term Role

China benefits from international cooperation on carbon intensity reduction through inflows of financial sources (including commercial investment and foreign aid), and the acquisition of equipment, information and technologies (including technical expertise). In fact, different forms of cooperation aimed at conferring these different benefits (investment, equipment and technology) are closely connected, because technology transfer can take various forms, including know-how training, blueprints and manuals, technical assistance or service, equipment and critical parts and components.

Financial Aspect in terms of Quantity and Scale

The magnitude of international investment can be used to illustrate the potential effectiveness of international cooperation in achieving strategic carbon goals of the participants. Being both a major contributor and a potential major victim of climate change, China has also become one of the major recipients of climate-related aid from bilateral and multilateral cooperation projects on climate change from the World Bank and other agencies including the UNDP, and the Asian Development Bank. For instance, China received 17% of the total funding for climate change projects from the Global Environmental Facility (GEF) between 1991 and 2002. Of the nearly $467 million GEF invested in China, more than $300 million has been spent on climate change related projects, such as energy efficiency, renewable energy etc (Good 2004; Heggelund et al 2005).[27]

While other sources of investment are clearly of greater volume, climate-related financial flows are not insignificant, particularly in resource-constrained economies, and given that the recipient sectors are not always traditional recipients of large volume FDI. Take the current development status of wind energy as an example: more than 60% of the investment comes from bilateral and multilateral institutions and domestic investment is about 40%. [28]

CDM projects have been established in China since 2002. From 2002 to 2005, total foreign investment of about 7.73 billion RMB (US$ 0.93 billion) has been provided for the development of 4 CDM projects in China, including the: Xiaogushan Hydro Project in 2003, Huitengxile Wind Project in 2004, Zhaonan Wind Project in 2005 and Daliangzi Hydro Project in 2005. [29]

Moreover, some other projects are in pipeline (Table 2). One estimate indicates that investment flow under CDM in 2010 will reach US$5.2----17.4 billion under perfect conditions (such as perfect competition, complete information, non-market distortions, and etc.) and the CDM investment in China will have a share of 6%----20% (Zou Ji, 2005). [30] Another study by the Qinghua University shows similar results that the CDM investment in China will increase to 3.94 billion RMB. [31]

Furthermore, other cooperation in carbon-associated areas has also been effective. The APP (Asia-Pacific Partnership on Clean Development and Climate) countries will work with multilateral development banks on financing for initiatives and programs identified by the task forces that will expand the use of technologies and practices designed to promote objectives of the Partnership. With regard to funding, the United States Government intends $52 million in supporting the work of the Partnership as part of the President's Fiscal Year 2007 Budget. The Australian Government plans to invest $100 million over five years to deliver practical outcomes by supporting Australia's involvement in the Partnership. 25 per cent of this investment has been specifically earmarked for renewable projects.

Table 5-1 Climate Change (CDM) Activities

Renewable Energy Projects		
Area	Project Title	Outline
Wind	Huitengxile 25.8MW Project	514,291 CERs over 10 Year Crediting period from 2004, Uses AM0005, Validated,

[27] Ida Bjorkum, 2005, China in the International Politics of Climate Change: A Foreign Policy Analysis,
[28] Lin, Wei (Toni), 2004, Climate Change & Renewable Energy in China, Chinese Renewable Energy Industries Association (CREIA), 3-5 November 2004, Auckland, New Zealand, The Australia-New Zealand Conference & Trade Expo 2004: Climate Change & Business
[29] Qinghua, 2005.
[30] Business from the Kyoto Protocol, See http://www.newenergy.org.cn/html/2005-2/20052416.html
[31] The Kyoto Protocol: a Fleeting Business Opportunities,
http://www.lifeweek.com.cn/temp/ok/third/200534q.htm

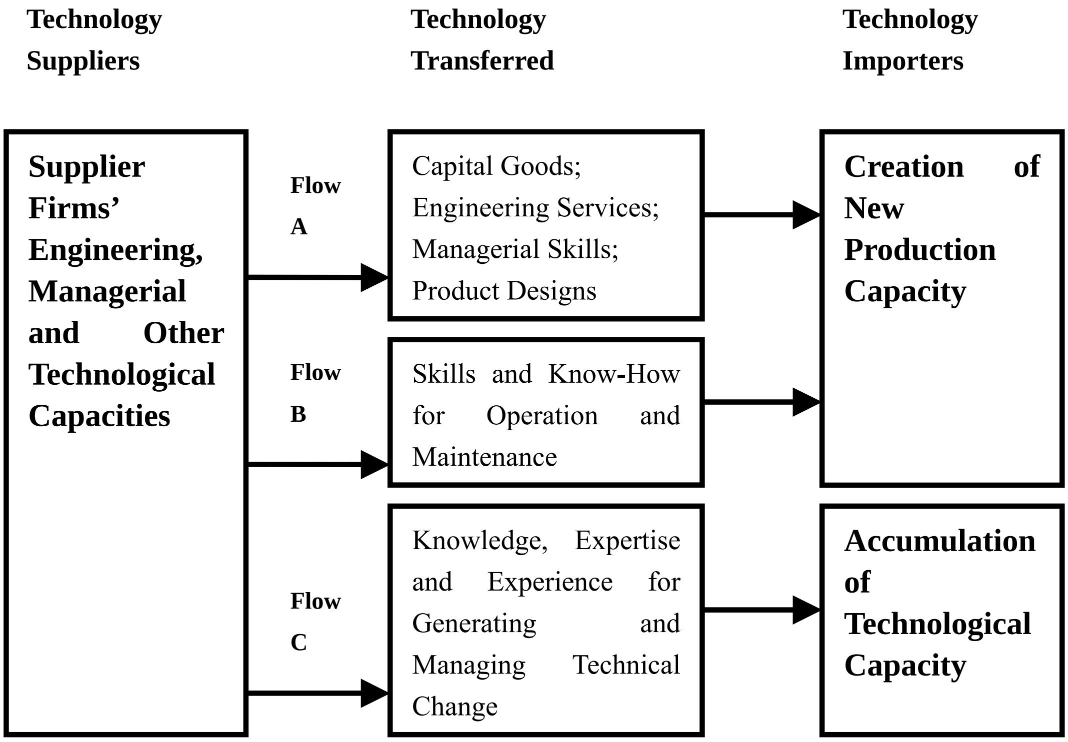
		Imminent submission to UNFCCC website
Wind	Mingmen 49 MW project	800,000 CERs, 8 year crediting period from 2005, uses AM0005, PDD under development
Hydro	Yunnan 32 MW project	500, 000 CERs, 10 year crediting period from 2005, uses AM0005, PDD under development
Biomass	GIEC rice husk gasification project	39,901 CERs per year, 10 year crediting period from 2005, new methodology, PDD under development
Tidal	Yalu River 300 MW	840,000 CERs per year, 10 year crediting period from 2008, New Methodology, Development phase
SWH	Lijiang	726,000 CERs, 10 year crediting period from 2003, new methodology, PDD under development
Landfill	Nanjing, 1.5MW	60,000 CERs, 10 Year Crediting period, to use approved consolidated methodology, trying to raise underlying finance
Energy Efficiency		
Area	Project Title	Outline
Waste Heat Recovery & Use for Power	Taishan Cement Works 13.2MW Project	150,000 CERs per year, 10 Year Crediting period from 2005, New Methodology, Aim to submit to 28th October Methodology Panel round
Waste Gas to Power	Shanghai ESCO Power Plant Project	47,000 CERs per year, 10 year crediting period from 2000, Similar to Jindals Methodology in India
District Heating	Haerbin Dao Li District Heating Project 1	To be drafted
Coal Mine Methane		
Area	Project Title	Outline
CMM to power	Jincheng	2,900,000 CERs per year, 10 year crediting period, follow the methodology of Hegang CBM for power project, PDD under development
CMM to power	Nanshan 1.8MW	62,400 CERs per year, 10 Year Crediting period, New Methodology, NM0066
CMM to Furnace	Yangquan (1)	>600,000 CERs per year, 10 year crediting period, PDD under development now, requires new methodology
CMM to power & flared excess	Panshan 4MW, Huainan	278,000 CERs per year, 10 Year Crediting period, New Methodology, Aim to submit to 28th October Methodology Panel round

Note: CER – Certified Emission Reductions; PDD – Project Design Document. Source: Lin, Wei (Toni), 2004, Climate Change & Renewable Energy in China, Chinese Renewable Energy Industries Association (CREIA), 3-5 November 2004, Auckland, New Zealand, The Australia-New Zealand Conference & Trade Expo 2004: Climate Change & Business

Technological Deployment and Diffusion

Quality and Type of Technology Transfer. Figure 5-2 provides a general classification of international technology transfer.[32] It shows that internationally transferred technologies differ widely in their form and function. Certainly, the question we need to answer is what kind of technology can China obtain through the international carbon cooperation.

Figure 5-2 the Technological Content of International Technology Transfer



Source: Jim Watson, The Transfer of Clean Coal Technologies to China: Learning From Experience, a working paper submitted to the Working Group on Trade and Environment of the China Council for International Cooperation on Environment and Development in 1999.

The types of technology that China can acquire through cooperation are closely linked to the motives of the international project partner. Usually, foreign CDM investors purchase mitigation equipment from the manufacturers in industrialised countries;

[32] Cited by Jim Watson in *The Transfer of Clean Coal Technologies to China: Learning From Experience*, SPRU, University of Sussex, a working paper submitted to the Working Group on Trade and Environment of the China Council for International Cooperation on Environment and Development in 1999.

then cooperate with a partner in a host country and jointly invest in a mutually agreed-upon and approved CDM project. Obviously, in these kinds of projects China only obtains mitigation equipments or capital goods----Flow A technology in Figure 5-1. While technologies (2) to (4) (figure 5-1) in Flow A and technologies in Flow B and Flow C (figure 5-2) involve transfer of the capacity to manufacture mitigation equipment or improve the ability to manufacture equipment. Transferring such technological capacity will threaten the technological superiority of the partner, thus threatening their potential to sustain commercial profits from their technological superiority.

Certainly, there are still good examples of Flow B and Flow C. GEF's support for highly-efficient industrial boilers in China has been a very successful story. This large Global Environment Facility (GEF) project to introduce efficient coal-fired industrial boilers in China has led to an estimated 637 Mt of emission reductions – about one-third of the total reductions for all GEF climate-related projects – at a cost of about US$ 0.03 per avoided tonne of CO2.[33] The project did not seek simply to market and sell efficient boilers to China. Instead it transferred the knowledge, the intellectual property rights and the tools to allow the Chinese boiler industry to produce its own efficient boilers. In other words, besides acquiring advanced equipment from abroad to upgrade these firms' designs for new boiler models, the project has also provided technical assistance to the boiler manufacturers to develop, produce, market, and finance the newer models and to strengthen customer service programs. In addition, the project provides technical assistance and training for industrial enterprises to understand, purchase, and operate high-efficiency boilers, along with support for research institutes and government agencies to disseminate the technologies to other boiler manufacturers.

The APP, focusing on developing and deploying new technologies that will put economies on low-emissions trajectories, puts an emphasis on focusing on practical action such as working on cleaner coal and more efficient power for energy-intensive industries. Table 5-2 shows that the Partner countries establish an initial set of public/private task forces that focus on eight areas. Cooperative efforts which aim to build capacity and transfer technologies that enable action on climate change are also making a significant contribution to China's low carbon transition and the overall climate change challenge.

Table 5-2 Asia-Pacific Partnership Task Forces

	Chair	Co-Chair
Cleaner fossil energy	Australia	China
Renewable Energy and distributed generation	Korea	Australia
Power generation and transmission	US	China

33 International Energy Technology Collaboration and Climate Change Mitigation, 2005, p.11 http://www.iea.org/Textbase/papers/2005/cp_synthesis.pdf

Steel	Japan	India
Aluminum	Australia	US
Cement	Japan	
Coal mining	US	India
Buildings and appliances	Korea	US

Source: APP

Problems in Technology Transfer: It is apparent that international carbon cooperation will contribute significantly to resource saving and production efficiency in the long run through expediting the efficiency promotion of energy and related sectors. However, in the near term there are still some problems in relation to international carbon cooperation, which constrain the realisation of its full potential. These include:

- Shortage of financing;
- High transaction cost with respect to procedures and formalities;
- Tendency to be small in scale in terms of carbon reductions;
- Limited impacts on enhancement of domestic innovation capacity.

Relatively weak protection of intellectual property rights may be the root cause for technology transfer. Foreign companies are often unwilling to provide free technologies and companies may be concerned that future revenues are not protected by intellectual property rights in the host countries. However, small-scale projects do not require sophisticated technologies. Therefore, the impacts of the international cooperation on the technology transfer are not as profound as is sometimes highlighted.

Actually, the impact of FDI on technology is very complex and difficult to measure. Some studies show that 42% of multi-national companies operating in China use the most advanced technology, while 58% use relatively advanced technology or even primitive technology (Zhang Bin, 2004). Wang Chunfa (2005) conducted a survey in Beijing, Shanghai, Suzhou, Dongguan from January to April 2003. This survey focuses on improving the capability of independent innovation by using foreign capital. It shows that at least at present foreign-funded corporations' contribution to cultivating domestic technical capacity is relatively weak.

The most likely form of technology transfer in most areas appears to be setting up, operating and repairing ability (Flow B), but seldom high level technology transfer such as innovation capacity (Flow C).

Managerial Skills.

International cooperation can ensure the transfer of advanced managerial skills and concepts to the host countries, particularly through FDI. From the perspective of private entrepreneurs，Yuan and Lu（2005）made a positive study about the spillover effects of FDI on management knowledge, with national sample survey data on private enterprises in 1997, 2000 and 2002. It shows that FDI has had positive effects on the Chinese entrepreneurs, but unfortunately the results are not as pronounced as was generally expected. In practice, the experiences in enterprises with foreign shares suggest that private entrepreneurs bring advanced management skills only in and do not enable uptake of a comprehensive managerial system. This is because:

- Foreign enterprises often find it unnecessary to send the best personnel with the most advanced management knowledge and experience to China because the major objectives is commonly to pursue cheaper labor and lower resource cost;
- More critically, local managers seldom have access to the position of the senior management or the core management, which hampers their acquisition of advanced knowledge and experience. Alternatively those who have access to the key management positions are not willing to take positions in local enterprises, which similarly hampered FDI's spillover on management.

In a survey (Lu and Yuan, 2005) on Chinese private entrepreneurs' professional experience, employment in "three-capital Enterprises"[34] is used as the explanatory variable for the spillover effect of FDI on management knowledge. When private entrepreneurs have work experiences in the "Three-capital Enterprises", FDI is expressed as 1 in the table; while FDI is recorded 0 if not. In the sample of 9,116 entrepreneurs surveyed, 342 have worked in the "Three-capital Enterprises", accounting for 3.75%; while those without any experience in the "Three-capital Enterprises" are 8774, about 96.25%. Table 5-3 gives the details of the survey results.

Table 5-3 FDI and the Spillover Effect of Management Knowledge

	1997		2000		2002		Total	
	Number	%	Number	%	Number	%	Number	%
0	1881	96.66	2943	95.77	3950	96.41	8774	96.25
1	65	3.34	130	4.23	147	3.59	342	3.75

Source: Lu Ting, Yuan Cheng (2005).

5.2.2 Mid/Long-Term Potential Role

The exact extent, to which international cooperation will contribute to technology transfer in the mid-and long- term, will depend on the evolution of both the local capacity (internal) as well as international efforts (external). If developed countries are dedicated to facilitating the pragmatic practices to raise the quantity and level of cooperation projects, China will have more opportunities to participate in various carbon projects as part of global carbon market and in the more knowledge-intensive carbon associated technology. In other words, cooperation will ensure the transfer of the technological R&D, design and manufacturing equipment (Flow C) which can improve China's domestic internal innovation capacity and thereby ensure the

[34] Joint venture, soley foreign owned, shareholding by foreign companies.

contribution of the cooperation towards the dual objectives of promoting sustainable development and assisting GHG emission reduction.

The quantity of technology transfer to China through international carbon cooperation will clearly grow, In addition, the content and the manner at the same time will make some new and important changes. Such new characteristics are the basis of the impact analysis of international cooperation on technology transfer, which can be presented as the following.

Strengthening Innovation Capacity (Research and Development, R&D): With regard to research and development (R&D), international carbon cooperation has a positive role in boosting China's innovation capacity. Cooperation in long-term will help build up local technological capacity, not merely equipment. This trend can be proven by TNCs' (Trans-National Companies) practices in China in the past decades. Since 1990s TNCs have actively engaged in the promotion of R&D investment in China besides the traditional focus on Organisational practices, Production technology and Process. There are more than 400 R&D centers in China set up by TNCs so far (Dong and Zhang, 2005).

Enhancing Technology Integration and Linkages: In order to satisfy the requirements of economic globalisation and technological advancement, the pattern of technology transfer through international cooperation will experience a gradual change from single technology transfer to technology transfer integration. Instead of unitary and disperse technology transfer, developed countries will provide a portfolio including consecutive technologies to developing countries. This means that China will possibly acquire *a complete package of technologies*, namely the mix of equipments, know-how and managerial skills. For example, in addition to production bases, multinational companies are setting up training bases, and more management operation centers, logistics procurement centres, research and development centers and regional headquarters, and so forth in China, providing a range of windows for the benefit of the hosting country.

Upgrading the Overall Technology Levels (Capacities). A study shows that cooperation on capital transfer has mainly concentrating on mechanical, electronics, energy, transportation, information, petrochemical and other areas over the last decades, while those industries are simultaneously the focus of TNCs (Dong and Zheng, 2005). It is obvious that FDI or TNCs have a large influence on China's technological upgrading. With further widening and deepening of the international carbon cooperation, developed nations are likely to increase their commitments to technological assistances to developing countries. China will undoubtedly benefit substantially from such activities with the target shift from the introduction of the single and specific advanced technology to the enhancement of the overall technological innovation capacity.

Promoting Private Sector Participation: As a key player, the private sector in China is increasingly getting involved in international energy and carbon cooperation. For example, Shenghua Corp.,one of the biggest coal companies in China, sponsored an international meeting on carbon capture and storage in June 2006[35]. The three documents signed by China and Russia during Russia president's visit in China March 2006 include an agreement between China National Petroleum Corp. (CNPC) and the Russian oil company of Rosneft tp form joint ventures on further oil cooperation, a memorandum of understanding between CNPC and Russia's natural gas company Gazprom for natural gas supply to China, and a summary of negotiations between CNPC and Transneft, a pipeline transport company of Russia.[36] These agreements may be aimed at energy security, but they must have direct implications for carbon reductions as oil and natural gases are of less carbon content. With oil, China would reduce the rate of conversion of coal to oil for transport uses.

5.3. Key Factors for Widening and Deepening ICC

At present, many forces, including profit making at enterprises' level and strategic interest at national level, drive the international carbon cooperation (ICC). Sketches are given here regarding the drivers for an ICC framework.

5.3.1 Scientific Knowledge and Political Consensus

There is evidence for consensus reaching regarding scientific knowledge and political actions[37]. Through its periodic assessments, the IPCC strengthens its conclusions linking a direct relationship between human activities, the rising levels of greenhouse gas concentration in the atmosphere, and climatic change[38]. The IPCC is not alone in its conclusions. In recent years, many major scientific bodies, for example, the US National Academy of Sciences, German Max Planck Institute for Meteorology, the UK Hadley Centre and etc, have confirmed the challenges posed by global climate change. In view of the global nature of the climate change challenge, political will to reduce carbon intensity at lowest possible cost through international cooperation, stemming from the scientific consensus on climate change, has never been stronger. For example, Davos World Economic Forum lists climate change as the third most challenging issue in the world in 2005 and the UK included climate change as a focal issue during its presidency of the G8 in the second half of 2005.

---

[35] The meeting was held in Beijing, 25-27 June 2006, with participation from the government, academic and representatives in the energy industries. The US Department of Energy and the Chinese Natioanl Development and Reform Commission were part of the organisers, too.

[36] This was singed on 21 March 2006.

[37] Naomi Oreskes, 2005, The Scientific Consensus on Climate Change, available at: http://www.sciencemag.org/cgi/content/full/306/5702/1686

[38] Intergovernmental Panel on Climate Change (IPCC) was established in 1988 jointly by UNEP and World meteorological Organisations. The 1st, 2nd and 3rd assessment reports were published in 1990, 1995 and 2001 respectively, with its 4th one expected for delivery in 2007. See www.ipcc.int.

5.3.2 International Regime Enhancement

As is known to all, stability, equity, and effectiveness are necessary for a well-functioning international regime. Rising interdependence between countries requires an even deeper and mutually-beneficial cooperation. UNFCCC and its Kyoto Protocol have come up during 1990s. UNFCCC provides the main framework to addressing climate change at the global level. Many other vehicles for international cooperation, such as “G8＋5”, G20 Energy and Environment Ministerial Meeting and “L20” (Pan et al, 2005) are already in operation, providing an effective venue for the exchange of up-to-date information and experience.

5.3.3 Information Sharing and Public Awareness

Information sharing will undoubtedly be productive. With the rapid development of information technology, particularly in the area of internet, effective means have been provided to facilitate and enlarge the magnitude of knowledge and information spreading, and, above all, to reduce the cost of acquiring information, as well as technology development and transfer. These consequentially bring more opportunities for all countries on technology cooperation. Concretely, technology cost, such as the introduction cost in terms of time, original direct cost, cost of absorbing and transforming, will fall substantially due to advanced information technology. For example, on-the-spot meeting can be conveniently replaced by video-telephone meeting, which can be helpful for the importer to learn and implement new technology timely with lower cost.

Public awareness on climate change has not been fully raised so far, which restricts extensive public participation and accordingly further development of international carbon cooperation. Activities that contribute to deepening understanding of climate change and informed public participation include compiling and printing training packages, publishing related materials, conducting training courses and workshops and disseminating information through broadcasting, TV, newspaper and other media channels. As more and more people recognise the potential impacts of climate change, understand how to mitigate these impacts and consequently encourage the public to make their own contributions, a solid foundation can be established for climate policy-making.

5.3.4 Difference of Technologies and Their Costs

From Table 5-4, it is clear that the energy intensity (energy consumption per GDP), energy consumption per capita and CO2 emission per capita differ across countries. This indicates that there are differences in energy efficiency and in the use of the same technology among countries. Of course, natural resource endowments, levels of economic development, cultural and social factors all contribute to differences in energy consumption. However, the difference of energy efficiency among countries is obviously the important interpretation factor. Take Brazil and Germany for example. In Brazil where carbon free hydropower is rich, CO2 emission intensity is about 0.49 kg CO_2/US$, similar to that in Germany, about 0.45 kg CO_2/US$; while in terms of energy intensity, 0.31 toe/US$ in Brazil is much higher than 0.18 toe/US$ in Germany (IEA, 2005).

Obviously, the wider the gap between countries on energy technology cost, the larger potential there is to introduce and enforce energy technology. Normally, developed countries enjoy the overwhelming advantage of technology, physical and institutional infrastructures over developing countries. Therefore, the flow of technologies is largely channeled from developed to developing countries. In conclusion, the differences of technologies and their costs among countries provide the foundation for international cooperation on development and diffusion of the affordable technologies for energy efficiency and conservation.

Table 5-4 Indicators for selected countries in 2003

	TPES(t/capita)	CO2/(t /capita)	TPES/GDP (t/thousand US$ 2000)	CO_2/GDP (Kg CO_2/ US$2000)
China*	1.10	2.90	0.92	2.43
India	0.52	0.99	1.02	1.93
Brazil	1.09	1.71	0.31	0.49
Africa	0.66	0.90	0.87	1.19
UK	3.91	9.10	0.15	0.35
US	7.84	19.68	0.22	0.55
Germany	4.21	10.35	0.18	0.45
Japan	4.05	9.41	0.11	0.25

Note: China*—People's Republic of China and Hong Kong China.

Source: IEA, 2005

5.3.5 Trade Liberalisation

Currently, the scope of international technology cooperation is relatively limited, because tariff and non-tariff barriers in each country impose strict conditions on technological flows by foreign investors. Fortunately, the accelerating process of trade liberalisation helps reduce all kinds of tariff and non-tariff barriers, and further harmonise environmental standards and regulations. This is reflected in importing high-tech equipment and acquisition of technological capabilities. Owing to the increasingly interconnected trend between technology cooperation and trade, international trade plays a continued role in securing a greater magnitude of the technology transfer to China and other developing countries for reduction of carbon intensity. Liberalisation of trade policies and ongoing reforms in the energy industry are expected to help China attract more international opportunities, particularly to help develop gas resources in western China and new electricity projects.

5.3.6 FDI (TNCs) Expansion

One important point to keep in mind when exploring ICC drivers is the relationship between FDI and ICC. Table 5.5 displays that economic factors in Column II are still the main determinants of ICC. It can be concluded that the primary motivations of TNCs are a prerequisite for ICC and ICC will further expand the traditional economic determinants of FDI, as the trans-national corporations (TNCs) perceive new carbon-related business opportunities.

Table 5-5 Comparative analysis of FDI and ICC

Key FDI Motives	Traditional economic determinants	Key ICC Motives
Market-seeking	Per capita income Market size Market growth Access to regional / global markets	New/expanded markets in developing countries for climate friendly technologies, products and services
Resource/Asset-seeking	Access to labour Access to raw materials Adequate infrastructure	Access to greenhouse gas reduction / sink enhancement opportunities (CERs)
Efficiency-seeking	Differential comparative advantages Better deployment of global resources	Technology upgrades in developing countries and Low-cost greenhouse gas reductions
Strategic asset-seeking	Access to new competitive advantages	Access to assets (resources; project pipelines; expertise/capabilities; markets) possessed by foreign-based firms and to improve company valuation

It is obvious to some extent that the overall investment climate is a good proxy for more specific carbon investment. Therefore, we can estimate the potential of climate-related investment only by exploring the general investment reality. Fankhauser and Lavric (2003) suggest that data on FDI flows per capita can serve as an indicator of relative investor satisfaction with the investment climate in different countries. According to World Investment Report 2005, the FDI grows from US$600 billion in 2004 to US$897 billion in 2005, by around 29%. It is not difficult to draw the conclusion that with FDI expansion, international economic, technology and trade cooperation in the carbon field will also be enlarged and deepened.

Strict regulation of carbon in home countries provides an economic incentive for TNCs to consider lower-cost opportunities abroad, which can certainly lead to enhancement of international investment abroad. While not all FDI brings along environmentally friendly practices, there is increasing evidence that foreign-owned or joint ventures tend to have higher environmental standards than local firms. One reason is that that they use the usually higher standards and technology adopted by the overseas parent company. And the other impetus comes from the fact that they export to environmentally sensitive markets, and do not want to tarnish their reputation (Panayotou 1997, Chudnovsky & Lopez 1999).

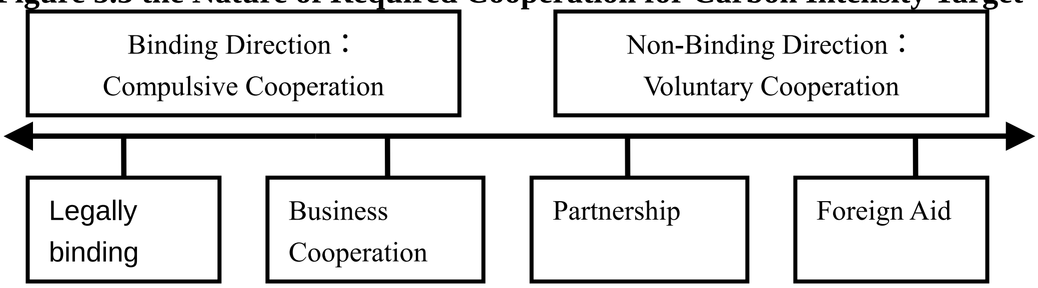
5.3.7 The Issue of China's Image

Another prominent aspect of China's approach to international regimes is China's concern about its international image, and how it wants to be viewed as a cooperative and responsible actor. Whether in commodities, clothing, computers, or capital markets, China's presence is felt every day. Undoubtedly, China is big, growing, and exerting increasing impacts on the world in the years to come. As it is becoming a major global player in energy and carbon areas, China has many opportunities to go further and to be a responsible stakeholder in its policy shift.

5.4. Nature and Scale of Required Cooperation for Carbon Intensity Target

The cases of WTO and IMF suggest that it is possible for a group of like-minded countries to pursue further integration or co-operation among themselves. In these cases, outsiders may join at a later stage. International carbon cooperation ranges from loose affiliations, non-binding agreements on reporting emissions and internal targets, to legally-binding negotiated agreements with non-compliance provisions, which can be deployed simultaneously in parallel with the national policy instrument (Figure 5-3).

Figure 5.3 the Nature of Required Cooperation for Carbon Intensity Target



5.4.1 Voluntary Foreign Aid （Climate ODA）

It is obvious that a shortage of capital has been a key obstacle to the enhancement of energy technologies and energy efficiency improvements in most developing countries. Consequently the international community attaches great importance to aid for poor countries. This kind of voluntary aid to reduce greenhouse gas emissions, as generally discussed in the literature, is a self initiated policy instrument rather than a regularly enabling mechanism for international collaboration. Yet, it can also provide the initiative and framework for collaborative R&D and dissemination of energy technologies.

Although free aid that could result from international cooperation achieving the carbon target may seem small. As a kind of initial demonstration, it is important in reducing GHG emissions and producing long-term environmental benefits. The aid has a significant role in technology availability, training and institutional construction, particularly in the area of innovation environment, including facilitating the necessary infrastructure and encouraging creative ideas.

Usually, developed countries require some special conditions when they promise aids in order to gain their own benefits in the host countries. Take Japan’s ODA to China for example, one popular requirement is generally clarified that China should purchase equipments and raw materials from Japanese enterprises with the loan provided by Japan. Such a requirement undoubtedly ensures that capital from Japan goes back partially to Japan again and at the same time Japanese enterprises can occupy the Chinese market rapidly and continuously. It has been proven by the Japan-to-South East Asia ODA case. Take another example, Japan has helped China construct the Qinhuangdao Port by means of the loan on the condition of China’s coal export to Japan.

5.4.2 Partnership

Partnership agreements vary significantly in their design and structure. Based on the proposed specific initiatives, partnership for strengthening the foundations of international cooperation relating to carbon technology can be categorised in the following three fields. ①R&D cooperation. Normally, cooperation in R&D is developed between strong science and technology institutes in developed countries and their counterparts in developing countries, in order to foster developing countries’ independent capacity for innovation capacity. ②Technology cooperation at project level. Through project activities, advanced equipments are simultaneously provided and many excellent experts also come to developing countries for guidance or supervision. ③Training.

R&D cooperation, including both policy and methodology studies and commercial feasibility studies, is a key component for partnership countries. Voluntary carbon intensity goals or commitments can be easier and quicker to put in place than regulatory or multilateral approaches. Carbon partnership agreements will be more attractive to developing countries if linked to mechanisms generating resource and technology flows that will help meet them. However, lack of monitoring and performance standards creates opportunities for free-riding among participants. Numerous studies suggest that voluntary agreements providing weak incentives for innovation or development of new abatement technologies do not provide certainty in reaching carbon goals. Evidence suggests that negotiated agreements and voluntary programs can be more efficient when employed in a policy mix and to explore new policy areas (OECD, 1999).

5.4.3 Business Cooperation

The role by corporations can be seen from the size of the private shares in the total world R&D, energy technology R&D, and global North-South capital flows. Table 5.6 displays the corporations' percentage among total national R&D in selected developed countries in 2002. It is obvious that corporations account for more than a half in R&D investment. Generally speaking, the more share of corporations in the total R&D investment, the more effective the industrial production of high-techs. In terms of employers, corporations' role is similar. Namely, the more employers in corporations are dedicated to R&D, the more effective the deployment of high-tech products.

Table 5.6 Enterprises' share in the national R&D in selected developed countries in 2002

Country	Enterprises' share(investment)	Enterprises' share (employee)	Country	Enterprises' share （investment）	Enterprises' share(employee)
Japan	74.8%	69.2%	Denmark	50.2%	
Sweden	67.7%	67.0%	UK	49.5%	60.7%
Switzerland	67.5%	68.5%	Austria	49.3%	61.8%
US	64.3%		Canada	48.9%	54.8%
Belgium	64.2%	59.8%	France	48.5%	50.7%
Germany	61.6%	61.0%	Australia	47.0%	
Czechoslovakia	59.8%		Italy	44.2%	42.8%

Source：http://202.38.66.66/news/hotspot/2002-4-2-9-1-48.htm

Thus, solution to problems related to climate change requires active and constructive participation by business sector at both micro level such as product development, production processes or marketing, and macro level dealing with regulatory complexity such as fragmentation of the business environment across regions and sectors or even within countries. The private sector has been playing a larger role in international cooperation, and this role in carbon areas should also grow over time.

5.4.4 Legally-Binding Agreement

International cooperation can also take the form of legally binding agreement, with carbon target as absolute quantity of emissions, growth rate, emission intensity, production technology and so on. Such kind of international cooperation has many merits. For one thing, the legally binding agreement is helpful for promoting the establishment of public awareness and having more effects on the individuals owing to its highly convincing authority. Secondly, achievement of the goal can be much more stable and certain. Thirdly, the associated measures are transparent and compulsive. Fourthly, the government is good at this kind of management on account of a lot of experiences from the past practices.

However, this legal instrument has its own disadvantages. Above all, "universal application" or "non-discretionary implementation" does not have cost-effectiveness as marginal cost differ for emission control among enterprises and regions. Next, due to asymmetric information between the government and polluters, the cost increases substantially for establishing standards, monitoring emissions and supervising law-enforcement, and increasing moral hazard of polluters.

5.5. The future of International Cooperation Mechanisms for Carbon Intensity Target

In the climate change debate, it is generally recognised that to be widely acceptable and effective, mitigation measures must also be basically fair. Therefore, based on the principle of Common but Differential Responsibility, it is necessary to use possible staged approaches in the flexible international cooperation towards a low-carbon economy. From the perspective of developing countries, new directions in future international efforts will possibly experience several phases as discussed below.

5.5.1 Capacity Building--Typical Demonstration--Wide-Spread Activities

Technology transfer will go through a few stages to have an impact on carbon reductions. The initial stage is capacity building, followed by demonstration and finally diffusion and large-scale deployment.

In climate change cooperation, early activities in the 1990s focused on capacity building including research and development, training, and public awareness raising. Such activities continue to dominate well into this century. A few demonstration projects such as green lighting with support from the UNDP (1997) and energy efficiency buildings in Qinghua University with support from the Italian government (2005) have been implemented. The EU and China on Sept. 2005 agreed a Partnership on Climate Change as one of the major outcomes of the China-EU Summit. One concrete co-operation goal to be achieved by 2020 is to develop and demonstrate, in

China and the EU, advanced ‘zero-emissions’ coal technology (EU-China, 2005). After the Kyoto Protocol came into force in 2005, CDM projects (World Bank, 2005).

5.5.2 Government Support—Market Initiative

The drivers for international cooperation will also shift from government and private initiatives for promotion of a low carbon economy.

Government Support. The private sector has the mandate to safeguard its capital, which means limiting its risks to a foreseeable and manageable scale. Many climate-friendly initiatives involve risks that are beyond normal commercial parameters in terms of timescale or certainty. In addition，The gap between what the private sector does and what society’s interests require is further enlarged by a variety of barriers to efficient market performance, which may include inadequate information, excessive concentration or fragmentation in markets, high transactions costs, and more. The public sector may have a vital role to play in the provision of a safety net, or to help with the non-commercial part of the risk, so that the private sector can provide finance for mitigation. This is particularly true regarding the early stage development of new energy technologies.

There is a wide array of mechanisms through which the government can support international carbon cooperation, including participation in, funding for, or other encouragement of cooperative efforts in the following areas. It is necessary to bear in mind that government initiatives should be structured to encourage, catalyze, and complement the corresponding activities of the private sector, not replace them.

- Fundamental energy-related research and applied energy-technology R&D;
- Demonstration and niche and pre-commercial deployment of innovative energy technologies;
- Shaping the environment for commercial deployment of innovative energy technologies—increasing incentives, lowering barriers (especially in relation to finance), and setting appropriate standards—to reflect their public benefits;
- Capacity building, integrated assessment, and institutional innovation in support of these approaches.

Market Initiative. The market is the final major force to promote research, development, application and industrialisation of high-tech. Especially after China's WTO entry, China's energy industry will become more market-oriented, and the role of the market in the allocation of resources will be constantly strengthened.

International carbon cooperation must fully consider how market forces work and address barriers to reduction of carbon intensity through market mechanisms. Through incentive measures such as green power quota system, mandatory market share for renewable energy and environmental compensation mechanism, enterprises can be guided to boost inputs on the development of clean energy with their internal motivation.

5.5.3 Energy Efficiency—Energy Structure—Emission Reduction

In the energy sector, the process of international cooperation will experience stages of focus on from energy efficiency to change of energy structure and finally to emissions reduction. The continued resistance by some developed and developing countries to make commitments within the existing climate framework suggests the need for alternative approaches. One method may help us move beyond the current dilemma of North-South collaboration on climate change, which is to put the development objective of developing countries as the priority at the beginning. Namely, rather than focusing exclusively on output (emissions), at a present, a future or modified regime might better match the overriding needs and priorities of developing countries, if directly engage them in international climate efforts through input (energy use and other emissions-generating activities).

Energy Efficiency----Energy Cost Initiative. In the beginning, energy conservation and energy efficiency are the focus by all stakeholders aiming at reducing the energy cost, which can easily facilitate the implementation of associated policy and measures.

Energy Structure----Energy Security. Availability, stability and affordability of energy supply are also paid attention to by both developed and developing countries.

Emission Reduction-----Environment Concerns. With improvement of living standard, environment quality, including carbon intensity reduction, will finally be considered as one important factor in the welfare function.

Normally, energy efficiency in developing countries is also at a low level, which not only caused serious environmental problems, but also greatly affected the competitiveness of industries in developing countries. Therefore, developing countries usually take energy conservation and efficiency as the priority area or the focus for international cooperation. Take China as an example, at present, China's average energy efficiency is only about 32%. This is 10% lower than that in developed countries; the average energy consumption per unit of eight major industries such as iron and steel, nonferrous metals, building materials, and chemical products in China is 40% higher than that of OECD level. It is relatively easy and effective to improve major equipments such as boilers, electrical, and motor vehicles and buildings with low energy efficiency (Xu, 2004); China's energy intensity is twice the developing countries' average, three times more than the world average, 4.5 times the OECD average, and 9.5 times Japanese level (Zhang and Xu, 2004).

Past experiences show that efforts driven not by climate concerns but by imperatives for development, energy efficiency and cost reduction in developing countries have significantly reduced growth in their GHG emissions. It is not difficult to draw the conclusion that the approach by stages from energy efficiency and structure to emission reduction will certainly be helpful for priority development goals in developing countries and the carbon intensity target in the international society.

5.5.4 ICC's role in the achievement of China's specific goal

Although China has a large potential for energy-saving, making the potential into reality is more arduous than that in the past 20 years. According to estimates, during 1980--2000, more than 70% of the national annual energy-saving results from restructuring the industrial structure and product mix. However, due to the scale and extent of industrialisation and urbanisation, upgrading consumption structure, and the shift of international manufacturing bases to China, unprecedented challenges will be faced in energy conservation. But this status can also provide good opportunities for expanding international cooperation in related fields, such as enhancing the investment in manufacturing energy-efficient products and energy saving equipment, and providing energy-efficient policy mechanisms, regulatory and organisational experiences.

To implement "the long-term strategy for energy conservation", in May, 2005, NDRC starts "Ten Key Energy Conservation Projects", through which 240 million tce will be saved. Ten projects, as the focus of the national bonds supported by the government, can also be worth paying attention to by ICC such as CDM, including conservation and alternative oil; coal-fired industrial boilers (kilns) transformation; regional cogeneration; the use of residual heat and residual pressure; energy-saving in the electrical system; energy system optimisation; energy-saving in buildings; green lighting; energy conservation in governmental agencies; and energy monitoring and technical service system.[39] Some study has shown that the greatest potential in China's CDM projects exists in the electricity sector. Annually, there are about 25 million tons to 117 million tons CO2 by 2010, accounting for 50% of total potential. Steel and cement industry are respectively 10% of the total potential, and the chemical industry accounts for 5%[40].

CDM's active role in the future is expected to enlarge. In essence, the CDM project is a kind of commercial activity. For CDM investors, the profit is always first. Therefore, the ultimate driving force for China to attract CDM is linked to the profit gained by investors. Theoretically, the driving factors for CDM projects are similar to those of other economic projects, which can be divided into push factors (external factors), and stimulating factors (internal factors), sometimes it is difficult to distinguish between the two kinds. In terms of the pull factor, there are mainly five factors, namely low-cost skilled labour, more comprehensive infrastructure, the numbers of preferential CDM-policies, China's huge market potential and a stable

[39] Ten key projects set in *Medium- and Long-Term Special Planning for Energy Conservation*. SeeL http://www.ndrc.gov.cn/hjbh/jnjs/t20050711_45815.htm

[40] CDM: pie or traps? http://www.newenergy.org.cn/html/2006-6/2006629_10589.html

macroeconomic environment.

6. Conclusions and discussions

From the above analysis, several conclusions may be drawn on the understandings of China's energy policy. First of all, China's determination of and push for economic growth to meet the target of a moderately well-off society has been the source driving the sustained high rate of increase in energy demand over the past three decades. The recent phenomenal increase in energy consumption since 2001 has been mainly attributable to a sudden acceleration of industrialisation and urbanisation, both of which requires substantial amount of energy intensive products such as metals, construction materials, heavy chemicals for physical infrastructure, buildings and machinery. In addition, much of the energy embedded in products has been exported for consumption outside China, as Chinese economy is highly export oriented. As capital-intensive industrialisation and urbanisation are a transitional process, growth of energy demand will be stabilised once China reaches post-industrialisation and equilibrium of urbanisation. However, irrational pricing also contributes to the large and rapid increase in energy consumption. Artificially kept low price and energy subsidies protect large state-owned and inefficient technologies from competition with advanced ones. Therefore, key drivers behind growth and emissions include capital intensive industrialisation, urbanisation, export oriented international trade, increase in income and thereby living standard and lack of price liberalisation. Technological progress has dual impacts. On the one hand, energy efficiency and renewable energy will be more competitive and thus carbon emissions can be reduced in terms of unit consumption of energy. On the other and, however, the impact of technological progress is often offset by price effect as the budget line is relaxed. And some technologies such as carbon capture and storage require energy for their maintenance and operation.

Secondly, existing analyses on energy demand projections tend to be conservative with respect to increase in energy demand and optimistic in terms of energy diversification and technological progress. Low energy demand elasticity at 0.5 or lower in the 1980s and 1990s has been wrongly used as the bases for projections in future demand. Similarly, recent high elasticity numbers at 1.5 or more cannot be sustained, either. Given the challenges of energy security and environmental pollution, for the elasticity number must be kept below 1.0 in the near future and at around 0.6 up to 2020. This would suggest that total energy demand would be more than 3.5 billion tce, twice more than the consumption level in 2000. The dominance of coal in the energy mix is unlikely to be changed but its share will be lowered slightly over the years. Therefore, carbon emissions are expected to grow over time. Per capita emissions will be above world average in the next few years and the total emissions gap in aggregate between the US and China will be narrower. By 2020, total energy demand in China is likely to be larger than that in the EU 15, but emissions will be certainly higher than that by EU 15 simply because energy in China is more carbon intensive. For China to pursue a low carbon development path, capital does not seem to be the key constraint as savings rate in China is high. Except no regret choices, many of the new and renewable technologies are commercially less competitive in comparison with conventional fossil fuels, but these can be enhanced through introduction of policy environment. Consumer behaviour and institutions can be the major constraints in inducing low carbon alternatives. Price liberalisation will reduce market distortions and thereby provide the right signal for both consumers and producers. Actions have to be taken sooner than later considering technological lock-in, institutional and behaviour inertia.

Thirdly, China has been making impressive and ambitious efforts to increase energy efficiency and reduce energy intensity although few policies are directed at carbon reductions. Energy intensity measured in terms of physical and monetary output has been decreasing substantially. Energy diversification is highly expensive and difficult, but China has been undertaking efforts to develop hydropower, nuclear power, wind, solar and biomass energy sources. The 11^{th} five-year plan (2006-2010) requires that energy intensity be reduced by 20%. This target has clear implications for carbon reductions as well. For energy intensive sectors such as steel and electricity, the key is to speed up the phase-out process of the outdated technologies, which can be 50% more inefficient than the advanced ones. The buildings sector was paid less attention to in the past. The potential is substantial as each year over one billion square meters floor spaces are being constructed. There are many policy instruments promoting low carbon development. Legislation has been made on promotion of energy saving, renewable energy and clean production. Effective sectoral policies have been the key driving forces pushing upgrading of technologies. Levy on SUVs and removals of oil subsidy have positive impact on the use of smaller and economic cars. As investors pay more attention to immediate financial returns than energy saving, incentives have to be introduced to encourage energy saving and the use of energy efficient technologies.

Fourthly, the government has pursued energy diversification since the 1950s. In particular, hydropower and bio-energy have a long history of development. Nuclear, wind and solar are more recent with steady increase in capacity although their share in the energy mix is somewhat negligible. Oil and natural gas are the major concerns for energy security as limited reserves are found inside China to meet the ever-increasing demand. As diversifying oil and natural gas sources in the world has international political implications, China is working on conversion of relatively more abundant coal and renewable biomass to oil. But coal liquefaction does not reduce emissions. However, the growth of nuclear power has been very fast. In 2005, total installed capacity reached 8.7 GW and it is planned that by 2020 total nuclear capacity will reach 40 GW, accounting for 6% of total electricity generating capacity in china. Hydropower is associated with many negative social and environmental impacts but the government has a plan to tap all the exploitable sources for electricity generation by 2020 or so. The potential of bioenergy can be as high as over 300 mtce, but commercial utilisation is constrained by high cost using existing technologies. Wind and solar power can be competitive in isolated remote areas, but subsidies have to be provided to make them survive in the market.

Last but not the least is on international cooperation. China is an integrated part of the world economy and an important player in the global energy market. Energy security requires cooperation between China and the rest of the world and China has to bear international responsibility in world energy and climate security. However, the focus on energy cooperation has to be in technological and financial areas. From a strategic and policy perspective, China has been active and positive in international cooperation. The use of Clean Development Mechanism can result in immediate technological upgrading for energy efficiency, renewable energy development, and reduction of emissions. Considering the capacity of world market and political complexities, the scale of CDM may be limited. However, CDM significance lies in the fact that emissions permits have a market value and this practice provides a market signal for investment and management in China for meeting its 20% energy intensity reduction target over its 11^{th} five year plan period (2006-2010). Because investment required in the energy sector is huge, international aid via governments is unlikely to play a big role in China's energy market, but positive impacts will have a value with respect to technological development and demonstration. It is the private sector that can play a decisive role in international cooperation. In promoting international cooperation, the government has a role to play in technological research and development and establishment of a friendly environment for the private sector to deploy and upgrade new technologies. Market liberalisation encourages competition and the use of advanced technologies. Non-energy factors such as environmental pollution control, nature conservation, and poverty alleviation are also important factors to widen and deepen international cooperation on energy and climate security. As there are many other priority areas and technologies are relatively expensive, international energy cooperation in China will have to go through several stages, from government to government through international aid, to public – private partnership, and finally to full market operations. Energy efficiency improvement will have a much bigger impact at the early stage than the development of expensive renewable energy in international cooperation.

A few more points deserve discussion here.

- Would the explosive increase in energy consumption in the past four years continue? Considering the scale and extent of industrailisation and urbanisation in China, the answer is yes but not indefinitely. However, a further question is how long and how far it would go. What we need is to shorten the period of rapid increase and lower the peak of energy consumption through price reform, technological development, international cooperation and many other mechanisms.
- China's energy intensity reduction target of 20% during 2006-2010 is highly ambitious. However, such target cannot be measured in physical terms considering market fluctuations and limited extent for physical reductions during

such a short period of time. This means that re-structuring of the economy must play an even more important role in meeting the goal.

- Price reform and incentives. Energy price has been rather distorted in China. Coal price has been kept low without taking into account safety and pollution factors. Government control over electricity, oil and natural gas prices have negative impacts on investment and competition. Further price liberalisation is deemed necessary for energy and climate security. Tax policies regarding energy and pollution can have positive impacts on energy efficiency and renewable energy development.
- CDM inflow of financial resources can be limited in comparison with China's FDI, but the signal is of high significance as carbon emissions have a price in the market. This will provide a right signal for investment and management in the energy sector.
- Embedded energy. A large portion of energy consumed in China is exported for consumption as embedded energy in goods. How should this part be counted? This constitutes a further case for international cooperation.
- Renewable energy. As these technologies are relatively more expensive and government subsidy can be limited, the development of renewable energy may have to be from a longer time frame instead of immediate rapid expansion. Energy efficiency improvement can save large amount of energy with less cost than renewable energy.

References

Chen Ying et al, 2006: BASIC Project Report. BASIC China Team. Beijing.

Chinese Academy for Environmental planning, Challenges of Chinese Environment and Energy in 2020 and Countermeasures, *Economic Information Daily,* 2005/10/11

Cui Mingxuan (ed.), 2006. China Energy Development Report 2006. Social Science Literature Press, Beijing.

Dong Ning and Zheng Yukun, 2005: Technological transfer of TNC and promotion to industrial structure upgrade in China, Beijing, International Economic Cooperation, 2005 vol.6 pp. 39-42.

EF-DRC, "China's National Comprehensive Energy Strategy and Policy", project report for the China Sustainable Energy Program (CSEP) of Energy Foundation, 2004, available at http://www.efchina.org/.

EIA (Energy In formation Administration), 2006. International Energy Outlook 2006. US DOE, Washington DC.

EU-China, 2005. Joint Declaration on Energy Cooperation.

Fankhauser, Sam and Lucia Lavric, 2003: "The investment climate for climate investment: joint implementation in transition countries" (London: EBRD), mimeo.

Garbaccio, Ho and jorgenson, 1999: Controlling carbon Emissions China, *Environment and Development Economics,* 4(4).

General implementation Situation of the second-phase WB/GEF's EMCo loan guarantees Programme in 2004/2005. See: http://www.guaranty.com.cn (China National Investment & Guaranty Co., LTD homepage).

Han Zhiyong, Wei Yiming, Fan Ying, 2004: Research on change features of Chinese energy intensity and economic structure. *Application of Statistics and Management,* 2004(11).

He Jiankun and Zhang Xiliang, 2005: Analysis of Declining Tendency in China's energy Consumption intensity during the 11th Five-year Plan Period, China Soft Science, 2006(4).

Huaqing Xu, 2005: report on climate change attached to EF-DRC project

Ida Bjorkum, 2005: China in the International Politics of Climate Change: A Foreign Policy Analysis

IEA (International Energy Agency, 2005). CO2 emissions from fossil fuels combustion, 2005 Edition. IEA, Paris.

IPCC (Intergovernmental Panel on Climate Change), 2001. Climate Change 2001: Mitigation. Cambridge University Press, Cambridge, UK.

Lin Jiang. 2005. Trends in Energy Efficiency Investments in China and the US. Ernest Orlando Lawrence Berkeley National Laboratory. June 2005

Lin, Wei (Toni), 2004, Climate Change & Renewable Energy in China, Chinese Renewable Energy Industries Association (CREIA), 3-5 November 2004, Auckland, New Zealand, The Australia-New Zealand Conference & Trade Expo 2004: Climate Change & Business

Lu Ting, Yuan Cheng (2005), FDI and the Spillover Effect of Management Knowledge: The Evidence from Chinese Private Entrepreneurs, http://www.ccer.edu.cn/download/4156-1.pdf

Naomi Oreskes, 2005, The Scientific Consensus on Climate Change, see: http://www.sciencemag.org/cgi/content/full/306/5702/1686

OECD, 1999, Voluntary Approaches for Environmental Management: An Assessment, OECD, Paris.

Pan, Jiahua, Zhuang guiyang and Chen Ying, 2005. Leadership of Climate 20 Group and Developing Country participation in Climate Regime Building. World Economics and Politics. No 10.，pp.52-57。

Wang Yanyan (Translator), 2005. Achievements and Challenges of China’s Energy Policy, Oversea Theory Developments, 2005 (8).

Wang, Chunfa, Jiang Jiang, 2005, FDI and Nurturing Endogenous Technical Capacity: Chinese Case Study, High-tech and Industrialisation, No.2.

Warwick J. Mckibbin, 2005: Environmental Consequences of Rising Energy use in China.

Watson, Jim. 1999. The Transfer of Clean Coal Technologies to China: Learning From Experience, a working paper submitted to the Working Group on Trade and Environment of the China Council for International Cooperation on Environment and Development in 1999.

Wei Yiming et al, 2005: Suggestions and Solutions to Carbon Emissions in China. *Advance in Climate Change Research*. 2006. 2(1): 15-20.

World Bank, 2005. Clean Development Mechanism in China. World bank, Washington DC.

World Health Organisation（WHO）: 2004. Environmental health Country profile—China, WHO: Geneva.

Xiulian Hu, “Development of China Carbon Emission Scenarios towards 2050”, presentation at COP11 and COP/MOP1 side event “Global Challenges Towards Low-Carbon Economy-Focus on Country-Specific Scenario Analysis”, held in Montreal, Dec.3, 2005.

Xu Dingming，2004：The status quo of Chinese energy industry and energy policy, China Electricity, Vol.37, No.9, pp.1-4

Yuan Cheng and Lu Ting, 2005: FDI and the spillover effects of management knowledge: Evidence from Chinese private entrepreneurs, Beijing, Economic Studies, 2005 Vol 3, pp. 69-79.

Zhang Bin, 2004, The Impact of FDI on China's Economy, International Economic Review, No.2, pp1-2;

Zhang Shikun and Xu Xiaoguang, 2004: the present energy issues of China and future energy development strategy, energy studies and information, Vol.20, No.4, pp.211-219

Zhidong Li: "Energy Demand and Supply Outlook in China for 2030 and a Northeast Asian Energy Community- the Automobile strategy and nuclear power strategy for China"

Zhou shengxian, 2006: Speech made at National Conference on Atmospheric Pollution Control. 30 May 2006.

Zhou, D., Dai, Y. Yi, C., Guo, Y. and Zhu, Y.: 2003, China's Sustainable Energy Scenarios in 2020, China Environmental Science Press, Beijing, August 2003.