MORE SUSTAINABLE ENERGY USE IN CHINA: ECONOMIC STRUCTURE AND THE APPLICATION OF NEW TECHNOLOGIES PROJECT

Part 1 – The Transition to a Low Carbon Economy: Implementation Issues and Constraints within China's Changing Economic Structure

Part 2 – Identifying Policies and Implementation Strategies for Improving Energy Efficiency

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About CSES

The Centre for Strategic Economic Studies (CSES) was established in 1993, and over time has developed a reputation for producing high quality research outputs in applied economics, with a focus on the processes of economic, technological, environmental and social change in the contemporary world. It seeks to understand the causes and consequences of these processes, and the appropriate policy responses for different situations in the Asia Pacific region.

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Acronyms

ADB	Asian Development Bank
BAU	Business as usual
BCM	Billion cubic meters
BTU	British thermal unit of energy equal to about 1.06 kilojoules
CAS	Chinese Academy of Sciences
CBM	Coal bed methane
CDM	Clean Development Mechanism
CEACER	China Energy and CO_2 Emissions Report
CO_2	Carbon dioxide
$CO_{2\text{-}e}$	Carbon dioxide equivalent
CSES	Centre for Strategic Economic Studies
CSM	Coal seam methane
ECS	Energy Conservation Scheduling
EIA	United States Energy Information Administration
ERI	Energy Research Institute
EU	European Union
FYP	Five Year Plan
GDP	Gross Domestic Product
GFC	Global Financial Crisis
GHG	Greenhouse gases
GW	Gigawatts
IEA	International Energy Agency
kW	Kilowatts
kWh	Kilowatt hours
LCE	Low carbon economy
MW	Megawatts
NBSC	National Bureau of Statistics China
NCGCC	National Coordination Group on Climate Change
NDRC	National Development and Reform Commission
NEA	National Energy Agency
NEC	National Energy Commission
NPC	National People's Congress
OECD	Organisation for Economic Co-operation and Development
PV	Photovoltaic (solar cells)
RMB	Renminbi or Chinese National Yuan
SGCC	State Grid Corporation of China
SMEs	Small and medium-sized companies
TCE	Tons of standard coal equivalent
TPY	Tons per year
US	United States
VAT	Value added tax
WTO	World Trade Organisation

EXECUTIVE SUMMARY

More Sustainable Energy Use in China:
Economic Structure and the Application of New Technologies Project

May 2010

Introduction

The International Context

In 2010 global emissions continue to increase rapidly, and the effects of climate change are being felt in many parts of the world. The threat of climate change is not receding - 2009 was the warmest year on record for the Southern Hemisphere, and for the world as a whole the first four months of 2010 were warmer than for the same period of any year on record[1]. Short of effective action global emissions look set to resume from 2010 the high growth rates seen over 2000-07.

After the failure to reach a universal, binding agreement at the Copenhagen Conference in December 2009, climate policy has moved into a new stage. This stage is likely to be based on major countries developing and implementing, on a non-binding and evolving basis, policies to stabilise and then reduce emissions, rather than on a universal, binding international agreement.

In this new stage China has become a central player, both because it contributes the lion's share of emissions growth and because it's large market is becoming a test-bed for new technologies and industries. China is a major force in international negotiations, and its relationship with the USA is critical. The 'cleantech' revolution is now well underway, with companies, governments and venture capitalists investing heavily in new clean technologies, products and services across the whole value chain. The revolution began in Europe and the USA, but the running is increasingly being taken by China. The new technologies that are emerging will play a major role in shaping patterns of competitiveness in the future.

Towards the Low Carbon Economy in China

China achieved remarkable reductions in the energy intensity of its economy (energy use per unit of real GDP) after the post-Mao economic reforms in 1979, at least up to 2001. Between 1979 and 2001 aggregate energy use per unit of GDP in China fell by about 70%, as policy makers used the tools of the command economy, which still prevailed in the energy sector, to eliminate inherited patterns of wasteful energy use. However, with a more energy intensive pattern of growth after China's entry into the WTO in 2001 and the progressive deregulation of the energy sector, those reductions came to an end after 2001: the energy intensity of China's GDP in 2009 was about 4% higher than in 2002, in spite of significant reductions achieved since 2005.

In spite of these difficulties the Chinese Government continues to target substantial reductions in energy use and emissions of greenhouse gases, with a targeted reduction in energy intensity of 20% over 2005-10 in the 11th Five Year Plan. By far the largest part of China's CO_2 emissions come from energy use, and the 11th Five Year Plan energy intensity target was extended to a 40-45% reduction

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[1] Based on the NASA Land-Ocean Temperature Index (http://data.giss.nasa.gov/gistemp).

in emissions per unit of GDP over 2005-20 in a proposal made in January 2010 under the Copenhagen Accord. These targets will not be easy to achieve: the energy intensive growth pattern has continued after the global financial crisis, and indeed was reinforced by it, while coal remains dominant in China's overall energy mix, in spite of strong commitments in the renewable energy sector. More generally, China is gradually implementing the institutions and mechanisms of the market in the energy sector, and the system remains in transition.

In recent years China has taken many major initiatives to reduce energy use and emissions, to develop clean technologies and to reduce environmental damage, and these are documented in this report. Premier Wen Jiabao and President Hu Jintao continue to publicly exhort and prioritise energy efficiency gains as a core political concern of government. But the challenge facing China – to reorient a rapidly growing, highly complex and dispersed economy and to achieve rapid adoption of new technologies and clean energy sources – is massive. In recent years, the concept of a low carbon economy has been identified within China as one that could act as a vehicle for tackling these challenges, and as an overall framework for policy initiatives.

Implementing the Low Carbon Economy in China: The Structure of this Report

This project examines some of the major issues arising in the implementation of China's policies for achieving growth and prosperity in a low carbon economy, with much lower energy use and emissions per unit of GDP. It is sharply focused on implementation issues. What are the best policies to achieve China's ends, and how should they be implemented in the specific conditions prevailing in China in the second decade of the 21^{st} Century?

Emissions from energy use per unit of GDP in a given country can be analysed in terms of three effects:

- The structure of GDP, in terms of the relative importance of high and low energy intensity industries within the economy (*the structure effect*);
- The intensity of energy use per unit of value added within individual industries (*the energy intensity effect*); and
- The level of emissions per unit of energy use (*the emissions intensity effect*).

The report as a whole deals with aspects of each of these effects. First, we examine the role of China's changing economic structure in shaping energy use, and the extent to which changing that structure can contribute to substantial reductions in energy use. But it is a major task, not previously attempted in any other country, to transform the structure of a rapidly growing, highly complex and dispersed economy. Hence serious consideration is necessary concerning the policy instruments that might be used, and how they might be implemented effectively in Chinese conditions.

Secondly, China has already taken many initiatives to reduce the energy intensity of individual industries and plans to adopt further measures in the 12th Five Year Plan (2011-15). China's intention here is not only to improve energy efficiency sharply but, in doing so, to become a world leader in clean technologies and to enhance its competitive position in particular industries. Again there are important implementation issues, related to what policies should be chosen and how they should be implemented in the context of both China's specific conditions and of global technology trajectories. In this report these issues are addressed through two case studies, of motor vehicles and air conditioners, with the focus being on policy implementation in the 12th Five Year Plan.

Thirdly, China has also taken many initiatives to shift its energy use to renewable sources and away from fossil fuels. But coal still remains dominant, and will account for more than 70% of China's energy consumption in 2010. These initiatives are reviewed in this report, but again we focus on one particular area: natural gas. China has to date made very limited use of natural gas, both historically and by comparison with other countries – while gas use has been increasing in recent years, it provided only 3.8% of China's energy use in 2008.

Natural gas has many potential advantages as a cleaner fuel for China. Gas has a carbon intensity of just over half that of coal and is much less polluting in other respects. Major new supplies of natural gas have recently emerged, both in China and internationally, in terms of natural gas fields, coal seam methane and shale gas. Gas can be used as either base load for power generation or as a readily available complement to intermittent renewable energy supplies. If China plans to increase its use of natural gas dramatically over the next decade or so, the key issues are again those of policy and policy implementation. What are the major constraints on rapidly increasing natural gas use in China? What are the key policies to overcome these constraints, and how should they be implemented in the specific circumstances facing China at the present time? These questions are addressed, in a preliminary way, in the natural gas case study in this report.

Changing China's Economic Structure and Development Strategy

In 2005 the Chinese Government recognised the need to adjust China's development model to one that is 'socially and environmentally sustainable' and that contributes to maintaining a 'harmonious society', and in the process to change China's economic structure. These were key goals of the 11th Five Year Plan, which included programs

- to make growth more sustainable and environmentally benign, and to reduce pollution and the rate of energy and water use;
- to increase innovation within all sectors, including industry, and shift the pattern of activity from low value added output based on low labour costs towards higher value added activities based on knowledge;
- to change the structure of growth towards the service sector, and accelerate the growth of particular service sectors that directly contribute to individual welfare; and,

- to improve rural welfare and to build structures and services that ensure the benefits of growth flow to people in rural areas.

Table 1 summarises some of the limitations of the prior energy-intensive strategy, with its focus on investment and exports, as perceived by the authors of the 11th Five Year Plan, and outlines the broad directions of their preferred policy responses to it. As the implementation of this Plan developed, through to 2008, it was evident that the Chinese Government was serious about this change in direction, and a wide range of measures were taken to give effect to it. Many of these are noted in the body of the report. One example, not widely known, is the discouragement of the export of energy intensive products, including by the use of export tariffs. That is, firms are required to pay a tariff if they wish to export one of a class of energy intensive products.

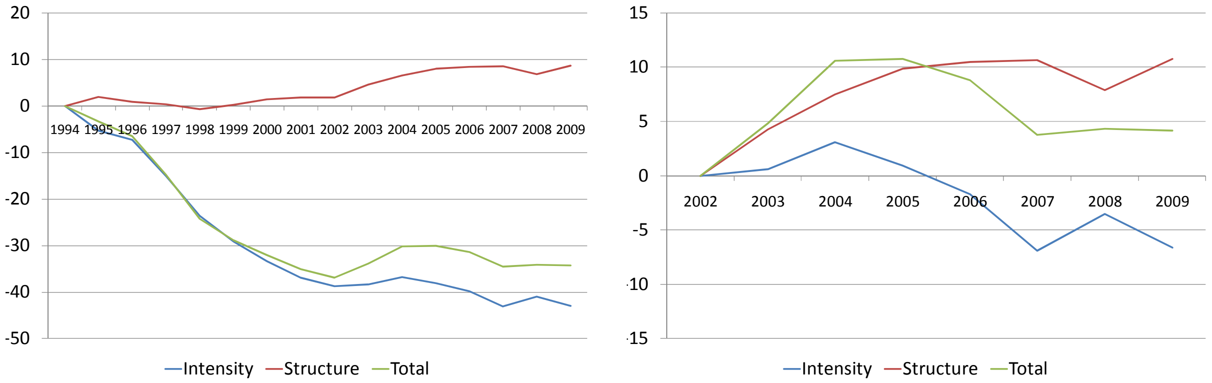
Table 1: Dimensions of China's Revised Development Strategy during the 11th Five Year Plan

Limitations of Existing Strategy	The New Strategy
Energy intensive growth	**More knowledge and technology intensive growth**
• Concentration on low value added activities • Inefficient energy use • High pollution and environmental damage • Low pricing of resources and no costing of social and environmental externalities • Advanced technologies not available	• Become market leader in use of advanced technologies • Mandate leading transport and consumer energy use • Constraints on energy intensive activities • Target energy efficiency gains amongst top energy users • Require global companies to share advanced technologies
Focus on export oriented manufacturing	**Shift to value added production**
• Low employment growth in industry • Low wages, limited broader benefits • Big trade surplus, foreign exchange	• Gradually increase Yuan's value • Reduce preferential climate for low value exports • Market pricing for energy and other inputs
Over-emphasis on investment activities	**Control over-investment**
• Excessive, unproductive investment • High energy and other resource use • Development of speculative activities	• Limitations on local government competition • Market pricing for land, energy and other inputs • Use monetary policy to avoid bubbles
Low growth of health, and other services	**Develop sources of services growth**
• Low public spending; high private costs • High savings; low consumer spending • Unequal access to basic services	• Higher taxation of incomes and growth sectors • Increased public outlays on 'soft' social infrastructure • Development of public health sector/other services • Improve consumer and SME access to credit
Low social dividend from growth	**More employment and better services**
• High level of rural poverty despite growth • Low employment growth • Limited access/high cost of rural services • Inadequate support for migrant workers	• Improve wages and labour conditions • Promote growth and income in agriculture • Develop comprehensive system of rural health, education and other services

In 2007 five industries (petroleum processing, chemicals, non-metallic minerals, ferrous metals and non-ferrous metals) accounted for 45% of China's energy use although providing only 10% of GDP, and had an overall energy intensity seven times that of the rest of the economy. Thus the shifting share of industries in GDP can have a big impact on China's overall intensity.

Using detailed data on energy use and real value added by industry for China over the period 1994-2009 we undertook a decomposition analysis to partition the change in China's energy use per unit of GDP into that due to the structural effect (that is, the change in the composition of GDP across industries with different energy intensities) and that due to the intensity effect (that is, the change in energy intensities within individual industries). The results are summarised in Figure 1 and discussed in more detail in the body of the report. The values shown represent the cumulative percentage change in the base intensity level (that for 1994 in the left panel and that for 2002 in the right panel) due to each of the effects, and in total.

Figure 1: Intensity and structural contributions to the change in aggregate energy intensity, China 1994-2009 (per cent of opening aggregate intensity value - %)



In 1994 China's aggregate energy intensity was 175,500 tons of standard coal equivalents per billion RMB in 2005 values. Four quite distinct periods are evident since 1994. The first period was 1994-2002, during which time the overall energy intensity fell by 64,800 tons SCE per billion RMB or 37%. As shown in the left panel of Figure 1, this was entirely due to declines in energy intensity within specific industries, which had contributed a decline of 39%, only slightly offset by a rise from structural factors of 2%. This is a continuation of the long decline in energy intensity from 1979, which was primarily driven by falling energy intensities within industries.

Secondly, very different trends are apparent over 2002-05. Industry structure began to become a force contributing to rising overall energy intensity after 1999, and this accelerated after 2002 as energy intensive growth took hold in China. These trends are evident in both panels of Figure 1, more clearly in the right hand panel (on a revised scale and as a percentage of the aggregate intensity in 2002). Aggregate energy intensity was 11% higher in 2005 than in 2002. Both the intensity and structural factors contributed to rising energy intensity after 2002, but the dominant factor was the shift in industry structure, which itself generated a 10% rise.

This surge in energy use, well in advance of GDP growth, shook policy makers in China, and contributed to the new policies incorporated in the 11th Five Year Plan. These policies took affect quite quickly, and over the third period (2005-07) China's overall energy intensity fell by over 7%. Industry structure was relatively stable over these years, with the renewed fall in sectoral intensities in terms of sectoral intensities accounting for all of this reduction.

In the absence of other shocks, it is likely that the 11th Plan measures would have generated further reductions in overall energy intensity, with structural change also beginning to contribute. But by 2008 China was beginning to experience the impact of the global financial crisis, on top of domestic measures to slow the boom. In November 2008 the Government announced a massive stimulus package to insulate China from the worst of the global crisis. This package was successful in achieving its immediate objectives, but at the cost of reinstating traditional, energy intensive growth. While there remain some uncertainties in the data, it seems likely that both China's overall energy intensity, and both its structural and intensity components, were at about the same level in 2009 as in 2007. It also seems likely that energy use per unit of GDP will rise in 2010, as heavy industries grow rapidly and the focus is more on output than on energy efficiency.

This analysis highlights both the importance of the structural issues – over 2002-09 structural change led to an 11% increase in energy intensity, only partly offset by an intensity effect of 7% - and the extent to which good policies can be hostage to major shocks, whether domestic or international in nature. Given China's domestic need to reduce energy use and pollution, as well as its international commitments, there is no doubt that renewed efforts to change China's development path and economic structure will be a feature of the 12th Five Year Plan. However this is a complex task, constrained by many factors such as:

- macroeconomic and pricing settings, such as the exchange rate and relative prices for energy and for other resources;
- the limited authority of the central government in terms of policy implementation, and the prevailing incentives for local governments to pursue rapid industrial growth;
- the role of international companies and foreign direct investment in China, and hence the role of Chinese operations in terms of the global division of labour; and
- the institutional, policy and demand constraints on the rapid expansion of key service areas such as health, education and community services.

These constraints and the required policy initiatives are discussed briefly in the full report, but need to be the subject of further detailed work.

Clean technologies, energy intensity and global competitiveness

The average energy intensity of China's industries, after correcting for structural effects, has been reduced by more than 40% over the fifteen years from 1994 to 2009. This reflects in good part an ongoing set of policies to upgrade technologies and to reduce energy use. Government policies are attempting to increase innovation within all sectors, including industry, and shift the pattern of economic activity from low value added output based on low labour costs towards higher value added activities based on knowledge.

China is expected to focus on maximising the competitive and growth potential of climate change more effectively than most other nations. China is already emerging as the largest manufacturer and market for cleantech industries including renewable energy production, such as wind turbines and solar panels. This is supported by domestic policy incentives and assistance for accessing credit aimed at promoting local manufacturing. The expansion of the renewables sector has not just focussed on manufacturing wind turbines and solar cells and expanding their markets, but has involved the investment of resources in expanding the skills base and bolstering the environment for innovation across a range of low carbon industrial sectors. Other notable examples include the mass production of new hybrid and electric vehicles, construction of third generation nuclear power plants, the operation of super-ultracritical coal fired power plants, trialling of commercial carbon capture and storage, construction of ultra-high voltage transmission lines for the national grid, the widespread use of cogeneration heat and energy systems in industry and the power sector, and the development of new energy storage devices. The commercialisation of new energy sector innovation continues to be a key focus of government policy which offers attractive incentives for its expansion.

Such policies continue to be central to China's strategy, and indeed are becoming more important over time. This rising importance reflects in part the urgency of China's need to secure diverse energy supplies, reduce pollution and of the global need to reduce emissions. But another important factor is the growing perception that China's long run development will be definitively shaped by the low carbon economy. As a result China's aim is to become a leader in the development and use of clean technologies, and in the emerging industries that will be characteristic of the low carbon economy.

Given this objective, there is a clear policy implementation task which is brought into clear relief by the task of formulating and implementing the 12th Five Year Plan. In the project to date this task has been addressed in terms of two case studies – motor vehicles and air-conditioners – the results of which are summarised below.

High Fuel Efficiency Motor Vehicles

China's burgeoning motor vehicle industry is moving from strength to strength on the domestic front. These changes are as revolutionary in terms of scale, design, innovation and future potential, but also perhaps in terms of the challenges that they raise. In 2009, China emerged as the world's largest manufacturer and market for motor vehicles; a market that has to date been dominated by foreign joint-venture companies. In recent years, the market is increasingly composed of independent and local manufacturers producing smaller vehicles. During the past decade, local brands such as Chery, Geely, BYD, SAIC, Dongfeng, BAIC and Guangzhou Auto have appeared from relative obscurity and are now starting to look at the potential of overseas markets. Companies such as BYD did not exist ten years ago and yet their small F3 sedan was China's top selling car in 2009. At the April 2010 Beijing Car Show, local cars dominated with Geely offering 40 new models, all apparently independently developed and breaking the industry's association with 'shanzhai' car models (山寨汽车), or copies of overseas models.

Although established in automotive component export markets for some time, the Chinese motor vehicle industry is poised to make a serious attempt to become a global presence in the automotive trade. China's auto industry is not satisfied with following the experience of the Japanese and Korean industry in terms of timing and also scope. While it took two to three decades for Japan's car industry to break into overseas markets and one decade for the Korean industry, China is aiming at succeeding in just five years. China is not only launching itself on the international market with a new generation of low cost vehicles, but it is also targeting the cutting edge of innovation with new energy vehicles. The ambitious call from government for the production of half a million so-called 'new energy vehicles' by 2011 has been embraced by manufacturers and cities across China with local hybrid and electric vehicles starting to roll off production lines. While this goal may not be reached until 2015, the production of new energy vehicles is expected to receive a significant boost from mid-2010 with plans for generous subsidies to individuals, including RMB3,000 for hybrid car purchases, up to RMB50,000 for plug-in hybrid cars and RMB60,000 for pure electric cars.

However, many unanswered questions and challenges remain for China's motor vehicle industry: How are China's already congested cities going to find room for the rapidly accelerating levels of vehicle ownership? What source of energy is going to power the cars of tomorrow and where is the fuel coming from? How will the government reduce carbon emissions from the transport sector? What strategic investment decisions is the industry making in terms of the domestic and international markets? While the current challenge for many new urban car owners is negotiating a place on the roads in the increasingly congested cities, what will the situation be like when 600 million vehicles jostle for space in 2050? Given the importance of each of these issues, what role does energy efficiency play?

The Chinese government has committed itself to building up a strong domestic motor vehicle industry, but it wants to do this in a responsible manner through the introduction of policies and programs to address pollution, congestion, fuel costs and climate change associated with motor vehicle use. At the same time, the government has shifted its auto policy in recent years towards supporting local and independent vehicle manufacturers. This occurred due to rising criticism that state owned foreign joint-venture manufacturers were required to open up market share for technologies, whilst remaining dependent upon overseas components and shifting profits back to the home country. This new strategy is starting to pay dividends with strong innovation and diverse production growth from the new players in the auto industry.

Additional challenges remain however, for Chinese manufacturers in meeting engineering, design, quality, environmental, safety and technological features of the new generation of vehicles in established overseas markets. As a result, manufacturers are increasingly adopting world's best practice manufacturing and supply chain management techniques and investing in the innovation necessary to achieve this within their own organisations and in collaboration with private and public technology organisations.

This case study provides a review of the technology options available for reducing carbon emissions from transport, and reviews some technology road maps that chart out potential future paths for the development of the global industry. Given this context, it also reviews and assesses the range of policies that can be adopted in terms of encouraging low carbon transport, including stronger emissions standards for vehicles, fuel taxes, vehicle purchase taxes, support for infrastructure for electric vehicles and encouragement of alternative transport modes. Both of the analyses are directed at informing the Government's policy choices for the 12^{th} Five Year Plan.

Energy Efficient Air Conditioners

There are currently around 240 million room air conditioners (RACs) in China, representing a relatively small component of China's total energy demand. However, this is one of the key areas of growth in energy demand, with expectations that there will be around 700 million RAC units installed by 2030. While overall energy use is not a significant consideration, air conditioner use is a major factor in exacerbating peak-energy demand, which risks posing serious energy supply constraints in the near future. A further consideration is the expanding global market for air conditioners. Presently, 80% of the world's RACs are manufactured in China. Therefore, the importance of introducing energy efficiency improvements and the adoption of advanced technologies in air conditioners is high.

This report acknowledges that tackling the issue of energy efficiency relating to air conditioners needs to occur within four interconnected aspects: (i) energy efficiency standards of air conditioner units; (ii) building energy efficiency and urban planning; (iii) lifestyle expectations and demands; and (iv) rising temperatures attributed to climate change and the urban heat effect. While not neglecting any of these aspects, this report focuses on the first aspect: the energy efficiency of individual air conditioners. At the same time, it is recognised that the energy efficiency rating of buildings (BEER), the use of passive measures for heating and cooling, retrofitting and the application of appropriate materials, design, insulation and layouts all directly influence the demand for and use of air conditioning.

The policies identified in this report for attaining improvements in the energy efficiency of air conditioners include: the progressive tightening of Minimum Energy Performance Standards (MEPs); the introduction and gradual tightening of average regional energy efficiency requirements and minimum standards, as well as the weighted average performance measures for units sold; the provision of capital subsidies or additional rebates for the purchase of super efficient air conditioners; the strengthening of monitoring and testing regimes; and, support for the installation of smart meters to monitor and control energy use.

The most successful policy program identified for achieving low cost and effective energy efficiency gains to date is Japan's Top Runner program, which was introduced as a countermeasure to the increasing consumption of energy within the residential, commercial and transportation sectors. The Top Runner program has effectively improved the energy efficiency of machinery and equipment by incrementally tightening both the minimum and average energy efficiency standards of products under the system. In the first seven years of the program since its commencement in 1997, the energy efficiency of air conditioners rose by 67.8%. Due to the success of the program, it has been broadened to cover 21 products. The introduction of a domestic variant of the Top Runner program would be highly beneficial for China, in terms of maintaining the domestic industry's competitive advantage as well as reducing the energy peak loading in China and across the globe.

Changing China's Energy Mix: Reduced Emissions per Unit of Energy Use

China's energy system has historically been dominated by coal, and remains so today, even though the Chinese Government has given serious attention to developing renewable energy sources. The initial priority was given to hydroelectric power plants, but in recent years strong policy support has been given to developing other renewable sources of energy. These developments have been support by the Renewable Energy Law (2006), and by its revision in 2009. Policy measures being used include preferential financial and tax policies, specialised funds subsidising the development of renewable energy sources, zero interest loans, the reduction or elimination of taxes for certain qualified renewable energy development activities and feed-in tariffs.

In 2009, several new government programs supporting renewables have been launched to accelerate the manufacture and installation of clean energy sources. One example of these programs, the *Golden Sun* initiative, provides half the cost of installation and power transmission costs for 275 new solar power stations. Remote off-grid solar power projects are eligible for subsidies up to 70%. As a result of the strong government support, China's ambitious renewable energy targets continue to be updated and expanded in recent years. As shown in Table 2 the latest targets for 2020 are not only a dramatic increase on actual 2009 levels but also , except for natural gas, a sharp upgrade of 2020 targets put in place as recently as 2007. The expansion of nuclear power is particularly striking, with almost a tenfold increase in capacity planned between 2009 and 2020.

Table 2: Government Electricity Generation Capacity Targets (gigawatts) [2]

	2009 capacity	2011 target	Updated 2020 target	Original 2020 target (2007)
Solar	0.3	2	20	1.8
Wind	25	35	150	20
Nuclear	9	12	70-86	40
Hydro	150	-	300	270
Natural gas	5*	36	50	70

One piece of this puzzle that has received less attention than others is natural gas, which is the only source of electricity generation in Table 2 for which the 2020 target was revised down since 2007. As a result the energy mix case study undertaken in the project relates to the utilisation of natural gas.

Increased Utilisation of Natural Gas

The natural gas market in China has entered a period of solid growth in terms of gas exploration, production, transmission and utilisation. In order to facilitate the growth of gas as one of China's key energy resources, the government has embarked upon an aggressive strategy of building new pipelines and LNG port facilities and developing new gas fields. Despite strong growth in the domestic production and transmission of natural gas in China, demand continues to outpace supply. As such, imports in the form of pipeline gas and LNG imports are set to play an increasingly important role. The growing gap has led to expectations that imports will contribute to half of China's gas market by 2020. As a result, China has matched its growing need for energy with a proactive overseas search for diverse energy supplies, including joint ventures, direct investments, acquisitions and resource-loan deals for access to new oil and gas fields. China's increasing interest in overseas oil and gas ventures has coincided with a lull in international investment in the area following the global financial crisis and tightening financial conditions.

Natural gas is an attractive option for the Chinese government in improving energy security through a policy of diversity, whilst also reducing pressure upon coal as the dominant fuel source. In

[2] The targets in Table 2 are yet to receive formal approval from the NDRC and State Council but are currently being circulated and have been widely cited in the Chinese media. Data sources: WEFN (2009) China's New Energy and Renewable Energy Yearbook 2009 Review, World Energy Finance Network (WEFN), 中国减排震动世界 新能源规划或将延迟《中国新能源网》 http://www.newenergy.org.cn/html/00912/1210930600.html *(in Chinese)*; CEACER (2009) *China to 2050: Energy and* CO_2 *Emissions Report*, A joint publication of the China Energy and CO_2 Emissions Report Group (CEACER) members: Energy Research Institute of the National Development and Reform Commission, State Council's Development Research Centre's Industrial Economics Research Department and Tsinghua University's Institute of Nuclear and New Energy Technology, Science Press, Beijing; 2050 中国能源和碳排放报告*(in Chinese).* Note: the 2009 natural gas figure is estimated actual generation rather than capacity.

addition, natural gas offers a cleaner, lower carbon fuel source for China's ever expanding urban population. Gas is unlikely to ever challenge the dominance of coal in China's energy mix, but it can play an important role in the country's attempt to reduce pollution, improve energy efficiency and facilitate the transition to a low carbon economy. This study suggests that natural gas can play an increasing role in China's power generation mix by replacing old, less efficient and more polluting coal power plants as well as being sited with large scale renewable sites to maximise the capacity of renewable energy generation with back-up secure and reliable base-load power. However, without further industry, policy, market and pricing reforms to the broader energy framework, then the potential of gas will continue to be inhibited.

This report suggests several policy areas requiring further attention including: the pairing of natural gas with renewables; acceleration of the shift towards regional or national gas markets; strengthened state investment in natural gas partnerships and investments through new financing techniques; setting natural gas utilisation targets within national five year plans; and increased support for distributed gas utilisation and power generation. These suggestions are made on the premise that the outlook for the global supply, demand and pricing of natural gas to 2025-30 is such as to justify China investing heavily to increase the share of natural gas in energy use significantly. This is not yet established, but is the subject of ongoing work.

Conclusion: Building a Supportive Policy Framework

This report highlights the paradoxes inherent in China's current initiatives to reduce energy use and emissions. On the one hand, major and highly ambitious programs are being urgently pursued to develop clean technologies and to reduce energy intensity within individual industries, as well as to shift the pattern of energy use to clean sources of energy. Yet, at the same time, little progress has been made, overall, in reducing energy use per unit of GDP since 2002, while coal will provide over 70% of China's energy use in 2010, the highest share since 1997.

In this context, further work is seen as necessary in each of the three main areas distinguished above. First, if China is to achieve its energy and emissions goals, it is imperative that real progress is made to change China's economic structure and development strategy. For this to be achieved greater understanding is required of the factors constraining change (such as the incentives facing regional governments, the role of foreign companies and the financing and other constraints on the expansion of key service industries). A more complete analysis is also required of the policy options available to governments to change economic structure, given the dynamism and complexity of the Chinese economy, and how these might be effectively employed in China's current situation.

Secondly, in terms of developing clean technologies and reducing energy intensity within individual industries, further documentation and analysis is needed for the cases of motor vehicles and air conditioners. These should cover both the likely global technology road map for these two cases and existing knowledge about the effectiveness of various policies, drawn from the experience of a range of countries. This information would provide a stronger foundation for developing realistic policy roadmaps for China. It would also be valuable to draw out the lessons learned from these case studies for application to other industries.

Finally, while China is pursuing rapid growth in renewable sources of energy, it is likely that much greater use of natural gas, a much cleaner fossil fuel source, will play an important role in its transition to the low carbon economy. The emerging change in the global gas market – arising from greatly increased supplies of LPG, coal seam gas and shale gas – is likely to facilitate this increased use of natural gas in China. But for this to be achievable further significant changes need to be made in the policy settings and institutional arrangements, and these need to be supported by a more detailed knowledge base on policy issues and options.

THE TRANSITION TO A LOW CARBON ECONOMY:

IMPLEMENTATION ISSUES AND CONSTRAINTS

WITHIN CHINA'S CHANGING ECONOMIC STRUCTURE

May 2010

Centre for Strategic Economic Studies

Victoria University, Australia

With the assistance of the

Energy Research Institute,

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Beijing, P.R. China

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Acronyms

ADB	Asian Development Bank
BAU	Business as usual
BTU	British thermal unit of energy equal to about 1.06 kilojoules
CAS	Chinese Academy of Sciences
CDM	Clean Development Mechanism
CEACER	China Energy and CO_2 Emissions Report
CEWC	Central Economic Work Conference
CO_2	Carbon dioxide
$CO_{2\text{-}e}$	Carbon dioxide equivalent
CSES	Centre for Strategic Economic Studies
ECS	Energy Conservation Scheduling
EIA	United States Energy Information Administration
ELCE	Enhanced low carbon
ERI	Energy Research Institute
EU	European Union
FYP	Five Year Plan
GDP	Gross Domestic Product
GHG	Greenhouse gases
GW	Gigawatts
IEA	International Energy Agency
kW	Kilowatts
kWh	Kilowatt hours
LCE	Low carbon economy
MW	Megawatts
NBSC	National Bureau of Statistics China
NCGCC	National Coordination Group on Climate Change
NDRC	National Development and Reform Commission
NEA	National Energy Agency
NEC	National Energy Commission
NLGCCS	National Leading Group on Climate Change Strategy
NLGESPR	National Leading Group on Energy Saving and Pollution Reduction
NPC	National People's Congress
OECD	Organisation for Economic Co-operation and Development
PV	Photovoltaic (solar cells)
RMB	Renminbi or Chinese National Yuan
SGCC	State Grid Corporation of China
SMEs	Small and medium-sized companies
TCE	Tons of coal equivalent
TPY	Tons per year
US	United States
VAT	Value added tax
WRI	World Resources Institute

Introduction

The rapid rise of China's economy on the global stage needs little introduction after 30 years of annual GDP growth averaging nearly 10%. The relatively smooth and stable process of transforming the world's most populous nation from a poor, largely rural and isolated centrally planned economy into a globally-integrated market-orientated manufacturing, industrial and trading global powerhouse is the envy of many nations. While China's pattern of development has transformed society and the economy, there is growing concern that this pattern is unsustainable in terms of environmental and social costs as well as future economic growth. The concerns about the impact of human-induced climate change has focused global attention upon China's development path. A path that has catapulted China into the unenviable position as the world's largest emitter of carbon dioxide, the main greenhouse gas (GHG) (Levine & Aden, 2008).

During the past decade, the pace and pattern of China's economic development has intensified the process of energy and resource intensive, industry-led growth. Energy intensive industry has become one of the key drivers of China's rapid growth during the past decade. Recent data shows that the growth in energy production and use has outpaced many reputable recent predictions (IEA, 2002; World Bank, 2002, 2007; McKinsey, 2007). In recent years, the use of primary energy and the construction of new electricity generation capacity have grown at percentage rates equal to and above that of real GDP. According to Andrews-Speed (2009), the reversal occurred for three reasons: the structural bias towards energy intensive heavy industry; a slowdown in technical innovation; and, a return to coal as the key energy source. Not only have these developments reversed earlier energy efficiency gains from structural adjustments and productivity gains, but they have exacerbated concerns about energy security, resource scarcities and environmental pollution.[1] Moreover, this growth has reinforced an underlying high dependence on black coal as the dominant source of primary energy, with its carbon emissions at two to three times the level of other primary fuels.

China has already taken many initiatives to this end. But the challenge facing China – to reorient a rapidly growing, highly complex and dispersed economy and to achieve rapid adoption of new technologies and clean energy sources – is massive. In recent years, a low carbon economy has been identified as a concept that could act as a vehicle for tackling these challenges. Accordingly, a growing chorus is demanding urgent economic adjustments towards cleaner primary energy forms for both new growth, and indeed to substitute away from the current dependence upon black coal within existing energy applications in the industrial, commercial and retail sectors, and especially in power generation. Retaining the current pattern of economic development based upon coal-powered energy intensive industry-led growth is not a viable option, economically, socially nor environmentally.

The Chinese government recognises both the need for structural adjustment to the economy, as well as weaknesses in state action for rebalancing. For example, in his 2006 Report on the Work of the

[1] Energy security is one of the key drivers of energy efficiency policies due to China's increasing reliance upon imported oil and petroleum products since it became a net oil importer after 1993.

Government to the National People's Congress (NPC), Premier Wen Jiabao reflected on these failings during the 10th Five Year Plan (2001-2005):

> *The main problems were an unbalanced economic structure, weak capacity for independent innovation, slow change in the pattern of economic growth, excessive consumption of energy and resources, worsening environmental pollution, serious unemployment, imbalance between investment and consumption, widening gaps in development between urban and rural areas and between regions, growing disparities between certain income groups, and inadequate development of social programs. We need to work hard to solve all these problems.*

These challenges are common to many countries, but what is unique about China is the scale and complexity of them, given China's rapid growth, extent of international engagement and decentralised development and governance model. In China's unique circumstances, the efforts of the Chinese government to achieve these ends are hindered by so-called implementation gaps, including limited information on how specific policies might best be implemented, on how successful they are likely to be, the level of actual implementation at the local level and on what this means for the choice of preferred policies.

Reflecting the complexity and seriousness of China's economic, environmental and social problems, the Chinese government has introduced a broad range of responses aimed at 'harmonising' development, including adjusting the economic structure away from a heavy reliance on manufacturing exports and investment in industrial capacity as the drivers of economic growth as well as diversifying its energy mix. A key component of the current rebalancing program is the adoption of the low carbon economy concept. This concept aims to decouple the relationship between energy and development. A low carbon economy, it is hoped, offers a new competitive economic advantage for growth whilst tackling the dichotomy between environment and development. In other words, the state is committed to a policy of rapid economic growth but wants to avoid the concomitant environmental impacts, the resource degradation and irreversible climatic change.

There are three key areas of focus for the Chinese government in implementing a low carbon economy. Firstly, the state is attempting to stimulate the adoption of advanced technologies, processes and practices which are both energy efficient and more environmentally benign. Secondly, it aims to shift the pattern of economic activity from energy intensive areas (for example, specific forms of heavy industry) to industry and service sectors that are knowledge intensive and are less reliant on energy and other resource inputs. A third consideration is at a deeper level – the need to shift the development model away from traditional patterns of the developed world. Instead, China is proposing a new path that promotes development whilst lifting the quality of life of its people, without relying upon the unsustainable utilisation of resources.

The sustainable use of energy and energy efficiency in particular are the subject of a considerable amount of recent and ongoing body of work within China and internationally.[2] Achieving improvements

[2] Key Chinese documents on the importance of energy efficiency include CAS (2009), Jiang et al. (2009), CEACER (2009). At the international level, one of the most consistent sponsors of quality research on energy efficiency in

in energy efficiency is a high priority for China given the significant attention the issue has received amongst the leadership of the government. The status of energy efficiency programs have been gradually elevated to key policy priority since they were first identified as a prerequisite of ongoing national development at the commencement of the economic reform agenda in the late 1970s. A great deal of work has been undertaken on the first issue of technical and other characteristics of individual low carbon and energy efficient technologies, most notably in the expansion of nuclear power generation and the renewables sectors of hydro, wind and solar (Wang and Watson, 2009; WRI, 2009). China has also taken a leading role in terms of enacting energy efficient standards for buildings, household appliances and motor vehicles (The Climate Group 2008, 2009). But in any given situation, such as that of contemporary China, there are many obstacles to the increased use of new products and processes that are known to be both technologically and economically superior. These include costs already sunk in existing technologies, uncertainty about the extent of market capture from investing in new technologies, resistance from various economic and social groups, including consumers and vested interests, a desire to protect national or regional interests and firms, inadequate central government authority to impose change, and so on.[3] As a result, the success of the rebalancing efforts to date remains mixed, especially in terms of adjusting the economic structure.

China is currently at an important turning point in rebalancing its pattern of development. The urgency of these issues are paramount given China's ambitions to triple the size of its economy by 2020, accelerate its urbanization process and lift the living standards of its people; all of which will further boost demand for limited energy and resources and double its carbon emissions. This report addresses these issues in five parts. It begins with a discussion of the structural economic characteristics of these issues and analyses their implications for energy use. In the second part, the role of the state as both a driver and obstacle for change is examined including a review of key policy measures. This is followed by an analysis of the implications of China's present and future economic structure on carbon emissions. The report then focuses on possible pathways for rebalancing the economic structure, including the role of a low carbon economy as a catalyst for gradually shifting away from the existing narrow and unsustainable approach to development. The final part reviews the progress to date in rebalancing the economic structure and introduces several issues requiring further work and consideration.

China comes from the Lawrence Berkeley National Laboratories (LBNL), but other important works have been produced by the NRDC & BCG (2009), WRI (2008, 2009), World Bank (2007, 2008, 2009), McKinsey (2008), the Climate Group (2008, 2009) and Chatham House & E3G (2008) amongst others.

[3] These issues are elaborated on in the final report of this project relating to the three case studies of motor vehicles, air conditioners and natural gas.

Changing the Economic Structure

A key focus of this report concerns the extent of structural reforms needed to rebalance China's pattern of development. Much of the current debate around China's economic structure emphasises the nation's 'capital-intensive, industry-led' mode of development and the weak presence of domestic consumption, service industries and social welfare. Vague terms such as 'harmonious society', 'moderately well-off society', 'scientific mode of development', 'ecological society', a 'low carbon and circular economy' and 'new energy revolution' have entered the official discourse to highlight the recognition by the state for a more balanced path of development, including greater social equity and environmental protection (Fewsmith, 2004). Yet despite the new rhetoric, the key ingredients of China's industrial-led development strategy remain in place; namely, the provision of easy access to credit and the underpricing of inputs, particularly resources, capital, land and the environment. Moreover, it is increasingly evident that the impact of the recent global financial crisis and the government's stimulus package are reinvigorating the tried and true mode of economic development: high investment in infrastructure, heavy industry and manufacturing.[4]

The organisation of this section is in three parts. The first part outlines the context of China's pattern of development during the post-Mao period. It follows the initial inertia of the economy to shift away from an established 'hot, wet and heavy' pattern of economic production and growth and the state's adoption of a more aggressive state response for the structural rebalancing of the economy. This is followed by an analysis of the relationship between the structure and intensity of China's energy use with a focus on the role of energy intensity at the sectoral level.

[4] The key priorities of the 2008 stimulus package includes: rural infrastructure, rail transport, affordable housing and the reconstruction of the 2008 earthquake areas.

China's Pattern of Development

During the past two years, China defied a global economic recession, the collapse of its exports and two major natural disasters to achieve rapid economic growth rates.[5] In 2008, the nation's GDP grew by 9.6% to RMB31.405 trillion and then grew by a further 8.7% during 2009 to RMB33.535 trillion (NBSC, 2010). Given China has a population of over 1.3 billion, this equates to a GDP per capita of around RMB25,000 or RMB40,000 on PPP basis (Figure 1).[6] Following the global financial crisis, China is the second largest economy on PPP terms, is the largest trading nation, the second largest manufacturer and the leading engine of the global economy. Significant and unprecedented improvements in living standards have also taken place due to China's rapid economic growth. Today, Chinese cities are bursting with commercial and construction activity; filled with glistening architecturally -designed skyscrapers; and, congested with modern cars shifting its citizens who are adorned in name-brand and luxury clothing and accessories. Beyond the cities half a billion people have been lifted out of poverty since 1981 (World Bank, 2009c). However, China is a nation of contrasts and remains a low to middle income nation due to the disparity in wealth between rich and poor; urban and rural; and, coastal and hinterland (Naughton, 2007). While there is growing wealth and opulence in China, over 300 million continue to live on less than US$1.25 per day.

The development experience of China echoes much of what was experienced elsewhere in East Asia, especially in post-war Japan and then Korea. What the figures don't reveal are the complexities and challenges that China has overcome to achieve such sustained levels of economic development. Moreover, it is clear that many more challenges remain in the coming decades, some old and understood, others new and unknown. Conventional neoclassical economics struggles to provide a useful theoretical framework for explaining China's economic development (Naughton, 1991; Rawski, 1994; Young, 2000; Coase & Wang, 2010). Moreover, many remain cautious about predicting the nation's future trajectory. In contrast, the Chinese government in Beijing remains confident that they will find the best balance in the future pattern of economic development. And yet, many local government officials are deeply tied to the current pattern of development with high levels of investment in energy intensive heavy industry and export-orientated manufacturing. It remains very difficult to persuade these officials that the existing strategy is inherently unsustainable when it has delivered consistently high levels of economic growth. One thing though that is increasingly apparent to many outside local government is that even if China's 'economic structure changes in the future (with less emphasis on resource-intensive manufacturing and exports) the current development trend is not sustainable' (World Bank, 2009c, 8). In order to appreciate this statement, it is necessary to briefly introduce China's pattern of development over the past three decades.

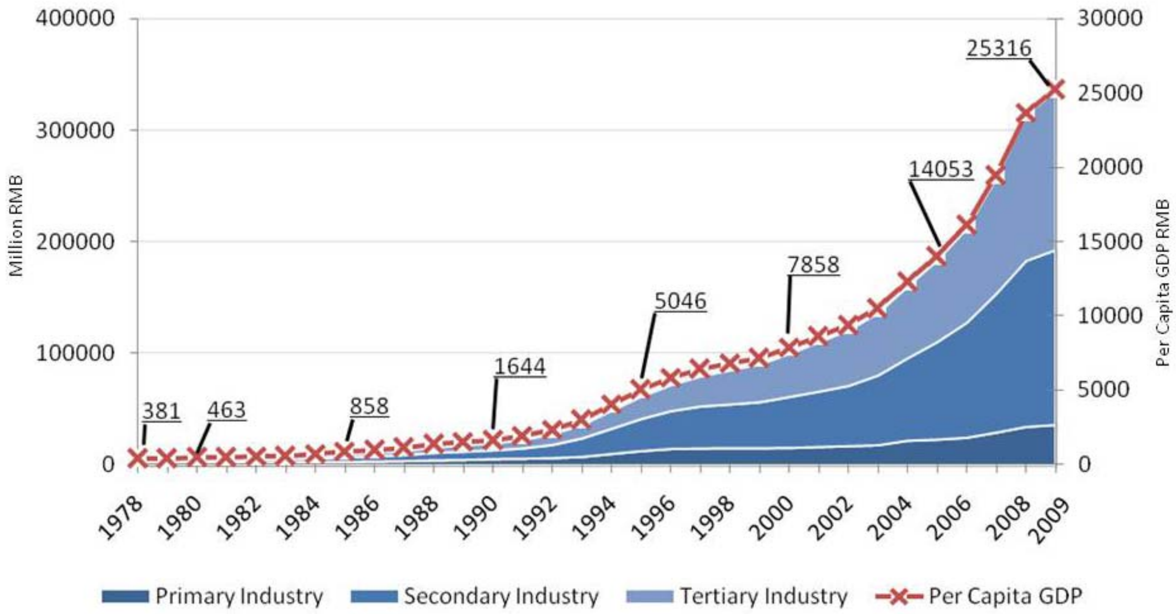
[5] In early 2008, China experienced severe winter storms in southern China. These storms crippled the nation's transport system resulting in serious logistic delays and exacted a heavy economic toll. Just three months later, a massive earthquake struck the central province of Sichuan killing up to 80,000 people, resulting in major social and economic disruption. Then in September 2009, the world experienced what is now referred to as the global financial crisis. This economic slowdown dragged nearly all developed economies into recession and dramatically reduced demand for China's exports.

[6] The Chinese Yuan (RMB), otherwise known as renminbi (RMB), is mostly used in this report with an exchange rate of: RMB1 = US$0.146 or US$1 = RMB6.829

At the beginning of China's economic reforms in the late 1970's, Deng Xiaoping called for the creation of a *xiao kang shehui* (小康社会) or well-off society by 2000 with a doubling of GDP per capita to US$800. The resulting reforms resulted in an incredible transformation of the economy so that nominal GDP per capita expanded 330% between 1978 and 1990 from (see Figure 1). It would be inaccurate to describe China's post-1979 period of economic reform as a head long rush into a capitalist market economy. Instead, pragmatism and gradual adjustment have marked the process of market-orientated reforms and opening up to the global economy. Deng's dictum of *crossing the river by feeling the stones* (过河摸石) reflects the important role of experimentation in loosening market and social controls whilst constantly assessing the political and economic impact at each stage. The state remains acutely aware of the impact of the reform process on historical traditions, including the natural and human resource base, formal and informal economic, social and institutional structures and the attendant risks of policy mistakes.

China's economic growth has been driven by a series of gradual reforms commencing with agriculture and the service sector followed by the more recent rapid expansion in industry and manufacturing. During the 1980s, the growth rate of value added in both agriculture and services more than doubled relative to the 1970s, to 6.2% and 12.3% respectively, while there was little increase in the growth rate in industry (see Figure 1). The services share of GDP rose more than eight percentage points between 1980 and 1990, and over this time the primary and tertiary sectors contributed 62% of total growth. As a result, Deng's target was realised almost a decade earlier than expected.

Figure 1: Gross Domestic Product (GDP) by Sector and Per Capita, Current Prices



Source: NBSC 2009, 2010

These dynamics changed substantially during the 1990s, as the expansion of industrial activity, linked into global markets and driven in significant part by foreign investment and a more competitive currency, became the main source of growth. Between 1990 and 1997 real industrial GDP grew by 15.7% per annum, while growth in both the agricultural and services sectors slowed. As a result, the industrial share of GDP rose sharply from 37.0% to 48.9% between 1990 and 1997, and secondary industry contributed to 60% of the growth of real GDP during this period. While the first two decades of economic reforms reduced the number of people living on less than $1 a day from 650 million to 200 million, the pattern of development was regarded as at "a low level", "not all-inclusive" and "very uneven" (Jiang Zemin, 2002). Therefore, the "main task of economic construction" remained the building of a *xiao kang* society based upon the tripling of GDP, increasing the rate of urbanisation above 50% and reducing the ratio of rural employment from 50% to 30% between 2000 and 2020.

Following the economic slowdown brought about by the East Asian crisis (1997-98), the real value added of the Chinese industrial sector doubled between 2001 and 2007.[7] This lifted China's output of industrial products to levels constituting a major proportion of total world output. As shown in Figure 1, GDP growth accelerated between 2004 and 2007 when it reached 13%. This expansion was largely fuelled by industry; making up nearly 60% of GDP growth compared with around 32% for services and agriculture less than 10%.[8] In 2008, China's merchandise exports were worth almost RMB10 trillion, five and a half times their 2001 level of RMB1.8 trillion. There is thus much reality to the current cliché of China becoming the 'factory of the world'.

The combination of burgeoning exports and high levels of fixed asset investment are undoubtedly closely related. Creating the capacity for such a high level of exports required heavy investment in fixed assets, not only within firms but also in a wide range of economic and social infrastructure, ranging from power stations, ports and railways to housing and urban facilities. Revenues being received by various parties, both firms and government agencies, from the export boom would also assist with the financing of that infrastructure. Thus the third feature of this period – a further rise in the role of the industrial sector in driving China's growth – is perhaps an inevitable result of these two trends. As a result, the share of secondary industry in GDP rose from 46% in 2001 to 48.6% in 2008, with virtually all the relative decline in the primary sector being taken up by industry.

The export of manufactured goods has played a central role in China's rapid economic growth during the past thirty years. While manufacturing contributes 40% to China's economy, exports make up 34% of GDP and experienced very strong growth between 2001 and 2008. In 2007, exports grew by 26% and then by a further 21% in 2008. Despite attempts to rebalance growth away from the industrial and towards the service sectors, industry continues to outpace services and investment outpaces consumption. Although in a slight shift in the balance of growth between the service and industry sectors, 2008 resulted in the first time since 2003 that the added value of the service industry exceeded

[7] Ironically, many of the current imbalances resulted from the government's economic stimulus program following the East Asian Crisis, which led to a massive surge in heavy manufacturing investment (much of it capital, energy and pollution intensive) to retain the pace of economic growth.

[8] China's own statistics are slightly different. See for example, the Statistical Communiqué of the PRC on the 2008 National Economic and Social Development (27 February 2009).

the growth rate of the secondary industry.[9] The share of the service sector in GDP was 41.8% in 2008, compared to an average of 70% in high income nations and 54% in middle income nations. China's pattern of economic growth is therefore described as capital intensive and industry-led, which has contributed to 60% of GDP growth during the past decade.

Given the scarcity of disaggregated data on Chinese industrial production in real terms, some illustration of that growth is provided in Figure 2 in terms of selected items in physical units. Each of the items shown in the table has grown very rapidly between 1990 and 2008.

Figure 2: Production of Major Industrial Products, 1990-2008

	Air conditioners (m units)	Household refrigerators (m units)	Colour TV sets (m units)	Crude steel (m tons)	Cement (100m tons)	Motor vehicles (m units)	Micro-computers (m units)
1990	0.2	4.6	10.3	66.4	2.1	0.5	0.1
1995	6.8	9.2	20.6	95.4	4.8	1.5	0.8
2000	18.3	12.8	39.4	128.5	6	2.1	6.7
2001	23.3	13.5	40.9	151.6	6.6	2.3	8.8
2002	31.4	16	51.6	182.4	7.3	3.3	14.6
2003	48.2	22.4	65.4	222.3	8.6	4.4	32.2
2004	66.5	30.3	73.3	272.8	9.7	5.1	59.7
2005	67.7	29.7	82.8	352.4	10.6	5.7	80.8
2006	68.5	35.3	83.8	419.1	12.4	7.3	93.4
2007	80.1	44	84.8	489.9	13.6	8.9	120.7
2008	82.3	47.6	90.3	500.9	14.0	9.3	136.7
2009	84.2	59.3	104.5	568	16.4	13.4	185.2
Estimated share of total world production, 2009 (%)							
	80	na	na	45	52	13	na

Source: NBSC, 2009 and author estimates

In 2009, China accounted for around 45% of global crude steel production due to a dramatic ramping up of capacity and production between 2001 and 2008 when it grew 300%. Production of non-ferrous metals, particularly aluminium, is also expanding sharply. Cement production, for which China accounts for over half of world output, continues to grow strongly, to meet the demands of the construction boom. Motor vehicle production is also increasing rapidly from a strong base, with China now the world's largest vehicle manufacturer and market with domestic sales exceeding 13.6 million units in 2009; a rise of 46% on 2008 figures. The automotive sector is likely to be an important next stage of China's export expansion, with exports of automobiles and automobile components expected to increase from US$ 10.9 billion in 2005 to US$70 billion by 2010.[10]

[9] See the State Council document 'The Opinions on Implementing the Policies and Measures for Accelerating the Development of the Service Industry' for further details of the government's policies to strengthen the service industry.

[10] Xinhua Online, 19 September 2006.

China's entry into the World Trade Organisation (WTO) and a strong global economy has produced, since 2001, a striking new stage in China's development.[11] Prior to China's entry to the WTO, China shared the impetus for global growth with Europe and North America of around 17.6%, 19% and 24%. However, since then, China's proportion of global growth has almost doubled. China's entry into the WTO not only gave China increased access to global markets, but also stimulated further interest on the part of multinational companies in basing production for world markets within China, and led to a further increase in foreign direct investment. Much of these exports still seem to involve relatively low value added production or assembly operations, although the government is seeking to increase the value added level through the increased application of science and technology.

Since 2001, the economy has been driven by very rapid growth in exports and in fixed asset investment, which are reflected in the growth in industrial output. The combination of the three measures – exports as a share of GDP, the ratio of fixed asset investment to household consumption spending and the secondary industry share of GDP – are at historically high levels, and are likely to increase further in the immediate future . A Caixin report (Wang Jing, 2010) referred to National Development and Reform Commission (NDRC) figures for fixed-asset investment during 2009 of over 344,000 new projects worth RMB15.2 trillion, representing a 67% increase on 2008 figures. The report added that "461,000 existing projects with planned investment of RMB42 trillion were continued last year, a 32% increase over ongoing projects in 2008".

Analysis of the explanations for this rapid growth in investing in infrastructure and heavy industry point to structural economic factors as the key to understanding this issue (Naughton, 2007; Kujis, 2009; Prasad 2009). Imbalances in the economy were created due to several interconnected reasons, including:

- government focus on industrial production to drive growth;
- depressed household incomes;
- high private funding of health, education and social security expenditure;
- low levels of domestic consumption;
- low resource (water and land) and energy pricing;
- perverse incentives for investing in capacity;
- low interest rates which discourage household savings and encourage corporate industrial investment; and
- weak enforcement of environmental standards.

The growth in investment, and heavy industry in particular, has not only played a key role in boosting GDP, it has also resulted in many of the imbalances in the economy with regards to natural resource use, energy consumption and environmental degradation. In 2009, the share of heavy industry in the gross value of industrial output exceeded 70%, which according to Feng Fei of the Research Department of Industrial Economy in the State Councils' DRC's, it is the highest since 1959 (Li Jing, 2010).

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[11] China has gained considerably from its entry into the WTO because protection in the advanced economies of manufacturing (other than textiles) has almost ceased. This has permitted a surge in the high-technology exports that have had the most widespread benefits to the Chinese economy.

The current economic crisis has occurred at the same time as the Chinese government is attempting to correct this imbalance in economic development. At this stage it is increasingly obvious that the crisis will curtail any of the earlier rebalancing of the economy rather than act as a stimulus towards a sustainable path of development.[12] According to the 11th Five Year Plan (FYP), China aims to increase the share of the service sector in GDP to 43.3%. However, it seems unlikely that the target will be met following the global economic downturn. Instead, between 2006 and 2008, industry growth continued to outpace services. Within the industrial sector, energy-intensive heavy and chemical industries (notably steel, petroleum and aluminium) have further expanded, despite some slowing in late 2008 due to the collapse of global markets. For instance, investment during the first ten months of 2009 in the cement, flat glass and steel industries grew by 64%, 35.3% and 3.8% respectively (Huang, 2010). Recent data suggest that strong growth in China during 2009 defied the global economic slowdown[13] and sharp drop in exports. Instead, growth is estimated to be around 8.7% on the back of high levels of investment in fixed assets, rising levels of domestic consumption and increasing industrial production. In 2010, economic growth may exceed 10% with the growth in investment at the provincial level varying from 10% to 30% (Wang Jing, 2010). Therefore, in terms of China's economy and society and the global climate, adjusting the pattern of development as well as adopting a more sustainable use of energy and limiting the environmental costs that it imposes is of the highest importance.

There is clearly a long road between the government's intention to move to a more sustainable growth path and the reality of overcoming the economic and industrial inertia. Limited capacity to alter the drivers of energy use further constrains the pace of change. Nevertheless, the economic and social pressures for more sustainable energy use and for an improved environment remain central realities in contemporary China. As growth in the world economy slowly recovers, and China's current economic strategy and competitiveness foster further increases in China's share of world markets, export-led, energy-intensive growth is likely to continue at a high level in China for some time to come.

Energy Use

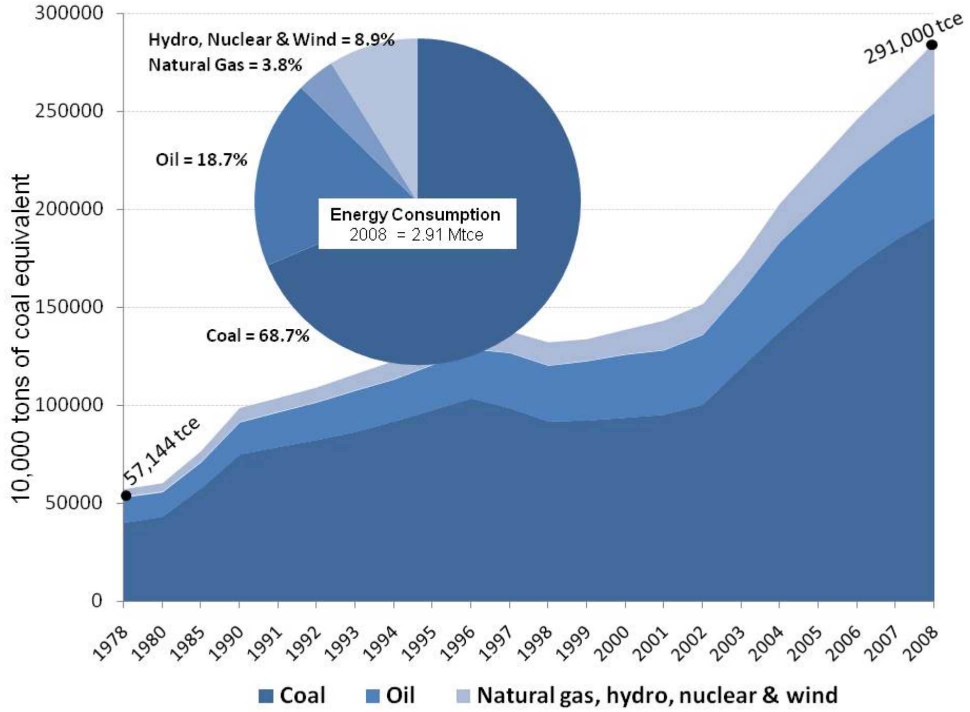
China is in the midst of a period of rapid industrialisation. As mentioned, its development path follows a similar pattern to its neighbours, Japan, Korea and Taiwan. China has learnt from the experience of its neighbours where rapid industrial growth is not mutually exclusive of energy efficiency gains through reductions in resource use and energy intensity. What is unique, however, is the scope and size of its growth as well as the implications of this development for energy use, natural resources and the environment at both the domestic and global level.

[12] The stimulus funding was also aimed at boosting rural living standards and was aimed at complementing existing social welfare programs in the 11th FYP, including RMB70 billion in 2009 for medical reforms and rural subsidies on top of RMB102.8 billion in allocations in 2008. Rural and urban relief programs have also increased RMB3 billion in 2007 to RMB9 billion in 2009 and RMB15 billion to RMB26.6 billion respectively (Naughton, 2009a).

[13] In early 2009, the World Bank, IMF and OECD continued to revise down their estimates of global development, including reducing the rate of China's economic growth in 2009 to around 6.5%. However, these institutions reminded us that global shrinkage would be worse without the modest growth of China. By mid-2009, these same institutions were upgrading global and China growth forecast largely on the basis of sustained economic activity in China following the massive state stimulus package.

The size and speed of China's growth necessitates enormous energy demands, currently second only to the United States. Figure 3 shows how China's energy mix has changed very little between 1978 and 2008. What has changed, however, is the demand for energy and its relationship to economic growth. Between 1978 and 2000, China's economy grew at an annual average rate of almost 10%, whilst annual energy demand grew at 4%. After 2000, economic growth accelerated slightly, yet the growth in energy surged on the back of an intensification of industrial production. Between 1978 and 1991, energy consumption doubled, requiring 14 years. It then doubled again in just seven years between 2001 and 2008. The outcome was that domestic energy supply struggled to keep up with demand causing black outs and brown outs. As a result, investment in new energy capacity and infrastructure accelerated in China as did the demand for energy imports.

Figure 3: China's Annual Energy Consumption Mix, 1978-2008

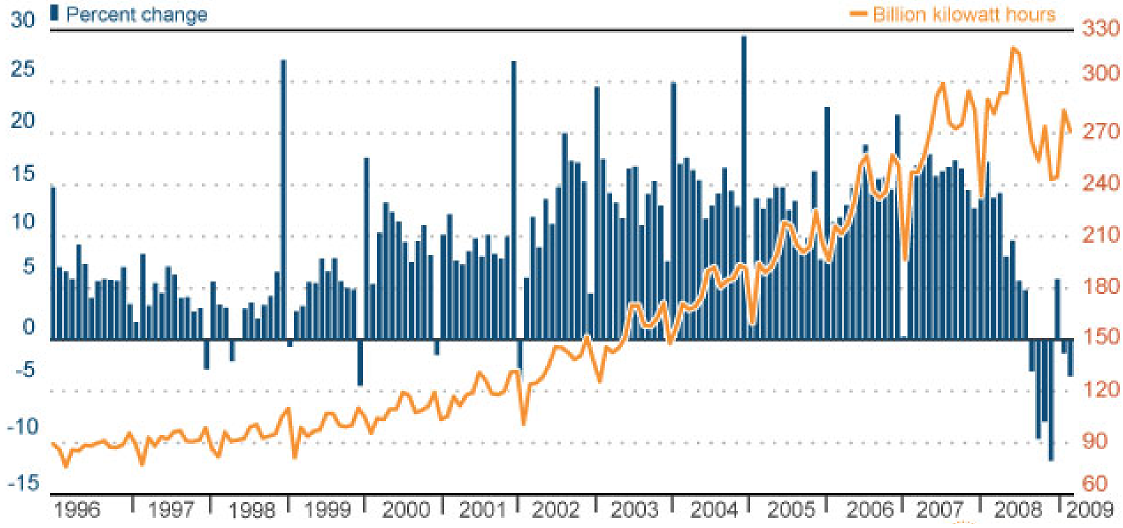


Source: NBSC, 2008

China's heavy dependence upon coal carries significant implications for these growing energy levels. Coal is the key resource in China's energy and power sectors with domestic coal production estimated to reach 3.3 billion tons in 2010. Coals share of primary energy consumption is 69% and in the power generation mix around 80% (Figure 3). Coal's dominant hold on energy supply remains consistent throughout the past thirty years. Oil also maintains a steady grip at around 20% of energy demand with hydro (6%), gas (4%) and nuclear (1%) also contributing. China's total energy consumption in 2008 was estimated at 2.91 billion tons of coal equivalent (tce) with per capita energy consumption being 2.2 tce, representing a 4.2% increase over 2007. China's energy consumption rose to 3 billion tce in 2009 with traditional fossil fuels providing over 90% of the energy. Coal remained steady at around 70% of the energy mix with renewables contributing 8.3%.[14]

Figure 4 highlights the steady growth in China's power generation between 2000 and 2006 when it more than doubled from 100 billion kWh to nearly 240 BkWh with electricity demand growing by around 14% annually. The noticeable decline in power generation growth in late 2007 occurred when the central government started to tighten fiscal and monetary policy in an attempt to slow down the over-heating economy. Figure 4 clearly shows the success of this policy.[15] However, power generation was immediately impacted by the sudden arrival of the global financial crisis which shifted generation into a short decline, followed by a period of stagnation.

Figure 4: China's Power Generation, 1996-2009



Source: National Bureau of Statistics cited in Reuters, 2009

One important aspect of recent developments, relevant both to energy use and to the demand for resources, is the increasing shift to heavy industry in China's industrial production. The strong growth of secondary industry is a key factor for the rebound in the energy to production relationship after 2002 when this sector experienced rapid growth. For example, the overall ratio of gross industrial output almost doubled between 2003 and 2008 from 90% to 160% of GDP. Most of this increase occurred with the tripling of heavy industrial production, notable in the resource and energy intensive sectors of steel, metals, petroleum chemicals, paper and glass production (Figure 13).

The industrial sector currently consumes almost 70% of total primary energy in China with the manufacturing sector alone consuming two-thirds of total energy. It is estimated that China's energy consumption for coal-burning power generation, steel and cement production is still 22%, 20% and 45%

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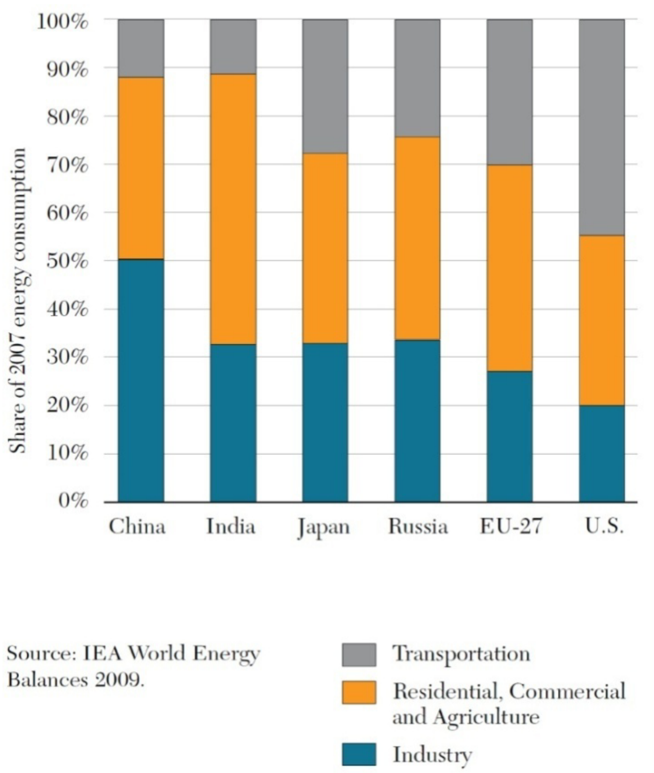
[14] Reuters UK (2009) China renewable energy use 8.3 pct of total in 2009 –official, 20 January 2010 online: http://uk.reuters.com/article/idUKTOE60J03Y20100120

[15] The annual sudden dips in consumption reflect the closure of most industry during the lunar new year festival.

higher respectively than those of advanced levels in developed countries.[16] These high levels of energy consumption also indicate, however, that structural changes and improvement of energy efficiency in energy intensive industries have great potential to contribute to energy conservation.

The strong bias towards industry in China's energy mix is most evident when compared against the international experience. In Figure 5, industry in China consumes more energy than any other country and even twice as much as the United States. Moreover, China's industrial plants remain more energy intensive per ton of output than those within the OECD by an average of 20-40% (Seligsohn et al., 2009). Industry has therefore been the main focus of the government's energy efficiency drive due to the significant benefits that can be achieved.

Figure 5: Energy Consumption by Sector



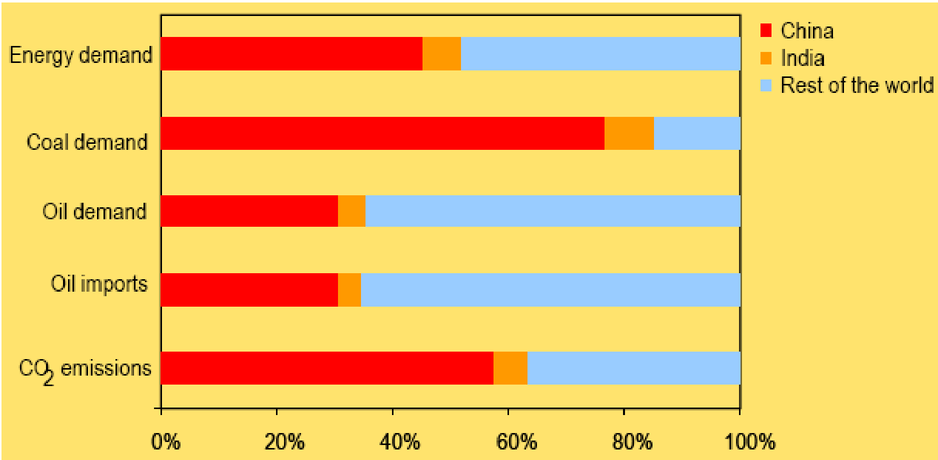
Source: Seligsohn et al., 2009

In 2000, China's primary energy demand accounted for around 10% of global demand, most of which was provided by domestic energy supplies. In the past decade, China's share has expanded to over 16% of global energy demand (IEA, 2009a, 76). A growing portion of this is being sourced from overseas, as evidenced by the booming resource economies of the world. China is relying upon imports for an increasing proportion of its supplies of the oil, gas, coal and uranium it consumes. This trend is apparent

16 According to Jiang Bing et al. (2010), the energy intensity of China's coal-fired power generation, steel, cement, oil processing and ethylene production are respectively 18%, 17%, 20%, 43% and 57% higher than the world average based upon figures from the National Energy Administration of China (NEAC).

when China's increasing share of key energy resources is examined. Figure 6 shows that in the period 2000-2006, China's energy demand made up nearly half of global energy growth and China's demand for coal contributed to nearly 80% of global growth in this core energy commodity. Then in 2008, China contributed to 74% of net global energy consumption growth and about 85% of the growth in coal usage. There was little change in 2008 in terms of economic structural drivers with the primary, secondary and tertiary industries accounting for 11.3%, 48.6% and 40.1% of GDP respectively. However, in the first 11 months of 2009, heavy industry grew by 22.2% compared to light industry's 12.6%.

Figure 6: China's Increasing Global Share of the Growth in Key Energy Related Indicators, 2000-2006



Source: IEA, 2007

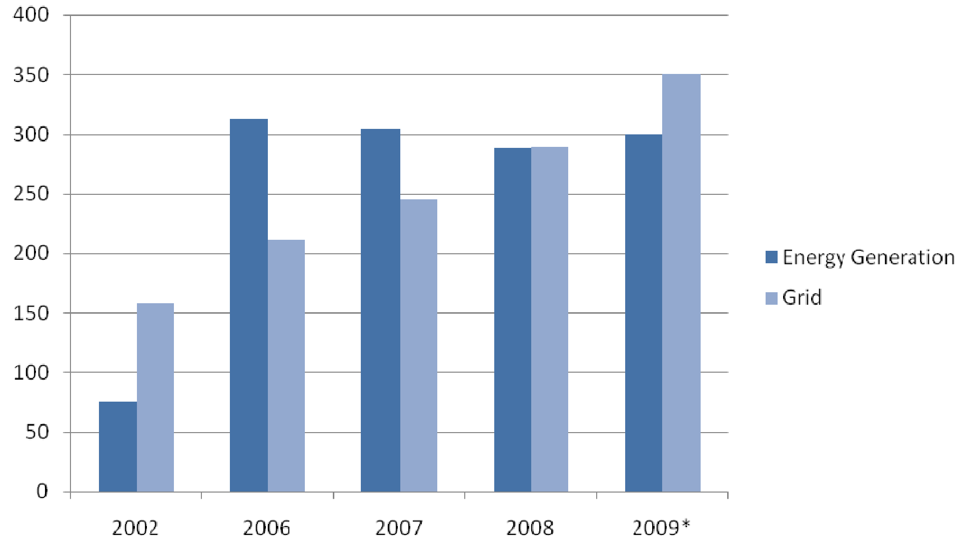
This explosive growth in energy use caught policymakers, energy analysts and energy providers in China unaware. As a result, power shortages emerged between 2001 and 2005 followed by a massive expansion in energy production capability (Figure 8). In response to the energy shortages, China's most-developed coastal regions strengthened policies towards developing their own energy security solutions, instead of relying upon coal from the interior and northern provinces. In the face of rapidly growing demand for power, the wealthier provincial and municipal governments along the industrialized coast are opting to invest in diverse energy supplies, such as nuclear, gas and hydro.

The electricity supply shortage also gave rise to locally-initiated solutions outside the reach of the regulatory framework. For instance, it is estimated that about 10% of China's total electric power consumption is supplied by the so-called 'within-the-fence' diesel generators, the installation of which is said to have been generally tolerated, and in some cases actively supported, by local officials (China Intel Group, 2008). Environmental regulation of these diesel generators has lagged behind that of central station power plants. As a result, China has now become the world's largest market for industrial diesel generators, and the country's consumption of diesel fuel, much of it produced from imported crude, has climbed substantially.

Meeting the rapidly growing energy demands of the nation remains a serious challenge for the government. In the four years between 2005 and 2008, China increased its electricity generation capacity by 350 GW (see Figure 8) to reach a total capacity of 800 GW.

In order to meet the growing demands on China's energy sector since 2002, the state increased investment in both the supply and distribution network (see Figure 7), including allocating RMB650 billion in the 2009 stimulus package for new generation and upgrading the grid and distribution systems (Fu Jing, 2009).

Figure 7: Investment in China's Power Generation and Grid, billion RMB



Note: * 2009 figure is an estimate.
Source: Shanghai Daily, 2009

A key component of the spending is the construction of ultra high voltage lines from the east to the west and the north to the south of the country as well as making moves towards developing a smart grid to support the rapid expansion of renewables, which are predominantly located in the north and west of the country.[17] China's existing grid experiences similar problems to other large land masses with weaknesses in the transmission system resulting from large surpluses in some regions and shortages in others. Much of this resulted from a lack of investment in grid and distribution infrastructure prior to 2003 (see Figure 7). Figure 8 illustrates the relatively stable levels of new energy generation capacity up until 2002. However, there has been a spike in investment in new power generation following the growth in heavy industry and resultant power shortages, black-outs and brown-outs in southern China. While the vast majority of the new capacity is supercritical and ultra-supercritical coal thermal power plants, there is strong growth in non-coal power generation, such as hydro, wind and nuclear power plants, since 2005. The rapid expansion of renewables, however, is exacerbating the capacity of the grid, especially in western and northeastern China, for example, where the growth of wind generation capacity has expanded rapidly. Northeastern China expects more than 13 GW of new wind power capacity to be installed in 2010, yet the grid can only cater for around 9 GW of added fluctuating wind power capacity (Reuters, 2010b). According to Liu Qi, deputy head of the NEA (NDRC, 2010), the lack of

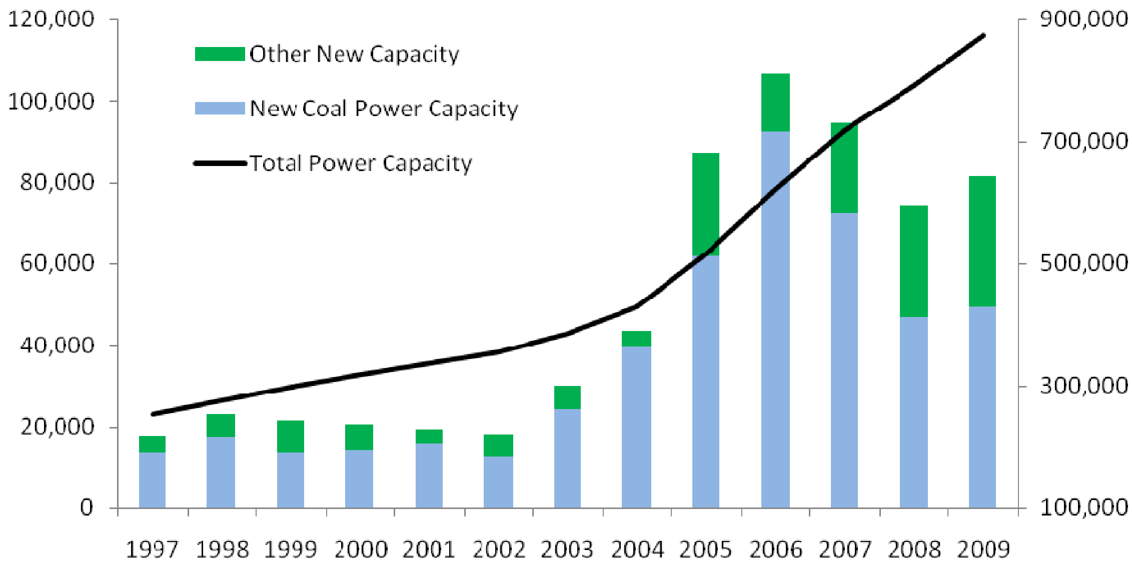
[17] There have been some recent concerns with progress on the first ultra-high voltage (UHV) AC system between Shanxi and Hubei, which continued to underperform against expectations and remained at an early stage of development (Yu Dawei, 2010).

grid capacity and grid connection remain the main challenges for new wind power generation in China. In contrast, an official from the NEA's renewable section argued that competing economic interests were the main inhibitor and that technological or grid-related issues were not an issue.

China's traditional energy fuel, coal, faces similar geographical and infrastructure constraints. The rapid expansion of renewables, however, is exacerbating the capacity of the grid, especially in western and Northeastern China, for example, where the growth of wind generation capacity has expanded rapidly. Northeastern China expects more than 13 GW of new wind power capacity to be installed in 2010, yet the grid can only cater for around 9 GW of added fluctuating wind power capacity (Reuters, 2010b). According to Liu Qi, deputy head of the NEA (NDRC, 2010), the lack of grid capacity and grid connection remain the main challenges for new wind power generation in China. In contrast, an official from the NEA's renewable section argued that competing economic interests were the main inhibitor and that technological or grid-related issues were not an issue.

As China's coal is mainly located inland, far from the major energy consuming regions along the coast, the government is implementing a clean-coal-based development strategy which favours the development of energy infrastructure with large-scale and technologically-advanced power plants located in the coal-rich areas of the north and the west, and linked to the coastal regions via long-distance power-grid.

Figure 8: Total Capacity and the Annual Increase in Power Generation Capacity, 1997-2008, MW



Source: CEIC data, 2010

Of the 217 GW of new coal-fired capacity under construction globally in 2008, China contributed around 112 GW or more than half. Most of these new plants are utilising supercritical technology and it is likely that ultra-supercritical technology will play a critical role in the coming decade. As a result of these developments, China's fleet of coal power generators are reportedly more efficient than those found in the United States (The Climate Group, 2009). While the efficiency of China's energy generation is improving, growth in demand continues especially from the expansion of the industrial sector. In order to understand the implications of this expansion for energy use, it is necessary to examine the energy intensity of the economy as a whole as well as adopt a sectoral analysis.

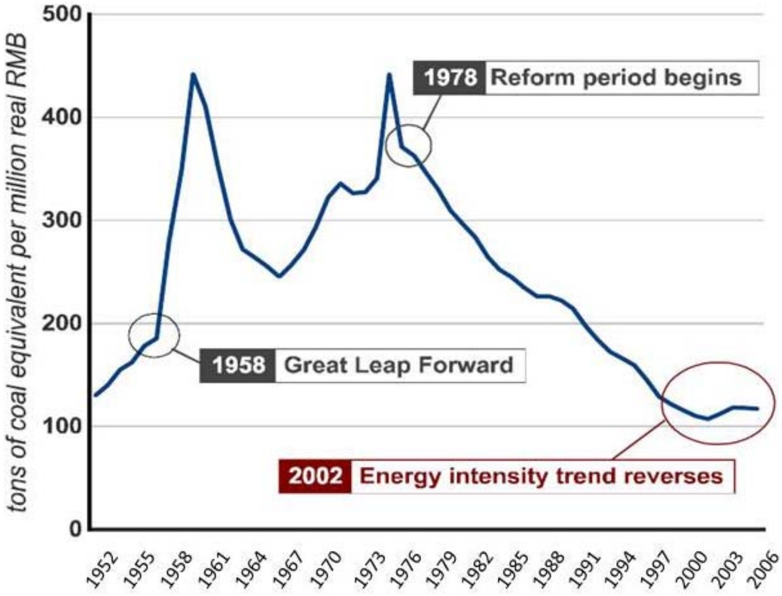
Energy Intensity

Energy intensity is a common measure of the relationship between energy use and the economy. It measures how much energy is required to produce a unit of national revenue. For example, in 2003, China's energy use per dollar of PPP-adjusted GDP was 0.23 kg of standard coal equivalent (sce) or about the same as the United States, Indonesia, South Korea and Malaysia. In contrast, Japan and the European Union used about half the amount of energy or 0.15 kg.

Prior to the 1978 economic reforms, the Chinese economy was both highly energy intensive and highly inefficient in its use of energy. Since the commencement of the 1978 economic reforms, China has achieved consistently improved energy efficiency and energy intensity figures (see Figure 9). A combination of productivity gains through the application of new technology and innovation, government policy measures aimed at achieving energy efficiency and structural economic change led to a sustained reduction of energy intensity during the 1980s and 1990s. As a result, energy use rose more slowly than GDP for the first fifteen years of the reform period, implying a fall in the energy intensity of GDP (Figure 9). China's experience remains generally positive especially when compared to the industrialisation process in Japan and Korea. Energy intensity in Japan between 1960 and 1974 increased 23%, and in Korea it increased 45% between 1971 and 1997.

Interpretation of trends became more complex in the second half of the 1990s, as the official Chinese energy data became unrealistic (Sinton & Fridley, 2003). Between 1996 and 2001 real Chinese GDP was reported to have increased by 46%, but total energy consumption was reported to be 3% lower in 2001 than in 1996, implying a negative value for energy elasticity. By the late 1990s, China's energy intensity was less than a third of 1980 levels. However, since China's entry to the WTO in 2001, the nation's energy intensity has deteriorated (Figures 9). Since 2001, China's energy intensity has increased due to strong investment in industrial production, notably manufacturing and heavy industry particularly of energy-intensive products, such as steel, aluminium and cement. To complicate matters, the post-2001 turnaround in China's declining energy intensity occurred at the same time as the nation experienced a burst of rapid economic growth; the earlier surplus in energy capacity was eroded; and, the energy demand outstripped supply. Additional factors, such as an increasing reliance upon energy imports and bottlenecks in the domestic distribution of energy and fuel supplies exacerbated the serious energy and resource shortages. In response, the government intensified its energy efficiency efforts so that energy and energy efficiency became core government considerations. This section explores some of the reasons for this shift in the relationship between energy and development.

Figure 9: Energy Intensity of the Chinese Economy, 1952-2006

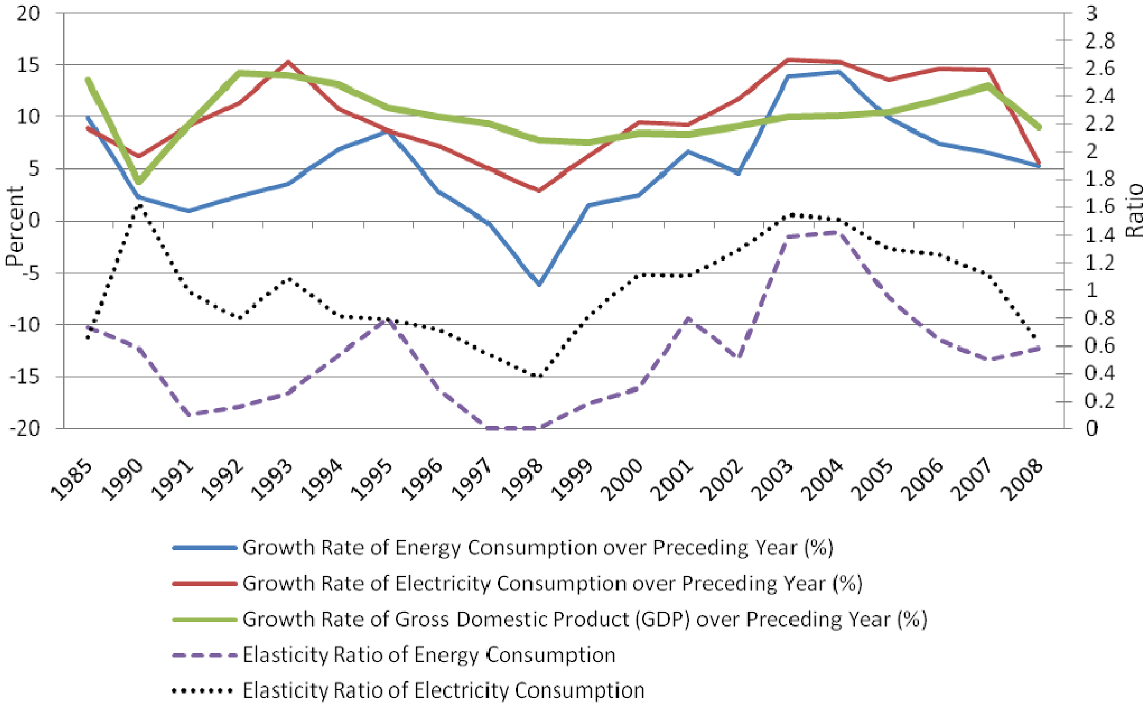


Source: Rosen & Houser, 2007, 6

A key issue in developing projections of energy use is the value for different countries of the energy elasticity of GDP. Energy elasticity is a term that is used in relation to the energy intensity of GDP and reflects the percentage change in energy consumption relative to a 1% shift in GDP. Typically, the elasticity of total primary energy use with respect to GDP is equal to or greater than one during the industrialisation phase of development. However, once a nation achieves higher living standards this elasticity reduces significantly below one, and indeed less than 0.5. The value of the elasticity parameter of energy is a more critical measure, especially when making comparisons between nations. For example, the energy elasticity of GDP for developing countries as a whole was 1.04 over 1971-2002. If China is removed from these figures, the elasticity for all other developing countries over this period was 1.34 compared to 0.57 for China (IEA, 2009d).

Figure 10 shows that prior to 2001, China's energy elasticity was well below one. However, between 2001 and 2005, energy use grew by 11.6%; implying an elasticity of 1.2 over this period.

Figure 10: Elasticity Ratio of Energy Production, 1985-2008



Source: NBSC, 2009

The rise in energy intensity (Figure 9) and energy elasticity (Figure 10) occurred because not only did the economy grow much quicker than anticipated, but this growth was fuelled by a rapid expansion of heavy industry, particularly of energy-intensive products, such as steel, aluminium and cement. Rosen & Houser (2007) explain that the energy demand elasticity grew from under 0.5 between 1978 and 2000 to 1.5 between 2001 and 2006. As a result, energy consumption increased four times faster than originally estimated.[18]

China officially claims that its energy elasticity of consumption was 0.62 in 2008 and -0.24 in 2009 and its energy intensity declined -1.51% in 2008 to 1.13. In fact, China reached a peak energy elasticity figure of 1.55 in 2003. Initial official estimates suggested energy intensity declined 5.2% year-on-year in 2008, a larger decline than the 3.66% recorded in 2007.[19] This would have resulted in a cumulative improvement from 2006-2008 of nearly 11%. It was then reported that in the first half of 2009, the energy required to produce a unit of GDP dropped a further 3.35% year-on-year reaching an accumulated total of 13.43%. According to the NDRC, the energy intensity of power generation was down 9.51%, oil and petrochemicals were down 8.21%, the coking coal industry declined 3.8%, non-ferrous metals declined

[18] Predictions at this time by the US Energy Information Administration (EIA, 2005) estimated China's energy elasticity at around 1.5. In other words, with GDP growth of 10%, energy demand grew by 15% (see Figure 9).
[19] Xinhua report this figure in February 2009 followed by a March report of a higher updated figure of a 4.59% decline in 2008 from the previous year.

19.59% and steel improved 8.43%.[20] As a result, Premier Wen Jiabao announced in March 2010 that China had reduced its energy intensity by 14.38% (China Daily, 2010).

CSES analysis is at odds with this latest statement and has found that energy efficiency measures have achieved less than half the targeted figure due to the rapid growth of the economy and the ongoing resilience of energy-intensive industrial expansion.

Figure 11 below provides an interpretation trend in real GDP and energy consumption between 2005 and 2010. This covers the period of the 11th Five Year Plan and is based upon the latest data provided by the National Bureau of Statistics and in part as provided on CEIC. The real growth rates for GDP are converted into levels using 2005 as a base. The table implies that over the first four years the reduction in energy intensity has been 7.7%, and that a reduction of about 10% is likely for the full 2005-2010 period. This conclusion is not consistent with other readings of this matter. Nor is it in line with the government's announcements on meeting the 20% reduction in energy intensity by 2010.

Figure 11: Real GDP Growth, Energy Use and Energy Intensity, China 2005-10

	Real GDP (2005 values)	Energy consumption (MT SCE)	Energy intensity Level	Energy intensity 2005=100	GDP Growth (% pa)	Energy Growth (% pa)
2005	18322	2247	12.3	100		
2006	20455	2463	12.0	98.2	11.6	9.6
2007	23122	2656	11.5	93.7	13.0	7.8
2008	25192	2910	11.6	94.2	9.0	9.6
2009	27388	3100	11.3	92.3	8.7	6.3
2010	30400	3364	11.1	90.2	*11.0*[1]	*8.5*[1]

[1]Assumptions for 2010

Source: NBSC, 2010; CEIC, 2010.

There are five areas of doubt about this conclusion:

Firstly, the GDP figures used reflect the increased levels of GDP, and the implied higher growth rates, arising out of the Second Economic Census, released on 25 December 2009, but only for 2008 and 2009. The basis for the GDP figures in Figure 11 is the latest published annual growth rates, for each of the four years. When the revised figures back to 2005 are available, the growth rates for 2005-08 may also be revised upwards. This would tend to lead to a larger reduction in energy intensity than shown in the table. The upward revision to GDP in 2008 was 4.4%. If the same pattern of distribution of that increase is used as for the First Economic Census (for 2004, released in 2005) the effect would be to increase the growth of GDP between 2005 and 2008 by about 1.2%, and reduce energy intensity by a similar amount.

Secondly, the energy consumption figures for 2008 and 2009 also reflect the results of the Second Economic Census, which had a special focus on energy use. The effect was to increase the level of energy use in 2008 from 2.85 MT SCE to 2.91 MT SCE (an adjustment of 2.1%), so as to put it 9.6% higher

[20] Source: http://www.chinadaily.com.cn/bizchina/2009-08/10/content_8548117.htm

than in 2007, if the 2007 figure is taken as unchanged (as the current CEIC tables do). The basis for the energy data in Figure 11 is the previously published levels of energy use in 2005-07, together with the new levels for 2008 and 2009. But it is quite likely that the higher 2008 estimate for energy use will also lead to higher energy use in earlier years (2005-2007). An upward revision to energy use in 2005 (perhaps of up to 1%) would again lead to a larger reduction in energy intensity than shown in the table.

Thirdly, the published figure for energy use for 2009 (3100 MT SCE, or a 6.5% increase on 2008) is preliminary, and may well be revised upwards. The accompanying data indicate that energy use based on fossil fuels rose by 9.2% in 2009, and that energy use from renewable sources (which is still mainly hydro) fell by 21.4%.

Fourthly, both Minister Xie Zhenhua and Premier Wen Jiabao were quoted as saying (Krishnan, 2010; China Daily, 2010) that over 2006-09 energy intensity fell by 14.38%. While they presumably have advice based on the latest data on the issues raised above, the difference between this estimate and that calculated in the table from the published data is large. The revisions foreshadowed above could lead to a bigger energy intensity reduction than calculated in Figure 11 by up to 2-2.5 percentage points, but seem unlikely to generate a figure in excess of 10% for 2006-09. There may be other issues of which we are unaware, or different calculations may be being made.

Finally, the figures for 2010 are only estimates, of course. They are based on the apparent continuation of rapid growth, but also on the fact that the published figures on coal production and on the growth of the energy intensive industries through the first two months of 2010 imply a rapid growth in energy use in 2010. Given the current pattern of growth there may indeed be little reduction in energy intensity in 2010.

The lack of reliable and consistent data on the energy intensity issue has resulted in much discussion around the ability to meet the targets and the implications of failure to meet them. According to Ma Liqiang (Global Times, 2009), China shall achieve the energy efficiency reduction of 20% by 2010 (equivalent to reducing emissions by 600 million tce) and reduce carbon emissions by at least 1.5 billion tons by 2015 (assuming from a BAU scenario). Some even suggested that the initial failure of the targets and subsequent central government criticism would ensure that local governments comply with national standards. However, it is increasingly apparent that the 2008 stimulus package has witnessed a return to the earlier pattern of rapid economic growth driven by investment in energy-intensive industries.[21] In early 2010, Tsinghua's Hu Angang argued that China would be lucky to reach a target of 10% considering the figure was around 8% on his estimates.[22] Hu's conservative estimates are correlate with estimates made by ANU's Howes (2010) of around 8.2%. Earlier in 2009, Lin Boqiang, director of Xiamen University's Energy Economics Research Center countered that "with all signs pointing to strong demand growth going into the second half [of 2009], the government's target … is becoming more unlikely.

[21] According to Xie Zhenhua, NDRC vice minister, China may reduce its energy consumption per unit of gross domestic product (GDP) by 5% in 2009, but he cautioned about meeting the 20% cut by 2010 (Xinhua, September 27: http://news.xinhuanet.com/english/2009-09/27/content_12116602.htm).

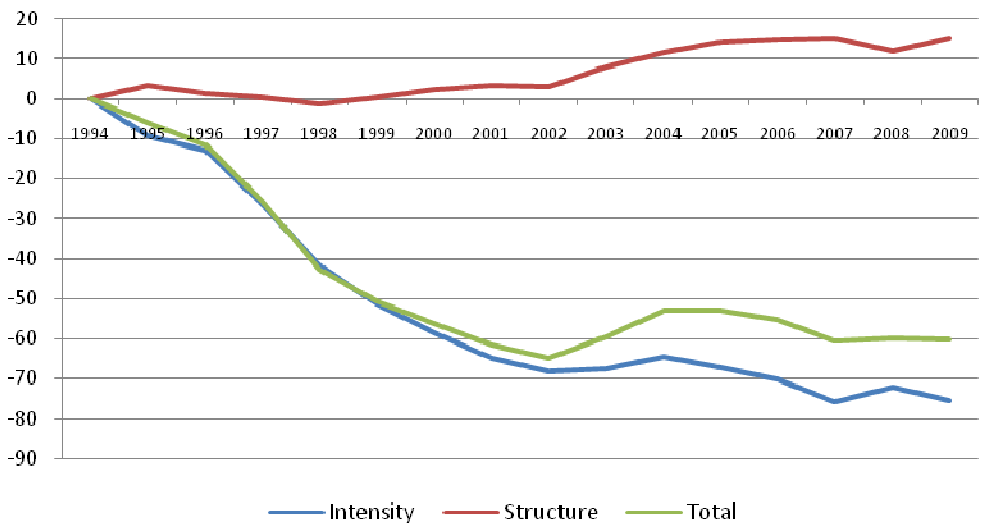
[22] Personal communication, March 2010 .

Instead a reduction of 15% to 16% is more realistic".[23] According to Professor He, the director of Tsinghua University's Low Carbon Energy Laboratory, this figure is still a very significant achievement for any country in the midst of industrialisation (Seligsohn, 2009). Naughton (2009a, 4-5) argued that the stimulus has actually 'distorted the Chinese economy by halting, and temporarily reversing, the decades-long trend for the state to retreat from the economy, and for private and non-governmental actors to play a greater role'. This has a dual effect of both reducing efficiencies and undermining the incentive structure for public and private decision-making. As such, the stimulus may have broader implications beyond energy use to affect the economic rebalancing program.

Presently, it remains difficult to quantify much of these issues until more detailed national and sectoral energy usage data for 2008 and 2009 are publicly available in early 2010. What is clear however, is that deep structural economic reforms are required if China wants to curtail energy demands and the resultant carbon emissions.

Analysis of national energy intensity and elasticity data against GDP alone is not however a reliable measure of energy efficiency. Using energy intensity as a measure of efficiency requires consideration of: the structure of GDP, in terms of the relative importance of high and low energy intensity industries within the economy (*the structure effect*); and the intensity of energy use per unit of value added within individual industries (*the energy intensity effect*).[24] The full implications of these effects are highlighted by examining the period 1994-2009, and particularly the period since 2001.

Figure 12: Intensity and Structural Contributions to the Change in Aggregate Energy Intensity, China, 1994-2009 (thousand tons of standard coal equivalent per billion RMB at 2005 values)



Source: NBSC, 2010; CEIC database and estimates of the authors (for details see Appendix)

[23] http://english.caijing.com.cn/2009-08-04/110220301.html

[24] Additional considerations include: China's geography in terms of its size and climate whereby China typically has a higher demand from the transport sector and climate determines the demand for heating or cooling; the value and fluctuations in exchange rates can affect analysis of energy efficiency; and, China's general energy mix and historical access to energy resources.

One key result of this intensity and structural analysis is summarised in Figure 12 above, which shows contributions to changes in China's overall energy intensity, in terms of energy use per unit of real GDP, over the period 1994-2009.

In 1994 China's aggregate energy intensity was 175,500 tons of standard coal equivalents per billion RMB in 2005 values. By 2002 this figure had fallen to 111,700, a decline of 64,800 tons SCE per billion RMB or 37%. As shown in Figure 12, this was entirely due to declines in energy intensity within specific industries, which had contributed a decline of 68,000 tons per billion RMB to offset a rise from structural factors of 3,200 tons per billion RMB (see Figure 13). This was a period of rapid declines in energy intensity within industries, particularly energy intensive ones, which both continued the long decline since 1980 and also in part reflected emerging energy shortages. It was also a period of relative stability in the structure of GDP.

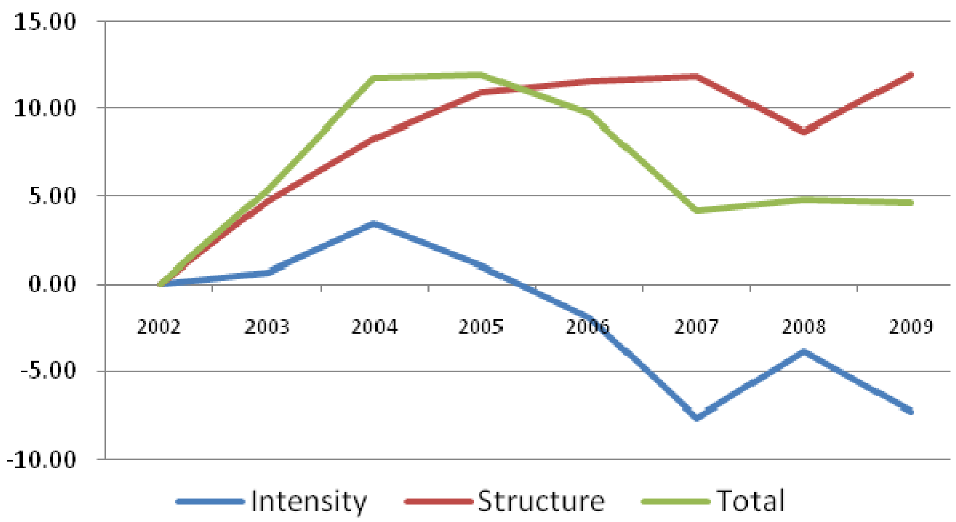
Figure 13: Sectoral Energy Elasticity and Energy Use Based Upon Primary Energy Consumption and Real Value Added, China, 1994-2007

Sector	Primary energy consumption			Real value added			Descriptive statistics	
	2007 (Mt SCE)	Change 1994-2001 (% pa)	Change 2001-07 (% pa)	2007 100 billion RMB at 2005 values	Change 1994-2001 (% pa)	Change 2001-09 (% pa)	Elasticity of energy use 2001-07	Energy use/ value added (Mt SCE per 100 billion RMB) 2007
Agriculture	82.4	3.3	4.3	24.4	3.6	4.8	1.01	3.4
Industry								
Mining	140.6	1.7	4.6	11.2	11.5	11.5	0.35	12.5
Petroleum processing	131.8	11.0	9.9	2.4	8.7	13.6	0.65	55.5
Chemicals	272.5	-2.7	12.5	5.8	10.9	13.8	0.96	47.4
Non-metallic minerals	203.5	-1.3	10.1	4.9	4.0	12.8	0.88	41.4
Ferrous metals	477.7	2.4	17.6	7.5	2.8	18.0	0.93	63.6
Non-ferrous metals	106.9	6.8	17.6	3.3	12.6	20.7	0.81	32.5
Other manufacturing	369.8	-0.1	9.6	57.3	10.8	12.6	0.83	6.5
Electric power, gas and water	198.9	8.7	9.0	7.8	19.2	8.4	1.28	25.4
Total	1901.7	1.7	11.6	100.2	10.5	12.7	0.95	19.0
Construction	40.3	7.5	10.3	13.0	7.0	11.5	0.91	3.1
Services								
Transportation	206.4	9.1	12.2	13.6	10.2	11.1	1.16	15.2
Wholesale, retail and hospitality	59.6	8.5	10.6	17.6	8.3	11.8	1.04	3.4
Other tertiary (inc. households)	365.3	1.1	8.3	62.4	10.1	12.2	0.72	5.9
Total	631.4	3.5	9.7	93.6	9.7	12.0	0.87	6.7
Total economy	2655.8	2.2	10.8	231.2	8.7	11.3	1.01	11.5
Memorandum item								
Five energy intensive industries	1192.4	1.1	14.0	23.8	6.4	15.5	0.89	50.0
Industry as a share of total	71.6%			43.3%				
Five industries as a share of total	44.9%			10.3%				

Source: NBSC, 2010; CEIC database and estimates of the authors (for details see Appendix)

Since 2002 the position has been quite different, as shown in Figure 12 and more clearly (on a revised scale) in Figure 14. On our estimates[25] aggregate energy intensity is about 5,000 tons SCE per billion RMB (or 4%) higher in 2009 than in 2002. With the rapid expansion of industry after China's entry into the WTO in 2001, and with energy supplies rising rapidly, both the intensity and structural factors contributed to rising energy intensity after 2002. But after 2004 the intensity measure began to fall, and this accelerated as the policies of the 11th Five Year Plan took effect. We estimate that falling industry-specific intensities reduced overall energy intensity by 7,300 tons SCE per billion RMB or 6.6% between 2002 and 2009.

Figure 14: Intensity and Structural contributions to the Change in Aggregate Energy Intensity, China 2002-2009 (thousand tons of standard coal equivalent per billion RMB at 2005 values)



Source: NBSC, 2010; CEIC database and estimates of the authors (for details see Appendix)

The measure of the structural composition of GDP continued to increase until 2007, and then dropped in 2008 as policy makers attempted to restrain the growth in energy intensive industries. But the economic stimulus package put in place in the wake of global financial crisis has led to renewed rapid growth in these industries. As a result, China's GDP became more energy intensive in 2009, and is likely to become more so in 2010. Overall, between 2002 and 2009 the shift to a more energy intensive economic structure is estimated to have contributed 11,900 tons SCE per billion RMB or 10.7% to overall energy intensity, more than outweighing the effects of falling intensities within specific industries. It seems clear that, in moving to reduce energy intensity in the future, China needs to give attention both to changing the structure of GDP as well as to improving the efficiency with which energy is used in individual industries.

[25] The structure of China's GDP can be estimated through to 2009, but on the basis of eleven months data for 2009. Aggregate energy use for 2009 will not be available until early 2010. On the basis of a range of partial indicators, we assume that the increase for 2009 over 2008 is 8.5%. The intensity effect for 2009 is then inferred from the aggregate data and the estimate of the structural measure.

Pathways for Rebalancing the Economic Structure

These structural economic imbalances are becoming increasingly difficult for the government in Beijing to ignore, especially as the global and transboundary implications of China's developmental path increase. As such, achieving a rebalancing of the economy is receiving both enormous momentum and attention from the central leadership. In response, central government leaders have called for immediate work to adjust China's pattern of economic development towards a more equitable and balanced approach to economic development. It is increasingly clear that, in moving to reduce energy intensity in the future, China needs to give greater attention both to changing the structure of GDP as well as to improving the efficiency with which energy is used in individual industries. This section firstly provides a brief but detailed review of the structural rebalancing program within the 11th Five Year Plan before exploring the broader policy measures China has chosen to adopt to achieve the dual aims of structural rebalancing and energy efficiency. This section also highlights some of the policy issues relating to the formulation, co-ordination and progress of specific energy efficiency policies. This is followed by an examination of the potential implementation constraints (and opportunities) relating to China's governing system, its differentiated development experience and the implications of the current pattern of development relating to economic growth, population and urbanisation.

In early 2010, China's deputy Prime Minister Li Keqiang, highlighted the critical nature of structural economic imbalances, but also of the urgency to adjust the pattern of development:

> *We stand at a historic juncture, … we must change the old way of inefficient growth and transform the current development model that is excessively reliant on investment and exports.*[26]

Li's comments also reveal the resilience of the "old" economy of investment and export-led growth, which continues to defy round-after-round of national policies and exhortations by state leaders.

The serious implications arising from the imbalances within China's economic structure add up to a powerful case, largely accepted by the government, for a significant change in its current development strategy. The state announced a raft of ambitious measures for rebalancing economic development in the current 11th FYP covering energy use, air and water pollution, service sector growth, urbanization and social welfare provisions.

A summary of the limitations of the existing pattern of development together with the key dimensions of the revised development strategy during the 11th FYP are provided in Figure 15.

[26] Bennhold, K. (2010) China's Next Leader Offers a Glimpse of the Future, *New York Times*, 28 January online: http://www.nytimes.com/2010/01/29/business/global/29yuan.html?partner=rssnyt&emc=rss

Figure 15: Dimensions of China's Revised Development Strategy during the 11th Five Year Plan

Limitations of Existing Strategy	The New Strategy
Energy intensive growth	**More knowledge and technology intensive growth**
• Concentration on low value added activities • Inefficient transport and consumer energy use • High-levels of pollution and environmental degradation • Low pricing of resources and no costing of social and environmental externalities • Heavy reliance on energy and resources • Advanced technologies not available	• Become market leader in use of advanced technologies • Mandate leading transport and consumer energy use • Constraints on energy intensive activities • Target energy efficiency gains amongst top energy users & sectors • Adopt clean production & stimulate the adoption of advanced, energy efficient and more environmentally benign technologies, processes and practices • Require global companies to share advanced technologies • Diversify energy mix emphasising low carbon energy generation, such as hydro, nuclear, wind and natural gas
Focus on export oriented manufacturing	**Shift to value added production**
• Low employment growth in industry • Low wages, limited broader benefits • Big trade surplus, foreign exchange	• Gradually increase Yuan's value • Reduce preferential climate for low value exports • Market pricing for energy and other inputs • Seek greater external value adding to resource imports
Over-emphasis on investment activities	**Control over-investment**
• Excessive, unproductive investment • High energy and other resource use • Development of speculative activities	• Limitations on local government competition • Market pricing for land, energy and other inputs • Use monetary policy to vary interest rates and credit controls to avoid bubbles
Low growth of health, and other services	**Develop sources of services growth**
• Low public spending; high private costs • High savings; low consumer spending • Unequal access to basic services	• Higher taxation of incomes and growth sectors • Increased public outlays on 'soft' social infrastructure • Development of public health sector/other services • Higher employment growth, especially in services • Improve consumer and SME access to credit
Low social dividend from growth	**More employment and better services**
• High level of rural poverty despite growth • Low employment growth • Limited access/high cost of rural services • Inadequate support for migrant workers	• Improve wages and labour conditions • Promote growth and income in agriculture • Develop comprehensive system of rural health, education and other services

The 11th FYP outlines a vision of development that is socially and environmentally sustainable and that contributes to maintaining a harmonious society. It outlines broad programs to be implemented towards achieving such a form of development as follows:

- to make growth more sustainable and environmentally benign, and to reduce pollution and the rate of energy and water use;
- to increase innovation within all sectors, including industry, and shift the pattern of activity from low value added output based on low labour costs towards higher value added activities based on knowledge;

- to change the structure of growth towards the service sector, and accelerate the growth of particular service sectors that directly contribute to individual welfare; and,
- to improve rural welfare and to build structures and services that ensure the benefits of growth flow to people in rural areas.

Reinforcing these qualitative declarations are quantitative commitments within the Plan across several areas, including the economy, population, resources, environment and social services. These indicators include both mandatory and anticipatory targets based upon figures supplied on an annual basis by sub-national governments. Figure 16 includes some of the key indicators, targets and progress to the end of 2008 relating to economic structure and energy. It appears that progress to date remains modest with a lot of catch-up required to meet the 2010 targets, especially regarding the service sector's share of GDP, energy intensity improvements and R&D spending. According to the World Bank's (2008) Louis Kuijs, despite the ambitious commitments within the 11th FYP, "China has been less successful in rebalancing its overall pattern of growth, which has limited progress on many key objectives of the 5YP." The Chinese government has introduced a comprehensive set of policy measures together with monitoring and verification procedures to ensure the targets are met, which are detailed later in the report.

Figure 16: 11th Five Year Plan Targets for Rebalancing the Economic Structure

	Indicators	Status in 2005	Status in 2008	2010 Target
Economic structure	Service industry's share of GDP	40.3%	41.8%	43.3%
	Urbanisation rate	43%	45.7%	47%
	R&D per unit of GDP	1.3%	1.52%	2%
Energy & climate related	Energy intensity	-	10.08%	20% reduction from 2005 levels
	Rate of comprehensive treatment of solid industrial waste	55.8%	62%	60%
	National forest coverage	18.2%	19%	20%

Source: State Council, 2006a; World Bank, 2008; WRI, 2009

According to Naughton (2006, 9), the plan is remarkable:

> *There emerges from this Plan document a rich and comprehensive vision of a sustainable development process in China, and a glimpse of the kind of government role that would be required by this development process. The vision is of a society that is more creative, more focused on human resource development, and treads with a lighter and more environmentally benign step.*

The most obvious feature of the task China faces in revising its strategy is the complexity of the undertaking, given the many inter-related areas of policy that need to be considered and the vast array of public and private agencies, both domestic and international, that play a significant role in China. The six elements of the revised strategy, while quite different in many respects, are all closely interrelated with one another. Successfully implementing them requires recognition of this interdependence, and a stronger knowledge base on the factors determining current outcomes on the inter-relationships between them, as well as the analysis of policy options in this full context. For example, if energy use and environmental damage is to be reduced while allowing strong growth to continue, the structure of growth needs to change. For this to occur, the application of knowledge and technology within industry must be strengthened and service industries, such as health and education, must develop more rapidly, and reach the whole population. And yet, to realise this later point, revised fiscal and governance arrangements might be necessary. Moreover, given that the development of coordinated policy responses over many sectors and issues are likely to be critical to achieving an overall change in strategic direction, the continuing role of the planning process in China, as an instrument for strategy development and reform rather than for operating a command economy, is of considerable importance. As such, time will be required before such a comprehensive range of adjustments can be implemented in a balanced and responsible manner.

It is one thing to outline a vision of a sustainable economy and a harmonious society and quite another to define and implement a detailed set of programs to give effect to this vision. This is especially so in such a diverse, vibrant and internationally engaged society as contemporary China. The forces shaping the current growth pattern of energy intensive, investment led development are complex and inter-related, and it will take a major effort to re-align them. Given the unprecedented nature of the changes taking place in China, and their integration into complex global processes, many questions remain regarding the most effective suite of policy options as well as the speed of change required.

State Energy Policy

This section introduces the national policies, plans and laws for achieving a more sustainable use of energy.

China has always emphasised the importance of the sustainable use of energy, especially in terms of energy security and resource management. Moreover, it has achieved significant improvements in improving energy efficiency during the past three decades of economic reform. More recently, the government has enacted a comprehensive range of policy and legislative measures aimed at tackling energy efficiency, including the *National Assessment Report on Climate Change* (2003), the *11th Five-Year Plan* (2005-2010), the *Medium and Long Term Energy Conservation Plan* (2004) and the *National Energy Policy* (2004). Since 2007, several additional national administrative measures, including legislation, targets, plans, standards, codes and the establishment of relevant organisations promoting LCE-type objectives for promoting energy efficiency have been recently introduced for both specific sectors and the broader economy, including *China's National Climate Change Program* (2007), the *Climate Change White Paper* (2008), *Comprehensive Working Plan of Energy Saving and Emission Reduction* (2007) and *National Action Plan for Technology Development for Climate Change* (2007), the *Synthesizing Working Program for Energy Conservation and Emission Reduction Document* (2007) and the *Guidance for Integrated Resource Utilization (2007) and Guidance for Accelerating Energy Conservation Service Industry* (2008). The guiding policy document for China's energy policy remains the current 11th FYP.

Energy efficiency measures are covered by several national laws with the key documents a *Clean Production Law* (2002), the amended *Renewable Energy Law* (2009), the *Circular Economy Promotion Law* (2008)[27], the amended *Energy Conservation Law* (2008) as well as specific notices, codes and guidelines, including the *Strengthening Energy Conservation Evaluation and Review of Fixed-Asset Investment Projects Notice* (2006) [28] and the *Guidelines for Energy Conservation Evaluation and Review of Fixed-Asset Investment Projects* (2007).

The amended *Energy Conservation Law* (2008) shifted energy conservation to national priority status.[29] While development will remain the top policy priority of the government, the revised Energy Conservation Law states that it "implements an energy strategy of promoting conservation and development concurrently while giving top priority to conservation". The Law was initially concerned with energy conservation in the industrial sector, but later extended to the commercial and residential sectors and incorporated more detailed implementation details, such as fiscal incentives, compliance measures, standards and implementation agencies at the local and national levels. The Law refers to the need for enhancing management over energy use and adopting technically feasible, economically reasonable and environment and society-acceptable measures, in order to reduce energy consumption, losses and pollution discharge, curb waste and effectively and reasonably utilize energy in the course of production to consumption. The amended Law extended energy conservation coverage to the construction, transportation and public sector and included for the first time incentive measures for compliance (Chapter 5).

Importantly, the amended Law stipulates that all governments at or above the county level need to incorporate energy conservation work within their annual social and economic development plans, programmes and reports as well as report on progress in meeting energy conservation targets (Article 5). Moreover, the Law stipulates that local governments and local leaders are now accountable for setting and meeting energy conservation targets. Article 6 notes that the state 'will implement a system of accountability for energy conservation targets and a system for energy evaluation whereby the fulfilment of energy conservation targets is taken as one part of the evaluation of local people's governments and their responsible persons' (see earlier discuss on performance evaluation).

The earlier 1997 energy conservation law remained largely a planning document with very little acknowledgment of the significant economic shifts and resource constraints confronting China. Therefore, the inclusion of market based incentives, enforcement measures, procurement policies, taxes, subsidies, soft loans and pricing adjustment reforms for energy conservation work are important components of the amendments. These market measures have been accompanied by the introduction

[27] The circular economy refers to the combination of redesigning products with the aim of waste reduction, improving durability, promoting reuse and recycling.

[28] This notice requires after 1 January 2007, all project feasibility reports or projects application reports valued at Y500,000 and above submitted to the NDRC for approval must contain a chapter on "Energy Conservation Notice Analysis".

[29] The introduction of the amended law coincided with one of China's most devastating snow storms which resulted in the loss of power to 17 provinces and cities and a short-fall in peak power demand of around 40 million KW. It also followed the aforementioned 2007 finding by the WHO, World Bank and OECD that air pollution had caused 750,000 premature deaths from respiratory disease in China.

of specific and detailed measures and procedures by various responsible ministries, such as the NDRC, Transport, Construction, Tax and Agriculture. It appears that these responses have been successfully implemented given the improvement in energy efficiency since 2007.

The Law further stipulates that the Ministry of Construction, and its local equivalents, will be responsible for reviewing such annual energy conservation submissions. Sub-national jurisdictions and enterprises can according to the Law introduce more stringent energy conservation standards, so long as they are approved by the State Council. The Energy Conservation Law similarly stipulates that fixed asset projects need to be designed and constructed in conformity with the standards for 'rational use of energy and energy conservation design'. If they fail to comply with such standards then they cannot be put into use or operation (Article 15).

Of particular relevance to this study is the inclusion of specific requirements for residential metering of energy use at the individual household level (Article 38). Previously, energy charges were levied based on the size of the residence and therefore provided little incentive for energy conservation. The new law stipulates that new buildings and those being renovated require the installation of meters and controls for setting temperature and measuring energy use.

While the new Law provides for a significant strengthening of legal and administrative authority for improving energy conservation, the critical issue will be the degree of implementation through monitoring and enforcement. Moreover, much of the responsibility for implementation remains with local governments at the sub-national level and especially with the priorities of the local leadership (see discussion later in this report).

A new Energy Law is presently undergoing consultation and review and is expected to be considered by the National People's Congress in 2010. The Energy Law will be a 'basic law'[30] which aims to provide a comprehensive framework for better integrating the multiple existing laws, policies and notices relating to energy so as to guide the work of government and industry. The new law is expected to cover all aspects of energy assessment, exploitation, production, utilisation and management. It is expected to further prioritise renewable and low carbon energy as well as ensure energy security, including reinforcing state ownership of strategic energy interests. Energy efficiency remains the primary energy priority for China because the term is broad enough to facilitate a policy that is economic, environmentally and socially sustainable. Economically, it provides savings in reduced and more efficient energy use but more critically the term does not place a cap on total energy use.

In China, the importance of policies for increasing energy efficiency derives from concerns about: (a) energy prices, which are in themselves a reflection of energy shortages in comparison with the current levels of demand as well as social concerns about inflation; (b) energy security, which reflects the desire of every country to secure its own supply of energy over the foreseeable future; and (c) climate change, which requires a reduction in greenhouse gas emissions that are in turn a by-product of energy generation from burning fossil fuels. Clearly, the global supply of energy sources is inadequate for meeting the anticipated total energy demand. While alternative sources of energy are being developed,

[30] Basic laws typically refer to strategically important areas of public policy.

competition for fossil fuels keeps exerting pressure on energy prices. It is also clear that from a global perspective, the current reliance on fossil fuels is unsustainable and strategies need to be developed and implemented for achieving greater energy efficiency and reducing energy consumption.

Energy Policy Measures

The role of governments for increasing energy efficiency derives from the failure of market forces to include the externalities, such as pollution and waste, generated by individual producer and consumer choices. Governments can adopt policy measures to internalise these externalities, however, and can implement measures to discourage producer and consumer behaviour and influence their choices by designing appropriate incentive or disincentive structures, such as taxes and subsidies or compel them through regulation and the setting of mandatory standards or targets, so that they make choices that align with socially desirable outcomes. During the past decade the Chinese government has introduced a comprehensive suite of energy efficiency policy measures, including incentives, disincentives, regulations, subsidies, standards, targets and procurement policies. At the same time it has endeavoured to raise awareness of energy efficiency through public awareness and educational campaigns.[31] This section of the report provides a summary of some of the key policy measures the Chinese government has undertaken and provides a review of the effectiveness of these measures.

Ironically, many of these new measures were introduced at the same time that China's energy use grew at a faster rate than the broader economy. While China achieved reductions in energy use across most sectors of the economy between 1979 and 2001, since then the situation began to reverse. Firstly, China failed to achieve its initial energy efficiency targets during the 10th FYP. Then, the national annual energy intensity reductions were not met in 2006 and 2007.[32] Therefore, in an attempt to reverse this unsustainable pattern, the government has tightened up the governance arrangements. The prominence of policy measures for achieving energy efficiency were heightened following the reversal of earlier efficiency gains following the post-2001 structural shift towards industry and after Wen Jiabao became premier in 2003.[33] The ongoing failure to meet the energy efficiency targets through the 11th FYP resulted in a directive by President Hu Jintao to industry and government to strictly monitor and report energy use, prioritise energy efficiency at the highest level and the announcement that the failure to meet energy targets would affect promotion (Xinhua, 2006). In his March 2006 Work Report, Premier

[31] The program to distribute fluorescent light bulbs is a good example. It is as much an energy saving campaign as an awareness raising program. Between 2008 and 2010, 150 million energy-saving bulbs will be distributed to households saving around 29 billion kwh of electricity and removing 29 million tons of carbon dioxide out of the atmosphere annually. The program is jointly funded by the central and local governments.

[32] During the Tenth Five-Year Plan (2001-2005), the government set a target of reducing energy intensity by 15-17% (State Development Planning Commission, 2001). The failure of this target resulted in the more ambitious 20% reduction goal for the 11th FYP (2006-2010). According to comments by the Deputy Minister for Industry and Information Technology, Lou Qinjian, China failed to meet reduced energy intensity targets in 2006, 2007 and 2008 (Shi Jiangtao, 2009). In a review of GDP and energy data, China appeared to met the 2008 annual target with a 4.6% reduction but this figure was later revised down due to revised energy and economic growth figures.

[33] In Wen Jiabao's 2004 Work Report, he argues: 'The way the economy grows must change, and all industries must eliminate waste, reduce consumption of energy and raw and processed materials, and use resources more efficiently, to develop production and consumption patterns that conserve resources and build a conservation-minded society.'

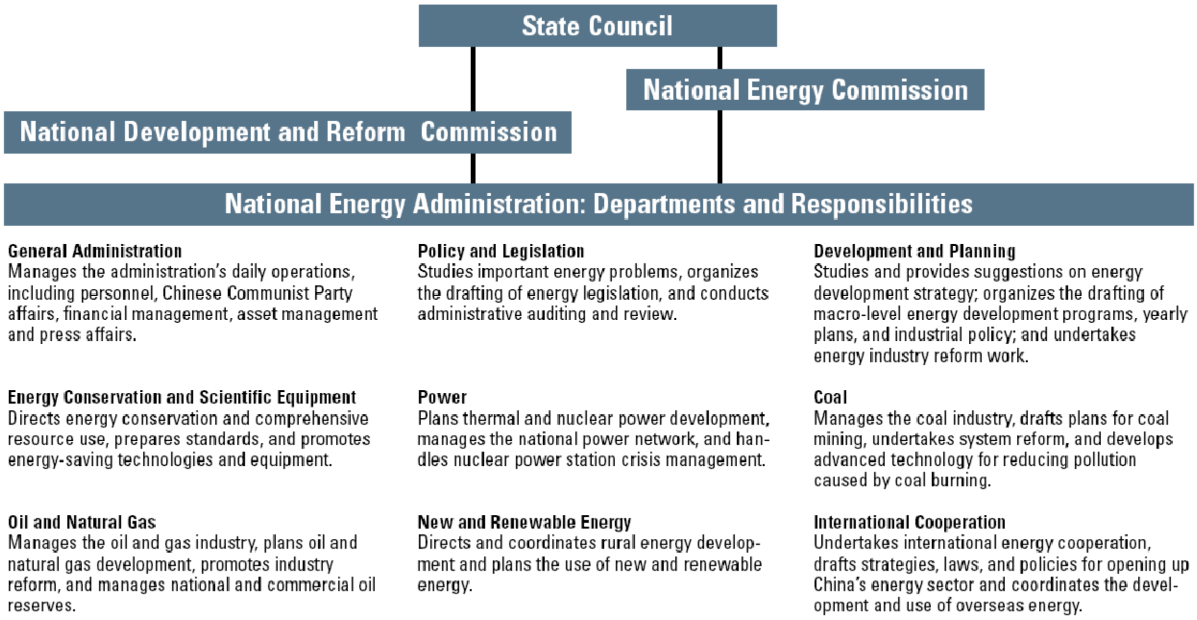
Wen Jiabao set a key target for 2006: the reduction of energy consumption per unit of GDP by 4%. This meant that, on expected GDP growth in 2006 of 8%, the increase in energy consumption would be held to 4%. However, in July the government announced that in the first half of 2006 energy consumption had risen by 11.7%, relative to the same period of 2005, on GDP growth of 10.9%, so that energy consumption per unit of GDP had actually risen by 0.8% (NBSC, 2006). As a result, the government urged all regions and departments to adopt the energy-saving target, promote structural adjustment, to focus on energy-saving in key industries and enterprises, and generally to 'make great efforts to achieve the energy-saving target for the year'. Despite all of the exhortations, the energy target for 2006 was not achieved. Therefore in 2007, the government realized it required a more comprehensive and aggressive policy approach if it was to avoid future energy policy failures. This resulted in a new sense of urgency and attention to the implementation and adoption of measures to improve energy use, especially at a sectoral level.

The importance of appropriate incentives in the implementation of public policies in China has remained a constant focus of attention (see for example, Lieberthal, 2005; Li & Zhou, 2005; Qi Ye et al., 2008). It is widely recognised that China's system of rewarding local government leaders with promotions and career opportunities on the basis of the economic growth performance of the local economies has been a strong and effective motivator of local officials. Therefore it was only time that the central government incorporated the energy targets in career promotion assessments due to the new priority for energy conservation and the earlier implementation failure. In terms of climate policy, the government has not only established mandatory targets for reducing energy consumption and the emission of CO_2 for lower level governments and for SOEs, the meeting of these targets has been made an essential part of the evaluation system for senior government officials. In a sharp break with the past, this mode of evaluation is to be used in career promotion decisions (Qi Ye et al., 2008).

Since 2008, much of the responsibility for developing, monitoring and revising these new policy approaches has fallen upon the newly established National Energy Administration (NEA), which is responsible for maintaining the country's energy supply. The NEA's responsibilities include administrating coal, natural gas, petroleum, electricity (including nuclear power), new energy and renewable energy, formulating standards for the energy industry, supervising the development of the industry, and guiding energy development in rural areas. The NEA remains under the NDRC, despite earlier claims that it would emerge from administrative reforms as a more powerful Ministry of Energy. Earlier energy policy has been plagued by coordination problems due to prevalence of "competing interest" and "splintered institutions" (Cunningham, 2007). The 2008 reforms were apparently aimed at unifying several energy related functions under the NEA. However, it seems very little has changed with energy pricing under the NDRC State Pricing Bureau and the Ministry of Commerce, oil and power firms are managed by the State Asset Supervision and Administration Commission and the MEP is responsible for energy conservation management. In a frank acknowledgement of the failure of the NEA to coordinate energy policy and apparently to strengthen Beijing's monitoring and implementation of energy policy, a National Energy Commission (NEC) was eventually set up in January 2010 after being initially announced back in the 2008 reforms (Wan Zhihong, 2010). The NEC replaces the National Energy Leading Group and as shown in Figure 17 is slightly more senior than the NEA, being led by

Premier Wen Jiabao and his deputy and aspiring leader, Li Keqiang (Downs, 2008). The NEC is tasked with formulating and coordinating energy policy, including the 20-year plan for energy, but it remains unclear if anything has really shifted (China Energy Network, 2010).[34] China is planning on establishing a Renewable Energy Centre in either 2010 or 2011 to promote the development of clean energy. According to the Energy Research Institute (ERI), the new centre will be responsible for key renewable energy projects, policymaking, international coordination, program management, market operations.

Figure 17: China's Energy Administration



Source: Downs (2008)

China's energy policy revolves are four key objectives: security of supply, economic efficiency, social equity and environmental protection (Andrews-Speed, 2004). It would be fair to say these objectives are ranked in descending order from supply security which drives policy to the lower priority of the environment. Security of supply refers to the need for adequate primary energy supplies to meet growing demand, which includes import security concerns and the domestic energy mix, as well as energy distribution and allocation. Economic efficiency refers to a gradual shift from utilising administrative and planning tools to relying on market signals for the efficient production and allocation of energy resources. Social equity considerations are however sometimes in conflict with these efficiency goals, especially the emphasis on the role of the market in terms of allocation and pricing. According to Meidan et al. (2009, 591) China's central leadership adopts a dualistic approach to energy policy by using administrative measures and controls in an effort to 'reassert control over a complex and diversified energy sector' whilst simultaneously maintaining the rhetoric for 'increased marketization of the energy sector'. Some tension remains because administrative mechanisms, rather than market-

[34] There is very little obvious difference between the NEC and the NEA, except that the former will not include the NBSC; a noticeable omission given the problems in recent years with transparency and availability of energy consumption data. On a more critical note, one observer noted that the presence of the Premier almost guaranteed that "nothing concrete would be done" (SCMP, 2010).

based measures, continue to take precedence in the design of policy implementation. At the same time, administrative measures such as state pricing controls remain important considerations in protecting certain sectors vulnerable to readjustment as well as maintaining social and political stability, especially in rural areas. Environmental protection is starting to play a more important role in energy policy, but only so far as it complements the preceding three objectives.

Industry-Specific Energy Efficiency Targets & Industrial Consolidation

The government has focussed most of its energy efficiency policies on the industrial sector, especially in the energy-intensive sectors of coal, petroleum, refining, power, steel and cement production. Current policies are pushing through reforms including industry-specific energy consumption standards, differential pricing for energy-intensive industries, industrial consolidation, mergers and the closure of small, inefficient industrial and power plants as well as the retrofitting of energy conservation devices. The justification for these policies was due to the sector's preeminent position as the largest energy user because the nation's industrial plant and equipment were generally energy-intensive, highly-polluting and wasteful as well as provided the greatest opportunities for GHG abatement. For example, analysis of the energy intensity of 13 key Chinese products in 2000 (Yusuf and Nabeshima, 2006, 22) revealed that they were 6-36% higher than the global average with stand out figures for steel (124%), cement (145%) and power generation (125%). Since 2005, production figures of these key energy intensive products continued to boom, whilst the measure of energy intensity has actually declined, but only slightly (Jiang Bing et al., 2010).

Several recent industrial energy efficiency policies introduced in 2006 and 2007 include the central government's "Top 1,000 Energy Enterprises Monitoring Program', '10 Industries Reform Plan', new energy consumption standards for specific industries, differential pricing for energy-intensive industries and the introduction of an approval process for new projects based upon an energy efficiency standard. The aim of these programs is targeting waste and overcapacity through the restructuring, consolidation, technological upgrading and closure of energy-intensive industrial sectors. The key sectors include the chemical, petrochemical, shipping, iron and steel, automobile and textiles amongst others. Smaller industrial plants in the energy-intensive sectors of cement, steel, non-ferrous metals and chemical industries have been specifically targeted for closure. Specific details include the target of closing down 15 million kW of power-generating capacity in small coal-powered plants, as well as obsolete industrial capacity in the iron (10 million tons) and steel (6 million tons) industries in 2009.[35]

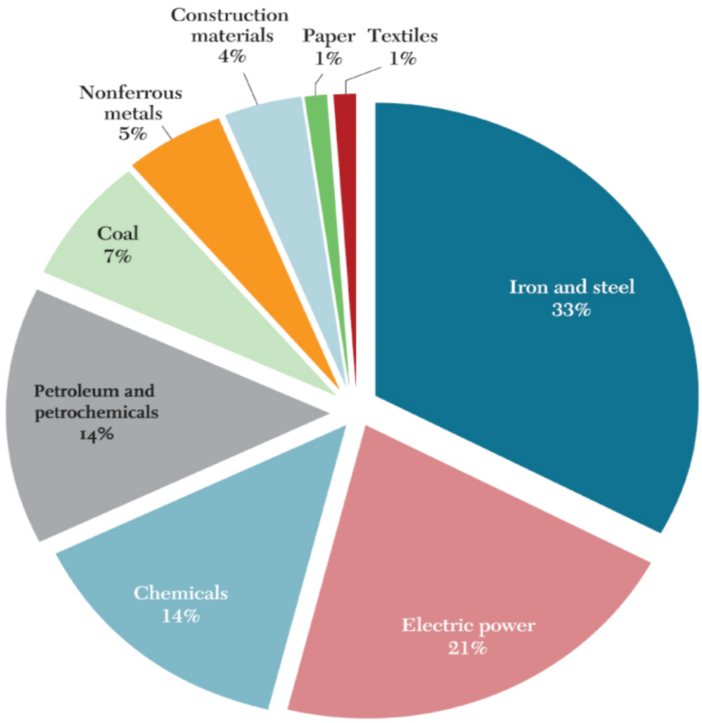
The industry-specific energy consumption standards apply to 22 major industries, including power generation. The mandatory minimum standards are based upon energy use per unit of output, type of plant and fuel or electricity consumption. For instance, the cement industry standards are measured against power consumption per ton of cement. The standards apply to existing and new facilities and are analysed according to plant size, region and type. Additional recommended and target energy efficiency standards are also provided to industry to encourage them to make the necessary upgrades to production process and plant and equipment.

[35] Source: http://news.xinhuanet.com/english/2009-05/20/content_11403629.htm

Of the 22 industries faced with energy standards, eight of the most energy intensive have been forced to pay higher energy prices based upon their efficient use of electricity (State Council, 2006b). The eight industries include: electrolytic aluminium, ferroalloy, calcium carbide, caustic soda, cement, steel, phosphorous and zinc producers. Less efficient plants classified as "eliminated" or "restricted" under the original 2006 circular faced an incremental electricity surcharge commencing from RMB0.02 per kWh and gradually rising to up to RMB0.20 per kWh by 2008. The incremental nature of the system was to encourage industrial firms to make the necessary adjustments to their plant, equipment and processes.

The "Top 1,000 Energy Consuming Enterprises Monitoring Program" is a key component of achieving the 20% improvement in energy efficiency and was introduced in 2006 by the NDRC.[36] The program targets China's 1000 most energy-intensive enterprises, which are mostly involved in heavy industry (see Figure 18), such as iron and steel, electric power, chemicals, petroleum, non-ferrous metals, coal mining, construction materials, textiles, and pulp and paper. This five year program (2006-2010) aims to abate 100 million tons of coal equivalent (mtce) and encourage China's industry to adopt world's best practice plant and equipment. The 1000 enterprises in the program were chosen in 2005, because in 2004 they consumed 673 Mtce (18.7 Quads, 19.7 EJ) of energy; emitted around 43% of China's carbon emissions; and, accounted for 33% of total primary energy demand and almost half of industrial energy demand (Price et al., 2009).

Figure 18: Energy Consumption amongst China's Top 1000 Enterprises (% by sector)



Source: NBSC, 2007 cited in Seligsohn et al., 2009

[36] This program was modelled on the successful Shandong Province Voluntary Agreement pilot project which had been running since 2000 (Price et al., 2003).

Progress was made in achieving the annual targeted reductions in 2006, 2007 and 2008 when they were exceeded in each year.[37] Moreover, some provinces, such as Jiangsu, Shandong and Guangdong, have extended the program to the provincial level to increase the programs coverage and effectiveness. The program includes a mixture of incentives and penalties with soft loans, rebates and tax breaks to industry for investment in energy efficiency measures followed up by assessments and audits with compliance enforced by incorporating goals into the performance evaluation and promotion system for local government officials.

The 'Top 1000' program has been supported by a range of additional national programs targeting energy conservation within the industrial sector. For instance, the *Consolidation and Closure Plan* for China's major industries targets the phase-out of small-scale and outdated production capacity, the advancement of technological levels, and energy conservation and pollution reduction. In May 2009, the NDRC announced a further RMB2.5 billion for the Top Ten Energy Conservation Projects focussed on energy efficiency, emissions control and the circular economy based upon agreements between government and industrial enterprises. This is the key measure for ensuring the 20% reduction in energy intensity is reached by targeting coal-fired industrial boilers, cogeneration units and residual heat, motor systems and petroleum production. Supportive policy measures include regulations, standards, low-interest loans, subsidies and a preferential tax regime. The Circular Economy Law (2004) focuses on reducing waste, increasing productivity and achieving social, economic and environmental targets in line with the principle of reduce, reuse and recycle on a lifecycle basis. In 2009, the Circular Economy Promotion Law was introduced to provide more detailed supervision and compliance measures, particularly in the energy and resource-intensive industrial sectors.

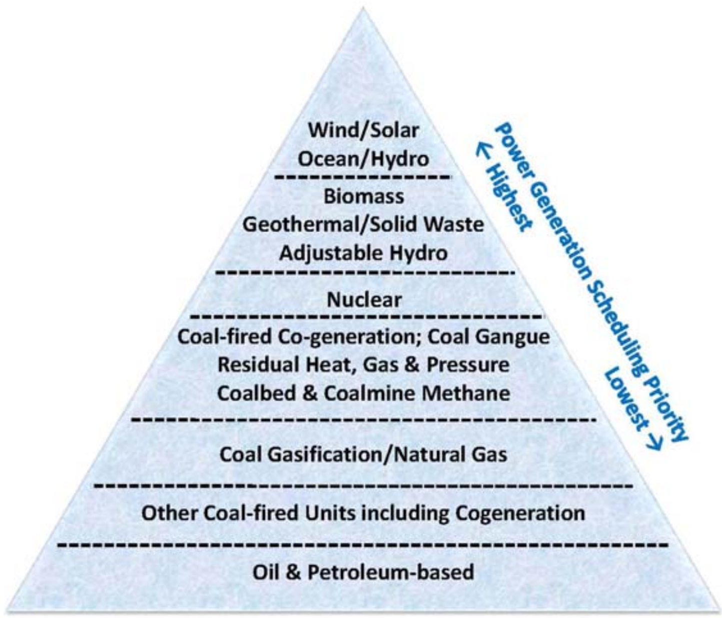
Since 2006, the central government has closed down small inefficient thermal power plants in order to achieve the 20% reduction in energy intensity through two programs: (i) Large Substituting for Small (LSS) and (ii) Energy Conservation power generation dispatching or scheduling (EC scheduling). These programs aim to remove 114 GW of small power generation units from operation. Under this scheme power companies planning on expanding power generation or building new thermal plants, for example, will need to first close less efficient plants before they are eligible to receive NDRC permission and support for purchasing new super critical coal units. The LSS program expects to decommission about half of China's existing inefficient thermal power plants below 100 MW between 2006 and 2010. By early 2009, 54 GW of small, inefficient coal plants had been closed.

In a step towards increasing transparency and public monitoring of the closure, the closed plants and units are publicly listed online to ensure they remain closed. The government shall then utilise the complementary EC scheduling program to gradually phase out the remaining units by prioritising the scheduling of power generation towards low carbon power generation from renewables, nuclear, efficient and cleaner coal power plants (Tian, 2008). This program has been piloted in several provinces since 2007 and is aimed at developing a market mechanism for phasing out the existing even load power

[37] A NDRC (2008) assessment found that 90% of the key industrial enterprises met the agreed energy efficiency targets.

generation scheduling rule with a new system that prioritises low carbon sources of energy generation.[38] The priorities of energy generation are detailed in Figure 19 and range from renewable energy at the top with petroleum-based energy at the bottom. The program includes additional sub-category priorities based upon energy efficiency, emission levels and water usage. Units can only be scheduled for generation once all high priority units have been utilised. It is envisaged that this system if successfully on a national level will provide the largest energy savings in the power sector, although there are no data available of estimated abatement or savings.

Figure 19: Hierarchy for Energy Conservation Scheduling (ECS)



Source: State Council, 2008

Consolidation and closure are being used as a key measure within each of the key energy intensive sectors, notably steel (see Figure 20).[39] According to the Ministry of Industry and Information Technology (MIIT, 2009), steel plants need to meet a minimum production capacity of 1 million tons, or 500,000 tons for specialized steel makers. Otherwise they face forced merger or closure. Plants also need to meet minimum energy consumption levels of 411 kilograms coal equivalent per ton of steel. In addition, for each ton of steel produced, mills cannot use more than 6 tonnes of water and their pollution emissions cannot exceed 2m^3 for waste water and 1.8 kg of sulphur dioxide. At the same time, the steel industry reportedly rejected RMB200 billion worth of new steel projects in 2009 and is

[38] The scheduling system could be perceived as a precursor for the introduction of a carbon tax as it provides a quasi-market mechanism to replace the existing current even load power generation scheduling.

[39] Following large losses by the two of the world's large steel producers, ArcelorMittel and Baosteel in 2009, China reportedly called for a focus on quality over quantity due to fears of steel overcapacity and economic losses (Bloomberg, 2010). Initially, draft consolidation plans called for the creation of one or two large steel producers of around 100 million tons annually. However, this may be revised down to around 50 million tons. There are also growing concerns within the steel sector that the consolidation program is biased towards the public sector (Naughton, 2009c).

planning to close plants that remain too inefficient. However, the NDRC remained concerned about the slow pace of consolidation and reform within the steel industry against the release of steel production figures for 2009 of 568 million tons, which is up 14% on 2008 (Bloomberg, 2009)

Between 2006 and June 2009, China shut down 54 GW of inefficient less than 100 MW coal plants and plans to shut a further 31 GW by 2012.[40] Plants under 200 MW are then set to be targeted for closure leading up to 2020. At the same time, a regulation for newly installed coal-fired power plants to be most advanced power plants (Super Critical Units, Ultra-super Critical Units) was introduced in 2007, resulting in China becoming "the major world market for advanced coal-fired power plants with high-specification emission control systems" (IEA, 2009c). Additional studies confirm the transformation of China's coal power plants from world's dirtiest to the most efficient (Zhao Lifeng et al., 2008; Steinfield et al., 2008; Greenpeace, 2009). In 2009, it was announced that China's top-ten energy companies all met the 2010 target of 355 grams of coal per KwH of coal power generation. In 2009, the average efficiency of China's coal-fired power plants was around 339 grams of coal per kilowatt-hour. The average in developed economies is around 330 grams. However, China's ulta-supercritical coal plants are reportedly using only 300 grams and one new Shanghai plant achieved a world leading efficiency of only 282 grams (Xinhua, 2009a). This is a marked improvement in the energy efficiency of China's coal power plants which burnt an average of 448g per kWh in 1980 and 400g in 2000.

Figure 20: National Planning Targets for the Closure of Energy Inefficient Capacity in Small Industry

Sector	Action	Unit	Capacity reduced during 11th FYP	Already closed in 2007
Power generation	Replace small power plants with large ones	GW	50	10
Iron making	Closure of blast furnaces with size smaller than 300 m3	Mt	100	30
Steel making	Closure of small convertor and electric arc furnaces with capacity smaller than 200 kt	Mt	55	35
Electronic plating	Closing small equipment	1,000 tons	650	100
Iron alloy	Furnaces smaller than 6,300 kVA	1,000 tons	4,000	1,200
Calcium carbide	Furnaces smaller than 6,300 kVA	1,000 ton	2,000	500
Coke	Small coke kilns with height less than 4.3 m	Mt	80	10
Cement	Replacing machinery, vertical kilns	Mt	250	50
Glass	Closure of old technology	1,000 cases	30,000	6,000
Paper making	Straw pulp plants with capacity smaller than 34 kt, chemical pulp plants with capacity smaller than 17 kt	1,000 ton	6,500	2,300

Source: ERI, 2009

It is difficult to ascertain the long-term effectiveness of the policy measure of closure as detailed in Figure 20 due to local resistance and weak compliance. Traditionally, local governments enforce closure during a political campaign, but then reopen operations once demand picks up and the attention of the central government shifts elsewhere. At the sub-national level, leaders who are driven by development oriented targets and incentives for promotion are often involved in the financing and under-reporting of power producing capacity that is forbidden by the central government. According to a recent report, Chinese government sources have estimated that approximately 120,000 MW of electric capacity

[40] See Tian Jun, 2008.

currently in the process of installation had not received approval from Beijing and is, therefore, illegal (Cunningham, 2007). The fact that this installed capacity is 'illegal' does not mean that the plants are hidden in a closet or that they lack any governmental oversight. Instead, it means that the plants are not part of a coherent national policy, and that they frequently operate outside national standards. These plants were obviously all financed, built and put into service, but nobody at the central government level can be sure under what terms or according to what standards. 'The key to understanding how this could happen lies in the local government role' (Lester & Steinfield, 2006).In an attempt to reduce local resistance and the reopening of closed plants, the government is using transparency measures, such as public monitoring by posting the details of closed plants online .

A key component of policies targeting large energy users is the sectoral-based energy intensity targets (introduced earlier in the report). These targets are part of the government's broader industrial production goals encompassed within the *Energy Conservation Plan* for different sectors, including steel, non-ferrous metals, cement, oil refining, power generation, plate glass, chemicals, etc. This plan and subsequent documents have set energy intensity targets per unit of production for 2010 and 2020. In contrast to the slow progress on energy efficiency gains, it seems likely, as illustrated in Figure 21, that the energy intensity targets for major industrial sectors will be met.[41]

Figure 21: Energy Intensity Targets for Key Industrial Products

	2000	2005	2010 Targets	2020 Targets
Thermal Power, gce/kWh	392	370	360	320
Steel, kgce/t	784	700	685	640
Aluminium, tce/t	9.923	9.595	9.471	9.22
Cement, kgce/t	181	159	148	129
Ethylene, kgce/t	848	700	650	600
Railway transportation, tce/Mt*km	10.41	9.65	9.4	9

Source: NDRC, 2004

Reducing energy intensity requires attention beyond industrial sectors to also include regional disparities. In September 2006, the government announced the system for achieving the 20% improvement in energy efficiency with differentiated allocation targets for each province (see Figure 22). Energy efficiency targets were weighted towards provinces with high carbon intensity levels and the targets included details and identified areas for low-cost improvement. For example, Jilin Province needs to reach a 30% reduction in energy intensity by 2010 and yet its energy intensity figure is half of Guizhou Province. If all the provinces are able to meet the targets by 2010 and GDP growth averages 9.9% then it will result in a reduction of 3.39 billion tce or around 25% higher than the national target of a 20% improvement.

[41] Perhaps as an outcome of the state's reforms, energy intensity figures during the first half of 2009 declined in several key industrial products: 8.43% within the steel industry; 3.83% in the coal industry; 19.59% in non-ferrous metals; and 9.51% in power production. Source: Xinhua http://news.xinhuanet.com/english/2009-08/02/content_11813538.htm

Figure 22: Differentiated Energy Efficiency Targets during the 11th Five Year Plan

	2005 Base calculation	2010 Target	Reduction	Region	2005 Base calculation	2010 Target	Reduction
	tce/RMB10,000		%	Unit	tce/RMB10,000		%
National	1.22	-	20	Jiangsu	0.92	0.74	20
Beijing	0.80	0.64	20	Fujian	0.94	0.79	16
Shanxi	2.95	2.21	25	Shandong	1.28	1.00	22
Inner Mongolia	2.48	1.86	25	Guangdong	0.79	0.66	16
Jilin	1.65	1.16	30	Chongqing	1.42	1.14	20
Shanghai	0.88	0.70	20	Guizhou	3.25	2.6	20

Note: 2005 constant values Source: CEACER, 2009

The Chinese government utilises a combination of planning and market measures to achieve energy conservation and improve energy efficiency gains including targeted taxation, subsidy and rebate programs. The government has extended a series of subsidy programs that were initially introduced as part of the November 2008 stimulus package into 2010 for the purchase of household appliances and motor vehicles. For example, an initial 'cash for clunkers' program lifted funding from RMB3-6,000 per vehicle over 10 years-old to RMB5-18,000. The reduced sales tax for 1.6 litre or smaller vehicles was also extended through to the end of 2010, but it was lifted from 5% to 7.5%. Additional support for more sustainable energy use in motor vehicles included a joint transport policy calling for subsidies to new energy vehicles, which was released in early 2009 by the Ministry of Finance, the NDRC, MIIT and the Ministry of Science and Technology. Proposed subsidies under the policy are to range from RMB4,000 to RMB600,000. It is expected that this subsidy will be extended to private purchases of new energy vehicles in 2010, but may be limited to the pilot cities and their respective local vehicle manufacturers.[42] A rebate program was also extended in 2010 for the purchase of energy efficient household appliances, such as Grade 5 air conditioners. To further boost rural incomes, the price cap on eligible products has been raised in rural areas. The combination of the subsidy and the lower taxes have been behind a surge in consumer spending, especially sales of motor vehicles with smaller vehicles contributing to 85% of the growth in sales for 2009 (China Daily, 2009). Additional state subsidies are aimed at promoting renewable energy with a feed-in tariff for biomass, wind and solar energy, including a RMB20-a-watt subsidy for solar projects, covering about half the capital cost. In 2009, the feed-in tariffs per kilowatt hour is set at RMB0.51, RMB0.54, RMB0.58 and RMB0.61 or about double the average kilowatt hour rate of RMB0.34 paid to coal power generators. Despite the tariff and recent reduction in the cost of

[42] According to the vice minister of MIIT, Miao Wei, a progressive subsidy system would be allocated for new energy vehicles based upon the degree of technological sophistication involved. Miao noted that the program would be aimed at "encouraging technological innovation" (Liang Dongmei, 2010). Miao also mentioned that the subsidy would be temporary to assist companies in developing the initial capacity and market share before returning to cost benefits. According to a Nanfang Daily (Chen Zhijie, 2010) report, a nation-wide rollout of new energy vehicle subsides is not likely. Instead, the subsidy program will be restricted to supporting local motor vehicle manufacturers. For example, Shenzhen Municipality is allocating subsidies for BYD's hybrid plug-in F3DM vehicles (interview with authors; Li Fangfang, 2009) and Chongqing Municipality announced that it will be only allocating them to Chang'an Motor's hybrid Jiexun vehicle (Reuters, 2009).

renewable energy production, wind power remains around 30% more expensive than coal power and solar is double the cost.

In addition, the government has introduced gradual reforms to energy and resource prices, as well as provided direct government investment on energy saving projects, such as the installation of heat pumps or cogeneration facilities. During 2009, diesel and gasoline prices were increased four times and coal prices were also increased. However, concerns about social stability are intricately linked to resource prices as are inflation and exchange rate shifts. A renewable energy fee is slowly reducing the gap in electricity generation costs between coal and renewables by charging electricity users, both residential and industrial, a 4% and 8% fee on their respective bills. The revenue is allocated to the grid operators to reduce the disparity in costs between coal and renewables.

The size and rapid growth of China's energy industry will continue to bring prices down by reducing the reliance upon imports, but also facilitate large scale manufacturing.[43] Moreover, the government utilises its significant budget and public works programs to procure and promote energy efficiency products, technologies and systems. Government procurement programs can play an important role in advancing the commercialisation of emerging developments. The new energy vehicle program includes 20 city governments procuring at least 1,000 hybrid and electric vehicles to assist car manufacturers in moving towards the 500,000 new energy vehicle figure for 2012.

Reforms to the tax system have played a part in not only increasing government revenue, rebalancing fiscal allocations between the central and local governments, but also in shaping production and consumer behaviour. In terms of energy and resource use, China's tax system includes several components, which have been readily adjusted in recent years in order to achieve energy conservation. Adjustments to VAT rebates have been used to promote investment and sale of wind turbines and solar PV. Since 2008, the wind generation sector has received a major boost with its VAT reduced from 17% to 8.5%, its income tax cut from 33% to 15% and direct government investment for the installation and feed-in tariffs for wind energy projects utilising at least 80% of domestic components.

In addition, some of the perverse resource and energy subsidies, taxes and rebates have been removed in recent years, including reducing the tax rebate for the export of energy intensive production and the subsidised differentiated energy prices for key energy-intensive industries. Due to relatively lower levels of energy efficiency in China's industry, they remain highly sensitive to adjustments in inputs, such as exchange rates, the price of materials and electricity. Resistance from the provincial levels to price increases has even resulted in non-compliance (Seligsohn et al., 2009). Similar concerns have arisen at the sub-national level and within industry groups following public debate over the introduction of a fuel tax, an environmental tax and a carbon tax.[44] According to Jiang Kejun (2009), a carbon tax is a possible

[43] In 2009, China became the world's largest manufacturer of wind turbines. While the growth in China's wind turbine industry has brought down prices and facilitated the massive expansion of wind power generation, it is unclear if these benefits will be spread globally due to protectionist concerns, especially in Europe and the US (Zeller & Bradsher, 2009).

[44] In August 2009, it was announced that the Ministry of Finance, State Administration of Taxation and Ministry of Environmental Protection have been jointly working on the introduction of an environmental tax

national policy, which could be introduced as soon as 2011 at an introductory level of around RMB10-20 per ton of carbon. Naturally, such a tax would result in increased energy and transport costs for consumers. One estimate expected the cost to be around RMB440 annually per person (AFP, 2009). At this stage, it is unlikely that a carbon tax will be introduced nationally until at least 2015 after its preliminary trial implementation in several pilot cities and regions. Moreover, a carbon tax is seen as somewhat premature prior to the government completing pricing and market reforms within the resources and energy sectors. Instead, the 2009 introduction of a RMB1 tax per litre of fuel was seen as offering an alternative approach to reducing fuel demand with Jiang Kejun (2009) estimating it could reduce fuel demand by 10% if it was set at around RMB2.4 per litre.

Energy efficiency standards and labelling programs emerged in the 1980s and have become an increasingly popular tool for achieving energy conservation in the transport, building and consumer appliance sectors. The mandatory energy standards and labelling systems cover most household appliances and motor vehicles, and are a key program for achieving energy savings across the consumer sector. By 2008, China had introduced a third catalogue of energy efficiency labelling for consumer products including a comprehensive publically-available energy efficiency database across 23 product categories. Analysis by Lawrence Berkeley Labs (LBNL, 2009) estimated that China's current labelling and standards program will reduce carbon emissions by 9.1 billion tons between 2009 and 2030.[45]

Renewables and Low Carbon Energy Generation

Tackling energy utilisation and demand-side energy issues remain crucial for China in making headway in energy conservation. Another important aspect is China energy generation mix, especially the need to break the dominance of coal and promote alternatives. One area that is expanding at a relatively faster pace than the development of coal-fired power is the low carbon sector, such as nuclear, natural gas and the renewables. Renewable energy sources, mainly hydro, wind, biomass and solar are experiencing strong growth. A major boost in renewable energy capacity in China has come from government policy measures, including subsidies, incentives, soft loans, local government renewable energy targets and regulatory provisions as well as the rapid growth in demand from outside China.

The *Medium-to-Long-Term Development Plan for Renewable Energy* (State Council, 2007) provided the initial guidance for expanding wind, solar, hydro and biomass energy generation capacity. The Plan was backed up with RMB3 trillion in funds and additional policy measures to stimulate the development and increased utilisation of renewable energy to 10% by 2010 and 15% by 2020. Specific targets for renewables included: 300 GW of hydropower; 30 GW of wind power (including several 1 GW wind farms); 30 GW of biomass; 1.8 GW of solar power; 300m^2 million coverage of solar hot water heaters; 44m^2 billion of annual methane gas utilisation; and 50 million tons per year (tpy) of biofuels. To achieve the government's ambitious target of increasing renewables in the energy mix to 15% by 2020, RMB300

(http://www.chinadaily.com.cn/bizchina/2009-08/31/content_8637587.htm). It was suggested that such a tax could be introduced by 2010. Criticisms arose however due to recent increases in fuel costs and the introduction of a fuel tax.

[45] Standards for the transport and building sector are addressed in more detail in the separate Case Study Final Report.

million was allocated between 2006 and 2008 by the central government in subsidies, mainly to support biomass and wind energy production.

The Plan was supported by the introduction of the Renewable Energy Law (2006), which was further revised in December 2009.[46] The Law offers a comprehensive national framework for renewables encompassing planning, grid connection, resource audits, fiscal and taxation measures, technology research and development, as well as education and public awareness. The Renewable Energy Law requires state grid and natural gas companies to prioritise power distribution generated from renewable energies, develop and implement emerging technologies, such as smart power grids and energy storage, improve the management and operation of the power grid and facilitate the grid connectivity and utilisation of renewable energies (Article 14). In addition, the law details the requirements for the development of, and monitoring system for, sub-national renewable energy development and utilization plans as well as penalties for non-compliance of the above measures. Failure to comply with the renewable energy components is met with a penalty regime of double the cost of the renewable energy.

Additional policy measures include preferential financial and tax policies, specialised funds subsidising the development of renewable energy sources, zero interest loans, the reduction or elimination of taxes for certain qualified renewable energy development activities and feed-in tariffs. The Plan required electricity grid companies to source at least 1% of electricity from non-hydro renewables, and medium to large power companies to source 3% of installed capacity from non-hydro renewables by 2010. This percentage would increase to 3% and 8% for grid and power companies respectively by 2020.

In 2009, several new government programs supporting renewables have been launched to accelerate the manufacture and installation of renewables. One of these programs, the *Golden Sun* initiative, provides half the cost of installation and power transmission costs for 275 new solar power stations. Remote off-grid solar power projects are eligible for subsidies up to 70%. The plan is designed to meet the dual goals of boosting local Chinese solar power manufacturers and connecting up 2 GW of installed solar capacity by 2011. Under the national renewable energy program encompassing the *Riding the Wind Plan* and the *Brightness Project*, rural and remote communities are eligible for financial and technical support for off-grid wind, biomass and solar renewable technologies (Zhang Lixiao et al., 2009).

As a result of the strong government support, China's ambitious program of renewable energy targets continue to be updated and expanded in recent years. As a result, the State Grid Corporation of China (SGCC) announced that the goals in the 2007 Plan would be exceeded with renewables actually reaching 17% of total installed capacity. The annual doubling of wind power capacity between 2005 and 2009 is testament to the success of the government programs and market demand. Since 2001, newly installed wind power capacity has grown at nearly 50% through to 2009, when a further 8 GW were added to reach around 35 GW. China is currently developing a renewable or low carbon energy investment plan worth an estimated RMB3-4.5 trillion over ten years to further support the development of low carbon energy. It remains unclear how the funds will be distributed between nuclear, hydro, wind, biomass and

[46] http://www.chinanews.com.cn/ny/news/2009/12-26/2040229.shtml

solar generation capacity. Some of the initial details are also included in the "Emerging Energy Industry Development Plan" [47] which calls for:

- hydro power generation to retain its leading role with a commitment to 300 GW by 2020;[48]
- solar photovoltaic (PV) capacity to reach 2 GW by 2011 and 20 GW by 2020 which is up from the previous target of 1.8 GW by 2020; and
- wind to reach 90 GW by 2015 and 150 GW by 2020.

Figure 23: Government Energy Capacity Targets (gigawatts)

	2009 capacity	2011 target	2015 target	Updated 2020 target	Original 2020 target (2007)
Solar	0.3	2		20	1.8
Wind	25	35	90	150	20
Nuclear	9	12		70-86	40
Hydro	150	-		300	270
Natural gas	5*	36		50	70

Source: WEFN, 2009; CEACER, 2009[49]
Note: the 2009 natural gas figure is estimated actual generation rather than capacity.

This plan also focuses on so-called low carbon energy generation, particularly nuclear. China currently has 11 nuclear power reactors in operation with a total installed capacity of 9.1 GW or around 2% of total installed capacity. In addition, a further 24 new nuclear plants are currently awaiting approval or under construction, mostly in eastern coastal areas. When these plants come online, China's total nuclear generation capacity will reach around 25.4 GW. It is currently, expected that nuclear power generation shall increase more than ten times from 8 GW in 2007 up to 86 GW by 2020[50] and around 100 GW by 2030 (ERI, 2009). This will increase the contribution of nuclear power to around 5-8% of total generating capacity.

It is increasingly clear that nuclear power is the preferred low carbon energy fuel for substituting coal and is most likely to receive a significant boost in the forthcoming 12th FYP. According to Zhang Guobao, the director of the National Energy Administration, China will require "at least 200 million kilowatts of nuclear generation capacity to meet the basic needs of China's future economic development". China is leading the world in the construction of new generation nuclear reactors. China currently has nine third generation nuclear plants under construction, including seven Westinghouse AP1000s and two Areva EPRs, three of which are being built in inland provinces. China also has plans to commence construction of the first "fourth generation" experimental fast reactor in 2012-13.

Another area of growth is natural gas with several major investments in the supply, transmission and distribution in recent years, including the west-east and north-south pipeline and dozens of new port

[47] Details of the plan are discussed in China New Energy (2009).
[48] In 2008, half of the 160 GW of global hydro projects were underway in China.
[49] The targets in Figure 23 are yet to receive formal approval from the NDRC and State Council but are currently being circulated and have been widely cited in the Chinese media.
[50] An earlier announcement noted that by 2020, China plans to expand nuclear power capacity to between 40-70 GW: *China Daily* 2009 Nuke power capacity set to increase, 4 February online: http://www.chinadaily.com.cn/china/2009-02/04/content_7443870.htm

terminals and storage facilities. The Shanghai government recently banned the construction of new coal-fired plants, while at the same time investing in building LNG infrastructure. In 2007 the use of natural gas increased 21% and then by a further 16% in 2008 while LNG imports increased annually by an average of 15% between 2001 and 2009.

Despite the aggressive plans for the expansion of renewables and low carbon energy, the underlying concern of the state remains with closing the gap between central-government policies, plans and legislation and action at the local level. Such implementation issues need to be resolves if China is going to effectively adjust the structure of the economy and achieve improvements in energy efficiency.

Remaining Implementation Considerations

The attempt to substantially change the structure of a large, rapidly growing economy is without precedent and is likely to prove difficult, especially in an economy still dealing with the transition from plan to market. Given the lack of precedent and the inherent difficulties, there is no established knowledge base about how to proceed and how to shape and prioritise policy options. Moreover, China's governing system is confronted by an array of complex institutional constraints, which determine the shape and direction, as well as effectiveness, of national policies at the local level. In our view five groups of factors constrain China's ability to change its economic structure rapidly:

1. The limited authority of the central government in terms of detailed implementation of many measures, and the prevailing incentives for local governments to pursue rapid industrial growth (for example, those implicit in revenue sharing arrangements).
2. The macroeconomic and pricing settings, such as relative prices for environmental cost, energy and for other resources.
3. The differentiated development experience with serious contrasts in wealth and opportunity between rich and poor, rural and urban as well as coastal and hinterland.
4. The institutional and effective market demand constraints on the rapid expansion of key service areas, such as health, employment, education and a social welfare system.
5. The combination of three 'inescapable realities': the lock-in effects of current industrial and infrastructure policies; the growing, and increasingly, urban population; and, the rising living standards of an increasingly middle class population.

This section elaborates on each of these interconnected factors and their role in weakening the strong government pronouncements on rebalancing the economic structure. Each factor is acknowledged by the government as an impediment for change, but is equally aware of the risks of adjusting policies too quickly and risking social and political instability.

Questions of Governance

China's institutional and policy system has been recently credited with the necessary attributes for tackling the difficult problem of climate change. A top-down authoritarian regime, equipped with systematic and decisive long-term planning and decision-making facilities, this argument goes, can deliver where democratic governments are dominated by short-term popular policy action. Ironically, it is the same political system that has been described as characterised by institutional and policy failures, which continue to weaken attempts to ameliorate environmental damage. According to the World Bank (2009a, 4):

> *Institutional and policy failures are a major cause of [China's] environmental and resource use problems. Pervasive market and policy failures, including subsidies for raw materials, weak enforcement of anti-pollution regulations, and low waste disposal fees result in low resource productivity and severe pollution. Institutional and policy reforms to remedy such failures are urgent and deserve the full attention of the government.*

Rather than accept the preceding argument about systems of government, it is obvious that the Chinese government realises the urgency of the current imbalances within the structure of the economy. What separates China from many developed economies is the growing understanding of the interconnectedness of the different dimensions to the problems from a social, economic and environmental perspective as well as the critical nature of these problems. In China, there is very little room for poor policy decisions due to the serious social, economic, environmental and political constraints of the nation.

While the formulation of energy policy is largely, though not exclusively, the responsibility of the NDRC and the newly established National Energy Commission, the implementation of this policy is dependent upon its respective agencies at the provincial and municipal-levels, which are exposed to regional and local forces and interests. Moreover, compliance with national policies in China is generally weak, reflecting conflict even within central government machinery as well as among central and local governments.[51] Many of the difficult decisions concerning rebalancing the economy and the allocation of resources need to be made at the local level of government. These are the same local governments that are at the heart of what Jahiel (1994, 766) calls China's ideological battle for increasing economic growth.

When several players representing their respective constituencies are involved in policy formulation or implementation, effective co-ordination plays a crucial part in their success or failure. Ideally, all levels of government should be represented in the co-ordination forums and have equal opportunities to contribute. The establishment of the NLGCC, for example, was perceived as an administrative measure designed to achieve such coordination and consensus. However, this initiative was followed, in the typical top-down approach, by directions given to the provincial governments to establish similar leading groups and to have their prefectural and county governments do the same. The responses of the local and regional governments have been described as being essentially administrative responses (Qi Ye et al., 2008). It remains to be seen how sustainable such a policy response remains particularly if the national initiatives challenge the status quo of local economic growth. Given past experience, it is more than likely that serious gaps in its implementation may arise in the not so distant future. The

[51] China's administrative structure and governance system are highly decentralised into 33 province-level regions, 333 prefecture-level regions, 2,862 county-level regions, 41,636 township-level regions, and many more of village-level regions. Not all of these regions have the same degree of autonomy in policy formulation for all public services, but the formulation and implementation of national policies throughout the country nevertheless involve co-ordination through these diverse layers of administration. While China has a decentralised, five-level governance structure, its approach to policy implementation remains essentially a top-down approach.

development of a policy co-ordination framework is lagging behind the progress towards decentralisation and marketisation.

A key principle of best practice public policies in a large country or a diverse society, such as China, is to adopt a decentralised bottom-up approach to policy formulation. This would ensure that local and regional interests and constraints are adequately reflected in the national policies. This way of policy formulation also raises the likelihood of greater local and regional co-operation in implementation, in contrast to a policy with little local involvement, but being imposed from above.

Often, governments at the county and township level do not have either technical or financial capacity to effectively participate in the co-ordination forums outlined above. This is especially likely to be the case in dealing with climate change and energy efficiency issues, because of the technical nature of the underlying issues. Local governments generally face the challenge of low levels of technical capacity and lack of awareness to deal with climate change issues. Even if a government is willing to take action, its capacity is often a limiting factor. Implementing suitable initiatives for capacity building and for technical and financial training of personnel has been identified as crucial. For example, ERI have been active in assisting several local governments in identifying energy and resource characteristics that require attention in shifting towards a low carbon economy.

The widespread practice of weak compliance and local resistance to central government directives has been widely reported in the literature (ADB 2005; Economy, 2003; Hills & Man, 1998; Jahiel, 1997; Lieberthal, 1997; Lo & Yip, 1999; Pei, 2006). Traditionally, a high level of scepticism greets bold Chinese pronouncements on new measures to reduce energy intensity, close down polluting factories or ramp up renewables. For example, the gap between rhetoric and reality in national energy policy epitomised this when the central government failed to meet the targets for reducing energy intensity as part of the Tenth and Eleventh FYPs (discussed earlier). Despite strong central government pronouncements on the need for energy efficiency, local governments continued to promote economic growth and allocated far more funds to energy production than to energy conservation (Andrews-Speed, 2004).

As long as a locality's main goal is to achieve economic growth, and cheap electric power is needed to fuel that growth, then environmental enforcement will play a secondary role. As one observer recently described the situation, local actors are now shaping China's energy markets at an unprecedented pace and scale, engaging in long-term investment decisions in fuel choice and technology that will remain in place for decades. Moreover, these actors are regulated by a fractured and diminished central bureaucracy (Cunningham, 2007, 2).

Driven by competition for higher economic growth, local jurisdictions are asserting their priorities, which do not always align with those of the central government. For instance, the competition for development is so fierce that local governments remain unwilling to cooperate with the central government or with their neighbouring jurisdictions for more efficient plants and are instead insisting on building small, less efficient and more polluting plants in their desire for self sufficiency and independent sources of tax revenue (China Intel Group, 2008).[52]

Similar examples of non-compliance abound in the case of energy policies. For example, since 2000, China's Law on the Prevention and Control of Atmospheric Pollution has been imposing national caps on total sulphur emissions, requiring coal-fired power plants to install pollution-reducing gas desulphurization systems, commonly known as 'scrubbers.' According to central government research, however, only about 10% of the coal-fired plants had purchased such equipment by 2005 (Lester & Steinfield 2006). Moreover, it was later found that many of the scrubbers were left switched off to save energy costs to the generators. More recently, the State Council reprimanded Provincial authorities for poor supervision of local lending practices: "Some regions act illegally, give approvals in violation of regulations or allow building before approval is granted" (cited in Lewis, 2009). Such open criticisms of Provincial authorities is uncommon and reflects Beijing's growing concern with provincial authorities deliberately ignoring the new energy efficiency standards and requirements with stimulus-related construction and infrastructure projects.

The example of the policy failure with the industrial consolidation program in the steel and iron industries highlights the resistance and autonomy of the local levels. Despite central government contracts requiring specific targets and evaluation procedures for the closure of 78 million tons of steel capacity and 89 million tons of iron capacity at the provincial level. According to Naughton (2009c), local governments avoided closure or consolidation by investing more in these sites, arguing that they were upgrading outdated plant and equipment with more advanced capacity (see Figure 37).

The growing support at the local level for the concept of a low carbon economy has resulted in an emerging shift in supporting the policies promoting energy efficiency. The key driver behind this change is the recognition that the clean technology and new energy sectors offer new economic opportunities for lifting local competitive advantage.

The introduction and adoption of new technologies will play a key role in minimizing GHG emissions (Socolow & Pacala, 2006). Currently, many promising technologies exist, but their adoption by industry has been slow. State policies can stimulate innovation and promote the adoption of technical developments, but they can also hinder these processes (Connor & Dovers, 2004; Lo Wing-Hung & Tang Shui-Yan, 2006). Recent research has focused on the efficacy of the state's implementation of environmental policies against the backdrop of China's ingrained institutional structure (English, 2006; Jahiel, 1997; SEI & UNDP, 2002). Moreover, there are increasing concerns of a growing disjuncture between central government policies and implementation at the local-level (Economy, 2003; Jahiel, 1997; Lo & Yip, 1999; Saich, 2001). Accordingly, "much of the environmental energy generated at the

[52] For example, in 2008, the government announced measures to cease all new capacity in steel production and close small, inefficient steel mills through to 2011 by restricting bank credit. However, since the announcement a further 32 new capacity projects have been announced (Waldmeir, 2009). The Financial Times article cites a Steel Business Briefing, "'Beijing has shown it can't police these small mills … and many of the smaller companies are not even known to the government anyway,' says Graeme Train, China research manager for Steel Business Briefing. Mills often buy environmental equipment required by government – 'but then they don't use it', he says". See also Bloomberg (2009).

national level dissipates as it diffuses through the multilayered state structure, producing outcomes that have little concrete effect" (Lieberthal, 1997, 3). Some observers have linked these policy failures to the state's own complex institutional structure and management system (Lieberthal, 1997; World Bank, 2003). A key point emerging from this literature is the need to understand institutional constraints if policies intending to encourage the adoption of new technologies are to succeed.

Given China's diversity, many local jurisdictions lack the capacity for appropriate policy development and implementation to support new technologies and innovation. Moreover, the criss-crossing jurisdictions responsible for energy efficiency programs can often slow down progress in implementation.[53] On the positive size, several cities have now declared themselves committed to the low carbon economy, such as Baoding, Shenzhen and Tianjin. Not only are these cities competing to attract clean tech and new energy firms, such as solar photovoltaic cell and wind turbine manufacturers, but they are also introducing energy efficiency targets and incentives for the adoption of cleaner production beyond those required at the national level. For example, in 2008 Beijing introduced the Civil Energy Act with the aim of promoting energy conservation, building energy efficiency and the use of renewable energy sources, such as solar and geothermal. The city government offers tariff reductions, tax incentives and penalties to support the implementation of the low carbon plan and to ensure that the city exceeds national targets and standards.

Local governments have played a critical role in facilitating the economic reforms and spurring economic development (Naughton, 2007). Furthermore, it is unlikely that there will be a noticeable shift away from this ideology of prioritising economic growth. In fact, it is likely that the economic imperative of bureaucratic decision-making will consolidate and strengthen during the next decade. However, the prevalence and pre-eminence devoted to this 'ideology of economic growth' within government decision-making and throughout society poses a number of serious challenges to non-economic policy areas, such as the environment, education, health and social welfare. While a narrow focus on short-term and immediate economic growth combined with the transformation of Chinese society and its landscape has brought about significant economic benefits, the pattern of development is deleterious to future growth and development (Saich, 2001, 295). Growing levels of social and economic inequality combined with environmental degradation are sowing the seeds of discontent, especially in rural areas. The central government is aware of these serious constraints; remaining highly sensitive to policy reforms to ensure that social, economic and political stability are not jeopardised.

Differentiated Development and the Implications for Energy Efficiency Policies in China

Given China's highly diverse and decentralised governance structure, it is clear that no energy efficiency policy can be successfully implemented without the cooperation of China's local governments, particularly provincial governments, which have responsibility for getting cooperation from county and city governments within their respective areas.

[53] For example, Lin and Fridley (2007, vi) argue that achieving energy efficiency remains slow due to, for instance, the complicated regulatory "maze that governs the implementation of appliance standards". Similar problems delay the commercialisation of new technologies.

China's economy is made up of a large number of regions and is characterised by high levels of diversity in respect of income levels, economic structure, urbanisation, resource endowments etc. In the 1980s, regional diversity in income narrowed, but has been widening since the 1990s. The widening diversity of regional incomes has been a concern of the Chinese government for many years, and was the basis of Deng Xiaoping's aim to establish a "x*iaokang*" or (well-off) society by 2000. The launch of the western region development strategy in 2000, and the rejuvenation of the north-eastern industrial region in 2004 are specific initiatives in this direction.

These diversities are further compounded by the fact that since the SOE reforms of the 1980s, local governments have been given responsibility for services including health, education, science and technology and for the environment, without being given commensurate revenue sources to finance the provision of these services. At the same time, distribution of central government fiscal transfers, on which local governments heavily rely, are still weighted in favour of the wealthier provinces, even though this bias has been weakening gradually (see Grewal, 2008).

The lack of sufficient independent fiscal revenue has led many local governments into developing extra-budgetary sources in the form of 'illegal' taxes, fees and charges on local businesses. These taxes and charges are entirely arbitrary and undermine the enforcement of laws and regulations. Similarly, local governments have bypassed the legal prohibition on local borrowings by setting up bogus companies that serve as conduits for raising loans for local governments.

Regional diversities and constraints have shaped local perspectives and priorities that are often in conflict with those of the central government, and undermine the enforcement of economic and environmental policies. Local protectionism has become a major hindrance to policy implementation.

Specifically in relation to the implementation of energy efficiency policies, where local cooperation is crucial, a major issue to be resolved will be that different provinces face different trade-offs between rapid economic growth and energy efficiency, because of their respective industrial structure and developmental imperatives. The impact of a given movement towards greater energy efficiency on employment, incomes and welfare would also be different. In the past, the trade-off between economic growth and climate change has been considered to be an important factor in the indifference of China's local governments towards climate change mitigation policies until 2007 (see, Qi Ye et al., 2008).

The data in Figure 24, for example, show that in 2008, the ten most inefficient energy consumers in China were Yunnan, Liaoning, Hebei, Xinjiang, Gansu, Inner Mongolia, Shanxi, Guizhou, Qinghai and Ningxia. All of these are located in the inland regions of China and are also among the least developed parts of the country in respect of per capita GDP. These provinces are also generally more dependent on SOEs for employment and production, as private enterprises are not yet developed in these areas. These observations are consistent with those of Wei Chu et al. (2009) who find that the energy efficiency of China's regional economies is negatively associated with the secondary industry share in GDP, the state-owned economic share in GDP and the government expenditure share in GDP, and is positively associated with the technical level and the non-coal share in final energy consumption. The negative correlation of the share of state-owned sectors in the economy indicates that the greater the component of SOEs in the industrial sector, the lower the energy efficiency.

Hong Lijian (2004) went so far as to suggest that the opening up of the Western region remains a government campaign, run by government and for its benefit, and that private entrepreneurs, especially small and medium-sized domestic investors, would find it hard to participate in local economic reconstruction. He noted that "it would be very difficult to persuade profit-seeking domestic and foreign investors to put their money hereunder [sic] those circumstances". The high dependence on public sector employment in these regions also serves as a social safety net and makes downsizing inefficient enterprises more difficult.

Figure 24: Energy Efficiency and Marketisation in the Lagging Regions of China

Province	Per Capita GDP (RMB) 2007*	Marketisation Index**	Energy Consumption	Electricity Consumption	Energy consumption per unit of IVA
			Per unit of GDP		
National Average	18885	6.15	1.102	1357.29	2.189
Chongqing	14660	6.33	1.267	1090.19	2.106
Guangxi	12555	5.95	1.106	1254.15	2.335
Sichuan	12893	5.7	1.381	1156.37	2.477
Yunnan	10540	4.89	1.562	1654.94	2.847
Gansu	10346	4.86	2.013	2539	4.05
Inner Mongolia	25393	4.76	2.159	1887.32	4.19
Guizhou	6915	4.62	2.875	2452.21	4.323
Shaanxi	14607	4.15	1.281	1256.02	2.009
Ningxia	14349	4.02	3.686	5084.09	7.13
Qinghai	14257	3.4	2.935	4061.64	3.243
Xinjiang	16999	3.15	1.963	1331.24	2.999

Notes: Tibet is excluded as comparable figures for all categories are not available; IVA refers to industrial value added and is sourced from NBSC (2009).
Source: Compiled on the basis of figures from: * NBSC (2008, 2009); ** Refers to Population Weighted Score of Index of Marketisation figures for 2001, from Fan Gang et al. (2002).

The population weighted score of index of marketisation of China's provinces in Figure 24 is constructed by the Beijing-based National Economic Research Institute, and consists of the following 5 major areas that work as "main components" in the Index: Size of the government in the regional economy (I); Economic structure, mainly concerning the growth of the non-state sector and the reform of the state enterprises (II); Inter-regional trade barriers, including the price control (III); Factor-market development, including factor mobility (IV); and Legal frameworks (V).

The implementation of energy efficiency initiatives will affect the level and redistribution of income across China. Thus, as the use of coal is reduced progressively according to a low carbon policy from 71% of total energy production in 2005 to 27.2% in 2050, the coal producing provinces would suffer a disproportionately larger impact on incomes and employment. These losses may be counterbalanced, in some cases but not necessarily in all, by the development of alternative sources of energy, such as hydro, solar, wind, nuclear and biomass. The central government would need to subsidise heavily this process of weaning the economy off coal and petroleum as main sources of energy. The pace of this transition will set the limits of how quickly China can achieve its energy efficiency targets.

As noted elsewhere in the report, China still relies heavily on administrative or control mechanisms for policy implementation, including the career promotion criteria of senior personnel in central and local governments. These mechanisms continue to be utilised for promoting economic growth through investment and exports. Although these mechanisms have been reportedly adapted now to the requirements of energy efficiency targets, their success in delivering outcomes still remains to be tested (Xue Lan et al., 2006).

The deeper problem with such mechanisms of enforcement is that they are *ad hoc*, arbitrary, susceptible to be biased by corruption, and not based on merit. This means that enforcement of laws and regulations is not based on objective, predictable market-based criteria. As the OECD (2005) review of governance in China pointed out, the main emphasis of the enforcement mechanisms is on punishment for corruption and failure, rather than on avoiding the opportunities for corruption and the risks of failure.

Financial incentives of various types have also played an important role in policy implementation in China. In the context of climate change, the rapid adoption of the Clean Development Mechanism (CDM) by local governments in China is a good example. Several local governments in China have enthusiastically adopted CDM eligible projects and programs. It would help if the intergovernmental fiscal transfers are also based on objective and transparent criteria of fiscal need.

The post 1979 economic reforms have involved an enormous degree of experimentation, adaptation and flexibility between the role of the market and the old planning system. However, overwhelmingly the reforms have resulted in a gradually increasing role and presence of market forces in the economy. The fundamental state consideration is sustained economic growth whilst maintaining social and political stability. Therefore, the public signals are typically pro-market with exhortations to increase market openness, economic competition and the role of market signals. The deputy prime Minister, Li Keqiang, supported these moves recently at the World Economic Forum in January 2010 arguing that China would “allow the market to play a primary role in allocation of resources” (Bennhold, 2010).

China continues to experiment with an increasing reliance upon market mechanisms for the implementation of its energy policy. However, progress remains slow as ‘the institutions of government have, in most cases, failed to adapt their structure and function and many players in the economy remain aloof from the market’ (Andrews-Speed, 2004, 146). In an effort to combat this problem, the central government has recently attempted to introduce complementary administrative and market mechanisms. The combination of fiscal incentives promoting energy efficiency measures and new energy industries together with prioritised administrative directives since 2007 have been more successful in tackling earlier energy policy implementation problems.

Increasing Social and Regional Inequality

The current 11th FYP sets out an ambitious list of priorities aimed at tackling growing social and regional inequality in China. The key focus of current policies is strengthening social welfare. While important gains have been made in recent years in improving living standards, the divide between rural and urban areas has grown. In addition, the recent slowdown in export orientated industries has highlighted the employment pressures and vulnerability facing many of China's migrant workers. Current policies therefore include the introduction of a broad range of measures related to: access to free education, health coverage and pension support; the availability of urban and rural social security; improved labor standards; support for migrant workers; and, greater flexibility to the *hukou* registration. The *hukou* system refers to the household responsibility system, which has limited rural-urban migration and kept farmers on the land for the past half century. Reforms to this complicated system will be a core component of removing the divide between urban and rural residents and hence access to social welfare provisions. In 2010, *hukou* registrations will be relaxed in small and medium towns to facilitate ongoing urbanisation, but also to take some of the pressure of the larger cities.

Many of the ambitious government announcements of strategic social priorities, however, are not automatically translated into reality on the ground. China's current level of public spending on health care and education is quite low and resources are distributed very unequally among China's sub-national government jurisdictions – provinces, prefectures, counties and townships. According to the Asian Development Bank (ADB, 2005), public spending on education and health care declined as a proportion of GDP between 1994 and 2002 from 17.6% and 4.4% of total expenditure to 14.1% and 2.9% of total expenditure respectively. This is despite consistent calls from Beijing to increase the share of budgetary allocations to education and health. By 2008, expenditure had risen only slightly to 14.4% for education and 4.4% for health.

Responsibility for social services such as health and education rests primarily with sub-national governments, in particular at the county and township level of government. For example, in 2008 virtually all the budgetary expenditure for health (98.3%) and education (94.5%) was the responsibility of local governments. The overall shortage of public funding combined with unequal distribution of resources continues to result in serious issues of access and equity in vital areas of economic and social services, and to an increasing reliance on non-government funding. The widening income gap has exacerbated this problem with the Gini coefficient of inequality of household incomes widening from 0.16 in 1978, prior to the reforms to 0.47 in 2004 (World Bank, 2006). Between 2004 and 2009, the household income of the top 10% increased from 24.3% of total household income to 35.7%. A 2006 Report noted that just 1% of households control over 60% of the nation's wealth (Pei Minxin, 2006). Pei argues that government policies are exacerbating the widening disparity at the risk of social stability. The gap in incomes is typically a split between urban and rural as well as between coastal and hinterland households. The general over-supply of labour, especially in rural areas continues to depress low income labour and pose a challenge for the state in expanding employment.

In recent years, the Chinese government has been seeking to address these issues by not only directing more public spending into areas of greater need, but also by encouraging greater participation of the private sector in these areas and boosting wage protection. Whilst wage disparity is increasing, low income households (bottom 20% of households) experienced strong wage growth since 2007 when agricultural commodity prices rose, lifting incomes by 50% (Credit Suisse, 2010).

The growth in China's economic capacity has been stimulated by the huge productivity increases associated with increasing capital-intensity and strong growth in total factor productivity. These productivity improvements have been accompanied by rapid growth in the demand for goods and services associated with big increases in China's share of world exports and internal fiscal expansion. This has enabled the growth in employment opportunities to broadly match the increase in labour supply of between 1.0% and 1.5% per annum. However, China's employment growth rates need to be higher to maintain the increase in aggregate employment, especially as working conditions remain very basic for many rural migrants. Between 2000 and 2008, China achieved an average annual rate of 10.8% GDP growth while employment growth was only 0.9% or less than one tenth of output growth. According to Prasad (2009), this is one of the lowest rates of employment growth in Asia's developing economies. The main explanation for this disparity is that the negative employment growth in agriculture was balanced by 3% employment growth in the secondary and service sectors. The growth in the industrial sector was in fact largely attributable to labor productivity gains, less so with employment growth which only grew 1.6% annually, reflecting in part the retrenchment policies of state owned enterprises (SOEs). The growth in service employment is expected to meet the growing demand for future employment, particularly at the local government level and provides a further justification for greater structural rebalancing.

The Environmental Cost of China's Development Path

There is a growing recognition that the natural environment is a major casualty of China's economic structure with accelerating levels of environmental degradation (Xiong Hongyang, 2005; Sheehan, 2008). Despite the government's vocal commitment to rebalancing the economy, critics point to the lack of progress in ameliorating China's environmental problems (Economy, 2007a; Li Yong & Oberheitmann, 2009; Pickles, 2002; Zhang Kunmin & Wen Zongguo, 2008). Domestic and international studies question the capacity of the state to produce tangible improvements in China's environment. They continue to note the uneven progress in tackling environmental degradation, emphasising that 'ecological destruction remains faster than remediation' (Xie Jun, 2000). And despite the concerted efforts of the state, they are failing to reduce the intensity and spread of degradation (SEI & UNDP, 2002).

China faces an array of serious environmental problems, including: increasing carcinogenic air particle matter in and around most large cities; dangerously high levels of organic pollutants in many of China's rivers and streams; severe water shortages; rapid desertification of China's grasslands; deforestation and soil erosion of upper valleys and catchments; widespread salinity; biodiversity loss; acid rain; increasingly frequent and more devastating natural disasters; and increasingly intense and frequent dust storms in northern China (Economy, 2004; Edmonds, 1994; Liu Jianguo & Diamond, 2005; Pan Yue and Zhou Jigang, 2006; Qu Geping & Li Woyen, 1984; World Bank, 2009b). While China's development remains at a relatively early stage, China's environment is witnessing a level of degradation so great that it may threaten the sustainability of China's economic growth and even the stability of its social system (SEPA, 2002; Economy, 2004; Liu Jianguo & Diamond, 2005; ADB, 2008). A World Bank report (1997, 2) estimated that the environmental cost of air and water pollution was equivalent to 8% of GDP in 1995.[54] The World Bank (2001, 85) indicated that many Chinese 'cities have [airborne] concentrations of fine particulates and sulphur dioxide that are amongst the world's highest'. A 2007 finding by the World Health Organisation, World Bank and OECD found that air pollution had caused 750,000 premature deaths from respiratory disease in China (Coonan, 2007; Financial Times, 2007). While there is a broad range of serious environmental degradation of China's land, air and water due to the pattern of economic development, a key area of concern for this report relates to the role of energy, the resource intensity of production and the resultant carbon emissions. The low price of resources and the lack of a price for waste and pollution are blamed as key factors in the inefficient allocation of resources and high levels of environmental degradation occurring in China. And a consistent ingredient in many of these environmental problems is the nation's heavy dependence upon energy-intensive industry powered by coal.

These issues present a sobering reminder of the challenges confronting China's development path. The environmental challenges facing China are huge, and yet, the nation's mixed success in tackling them provides insight into the reach of the state and the ongoing divide between central government ameliorative policies on the one hand and unsustainable local government policies on the other. It is necessary that the central government quickly learn from the policy outcomes in the environmental realm in designing and implementing its structural rebalancing plans.

While many of the social welfare, health, educational and environmental reforms will be gradual in manner and take over a decade to be realised, there are certain aspects of the rebalancing program that need urgent attention and adjustments to ensure the delayed costs are not exponential in nature. This refers to sectors of the economy where the lock-in effects of poor decision making today will be felt for decades to come.

The Cost of Delay: The Risks of Lock-in Effects

There is an urgency linked to the problem of rebalancing China's economy due to the growing costs arising from the lock-in effect arising from everyday decisions by governments, companies and the public. This is especially critical in the three sectors of energy, transport and housing, which are rapidly expanding their energy use demands on the back of an increasingly urban population with rising living standards. Moreover, this problem is exacerbated by the limited time available for making cost-effective use of the technological opportunities available today and the potential implications of delayed action in terms of climate change. A recent report by McKinsey (2009) identifies many opportunities for energy efficiency, the application of technology and the diversification of fuel supply, but warns that while there is a 'window of opportunity' for greater efficiency gains, that window is a short one. And there is concern that the window is closing fast. This makes for a compelling argument for immediate action.

Therefore, time sensitivity remains a critical issue in making decisions regarding energy efficiency. To meet the expected growth in demand for the three key sectors of energy, housing and transport, China will further expand the construction of new power plants, highways, railways and buildings. Because

[54] The most conservative World Bank (1997) figures estimate the environmental costs of economic development of around 3.5% of GDP.

such infrastructure will largely remain in place for the next 40-plus years, there is a need to ensure that such investments are carefully planned, executed and adopt best practice in terms of energy efficiency.

Previous sections have discussed the government's mixed record in tackling the lock-in effect within the power sector by closing down smaller inefficient power generators and those failing to meet pollution and energy efficiency requirements on the one hand, whilst failing to adequately regulate or monitor local government decisions on energy generation and use. Existing energy-related policies, especially related to consumption in the long-term will play a key role in shaping the structure and scale of final demand. In terms of the building sector, serious concerns remain with the current property boom across the country locking-in strong future growth in energy demand. Moreover, a major aspect of the rebalancing process involves calls for speeding up the urbanisation process and increasing domestic consumption as a driver for the economy. Both of these wield significant risks as well as opportunities for future energy use.

The Urban Billion and Rising Living Standards

There are several reasons for China's present rapid growth in energy consumption, but three reasons dominate: the strong presence of heavy industry in the economy, relatively low levels of per capita energy consumption and the rapid urbanisation of China's population. At around 1700 Kilowatts per person per year, China's consumption of electricity is only about one-fifth of the average per capita consumption in advanced countries. However, it is unlikely to stay at this low level for very long. There is a dependent relationship between future energy use, China's pattern of development, the rate of urbanisation and the lifestyle expectations of its people. While current levels of household consumption of electricity is not a critical factor in energy use, the growth in buildings, appliances and transport and attendant power demands are expected to become the major drivers of increasing energy use and carbon emissions in the near future.

Population growth and rapid urbanisation are a major driver of China's growing energy consumption. The share of urban population in China's total population has increased rapidly from 26% in 1990 to 45.5% in 2008 or from 254 million to 607 million people (see Figure 25). This is equivalent to an annual increase of almost 1% of the total population or about 13 million shifting to China's urban centres every year. During this period, one third of this increase or around 110 million people resulted from rural to urban migration. It is estimated that 1 billion Chinese will be living in urban areas by 2030.

Figure 25: China's Urban and Rural Population, 2005-2050

Population structure	2005	2010	2020	2030	2040	2050
Total population (million)	1307	1360	1440	1470	1470	1460
Urbanisation rate (%)	43	49	63	70	74	79
Urban population (million)	562	666	907	1029	1088	1138
Urban household size (persons)	2.96	2.88	2.80	2.75	2.70	2.65
Total urban households (million)	190	222	288	337	365	380
Rural population (million)	745	694	533	441	382	302
Rural household size (persons)	4.08	3.80	3.50	3.40	3.20	3.00
Rural households (million)	183	190	181	160	152	144

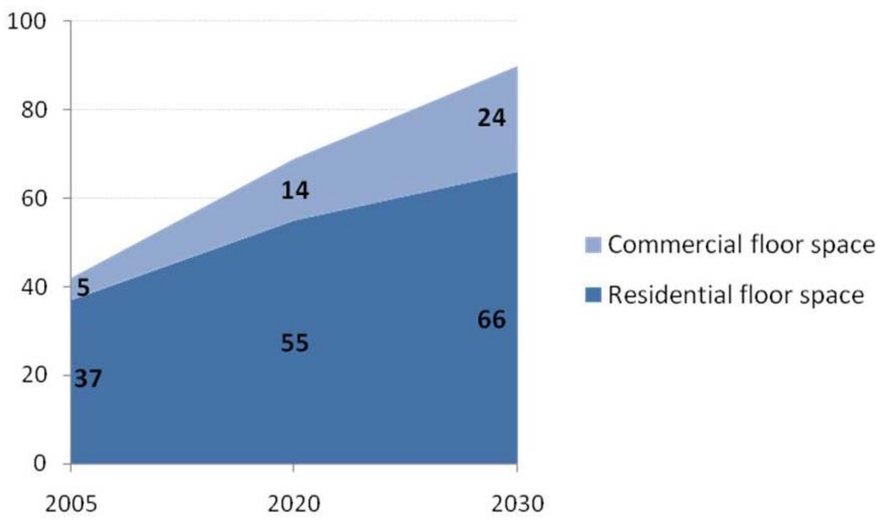
Source: CEACER, 2009

The urbanisation rate will remain steady over the next twenty years growing from the present 650 million or half of the population to 800 million in 2020 before reaching 1 billion by 2030 or two thirds of the total population of 1.5 billion. The growing urban population creates massive pressures on existing infrastructure as well as demands for the construction of new housing, offices and infrastructure, all of which require building materials, construction machinery, steel, cement, chemicals, power, land and water. Between now and 2030, according to McKinsey (2009, 32), 'China plans to build 50,000 new high-rise residential buildings and 170 new mass-transit systems' to cater for this new urban population. By 2030, China is expected to have around 337 million vehicles on the road and there will be 800 million air conditioner units.

Rising urbanisation has generated additional pressures on employment, consumption patterns and infrastructure construction, all of which in turn have contributed to higher energy demand. Residential energy consumption now contributes to over 11% of China's total energy consumption and is the second highest energy consumption sector following the industrial sector. Furthermore, there is already considerable scope for achieving energy savings by targeting urban households, whose energy consumption is three times that of rural households (Zhang Lixiao et al., 2009).

The combination of rapid urbanisation and rising living standards provides a serious challenge for China's economy beyond providing adequate housing, employment and social services, but to provide the necessary energy to power the cities of tomorrow. By 2030 there will be a further 350 million urban residents searching for employment and housing; all of whom will require new apartments, office buildings and commercial centres. Figure 26 highlights how commercial and residential floor space will increase by around 2 billion square metres annually or from 42m^2 billion to 91m^2 billion between 2005 and 2030.[55] As a result, the energy demands from buildings will double by 2030 (McKinsey, 2009; CEACER, 2009).

Figure 26: Estimated Growth in Building Floor Space, 2005-2030, billion m^2



[55] NBSC (2007) *China Statistics Yearbook* 建筑业房室建筑面 *zhi* [Construction area of building industry], National Bureau of Statistics China, Accessed June 2009 online http://www.stats.gov.cn/tjsj/ndsj/2007/html/01537.xls

Source: McKinsey, 2009

In 2006, regulations were introduced requiring the halving of energy consumption levels in new buildings compared to the current levels. However, very few existing buildings and not many new buildings, especially outside major cities such as Beijing and Shanghai, meet the new energy efficiency guidelines. A green star building evaluation standard has been more successful in urban areas, especially in raising the levels of awareness of the importance of energy efficiency at the building design stage. The program has been less successful at the construction stage, but remains in its early days. Another buildings program has been the introduction of temperature controls for government buildings that requires winter heating does not exceed 20 degrees and summer cooling temperatures are set no lower than 26 degrees.

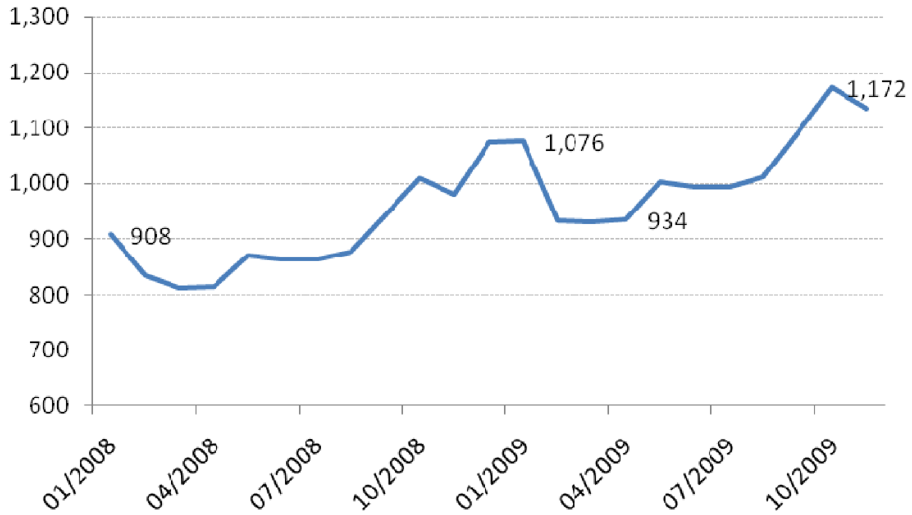
Conservative estimates of growing energy demand show the building and appliances sector's contribution to total energy consumption rising from the present 17% to 25% by 2030 which would require the construction of a further eighteen 1,000 MW coal-fired power stations. This increase would result in an annual increase of 80 million tons of GHG emissions so that by 2030 the sector produces 3.2 Gt of CO_2-e.

According to "China's comprehensive energy development strategy and policy" (State Council DRC, 2005) in order to reach a *xiao kang* society by 2020, energy efficiency programs should focus on promoting industrial energy conservation and energy efficiency in buildings and transport. The rising incomes, living standards and consumption patterns of these urban residents will fuel an appetite for larger residential and commercial buildings. By 2020, China's *xiao kang* society will entail a residential area of 35m^2 per capita, a population of 1.47 billion, an urbanisation rate of 55.78% and total residential area of 55m^2 billion. More critically, each household will most likely be equipped with all the indispensable list of requisite energy intensive functions and facilities, including air conditioners, PCs, plasma TVs, clothes dryer and the family car. The behavioural characteristics and lifestyle expectations of ordinary Chinese will play an increasingly important role in determining future energy demands and the success of energy efficiency initiatives.

The improving quality of life experienced by a growing number of Chinese is marked by increasing levels of consumption. While the main source of energy growth is energy-intensive heavy industry, consumption-led energy demand is set to become the main driver in the future. In fact, it is already playing a significant role in absolute terms. For example, despite the current global recession, Chinese consumers shifted into over-drive on the back of generous government subsidy, rebate and lending programs. During 2009, sales of consumer goods rose 15.5% or double GDP growth. For instance, vehicle sales in 2009 rose 42% compared with 2008 lifting China's vehicle market above the United States to become the largest with 13.6 million new cars and light trucks sold. Sales of household appliances, such as refrigerators, washing machines and other kitchen and laundry equipment, have experienced similar growth with total sales for 2009 expected to reach 185 million units (Bradsher, 2009).

In defiance of the literature arguing that the Chinese are conservative and discretionary consumers, an increasing proportion of sales are being funded by debt. In the first three quarters of 2009, household credit card use increased 40% and car loans rose 25%. By 2009, China had 175.2 million operating credit cards or seven times as many as in 2003 and 30% more than in 2008 (Financial Times, 2010).[56] There was a significant shift in lending in 2009 towards households when their share of lending increased from 15% in the first quarter to 60% by the third quarter (Naughton, 2009c). The resilient growth in retail sales data between July and October 2009 of 15.7% suggest that private consumption has rebounded from the impact of the global slowdown (Figure 27).

Figure 27: Retail Sales of Consumer Goods, billion RMB



Source: CEIC data, 2010

A combination of factors are behind the growing consumption levels in China, including rising household salaries, growing consumer confidence, greater access to credit and critically the recent government stimulus measures such as rebates and tax reductions. Interestingly, household savings rates have come down markedly in China from 26% in 2004 to 12% in 2009. Such a shift defies the accepted economic argument that savings will remain high until the current social reforms covering health, wages, education, social security and pensions, are fully implemented (Credit Suisse, 2010). During the same period, household income of the lowest 20% has risen by 50%, while the top 10% has grown 255% to around RMB34,000 per month. In comparison, the United States savings rate is around 4-6% and consumption levels five times higher than in China. Such levels correlate with GDP per capita figures and per capita annual incomes of US$2,775 in the city and US$840 in the countryside. However, as the Chinese rapidly scale up the wealth ladder, the gap in consumer spending between the two nations is expected to narrow. While offering a boon for retail outlets and manufacturers, the implications for energy and resource use as well as carbon emissions will become an increasingly challenging problem.

During the past three decades China's energy demand was largely driven by heavy industry and manufacturing, future demand, however, is expected to be consumption-led, particularly arising from

[56] The same report cited credit card penetration rates of 0.13 per capita in China compared with 0.99 in the UK and 2.06 in the US.

the increasing use of household appliances, such as air conditioners and motor vehicles. Currently, this sector is not a significant contributor to the energy use equation in China, but remains a critical consideration in decision making today due to the national and transboundary implications of 'getting it wrong'.

This section has outlined several important implementation considerations, including the governance limitations, the differentiated development experience and the risks of lock-in associated with current policy decisions. These issues offer a sobering reminder of the remaining challenges for more broadly rebalancing China's economy as well as achieving specific energy efficiency improvements. These problems will become harder for the government in Beijing to ignore, especially as the global and transboundary implications of China's developmental path increase. While rising standards of living, a growing urban population and sustained rapid GDP growth will increase China's GHG emissions, energy efficiency improvements, technological developments and embracing a more sustainable mode of development will bring down emissions significantly. The big question remains, however, by how much and how soon?

The Structural Implications of China's Energy Use for Emissions

If China's economy continues to maintain the current high levels of rapid growth, then over the next decade China is expected to double its GDP and to rank as an upper middle income country. Many of the policy and investment decisions made today wield ongoing implications for the future structure of the economy, China's pattern of energy generation and use, and carbon emissions. Therefore, China needs to accelerate existing policies promoting the quality of development rather than just quantitative expansion. While the rhetoric of the government has shifted dramatically to promote energy efficiency and economic rebalancing, fundamental structural economic inertia remains apparent and is likely to remain slow for another decade. This section discusses the more recent convergence of China's energy use policies with its climate change policies. An explanation for the government's position and chosen policy measures is provided before providing a detailed analysis of the relationship between carbon emissions and carbon intensity especially at the sectoral level. This is followed by a summary of the key findings and data of the recently released 'China to 2050: Energy and CO2 Emissions Report' (CEACER, 2009). This final section highlights some of the important structural considerations relating to the drivers behind the different growth scenarios for China's future energy use and carbon emissions.

The Convergence of Sustainable Energy Use and Climate Change Policy

In 2009, the Standing Committee of the 11th National NPC endorsed a draft resolution on new climate change legislation calling for specific plans and policies to develop a "green economy" and a low carbon economy, including increasing "green investment", and advocating "green consumption" and "green growth" (Li Jing, 2009). These policy measures shifted the focus on energy away from energy exploitation to energy conservation and improving energy efficiency and included a long-term energy-saving plan. In addition, they set the path for the introduction of specific sectoral and appliance energy efficiency standards. In terms of energy use, China is not only attempting to reduce overall energy use, but it is trying to gradually break its heavy dependence upon coal and introduce a more diversified and low carbon energy mix. The justifications for this shift include concerns over energy security, air pollution, climate change and economic competitiveness.

Between 1982 and 2007, the world emitted 715.2 trillion tons of industrial carbon dioxide into the atmosphere. Since 2000, global GHG emissions have grown by an annual average of 3.6% (Le Quere et al., 2009). Global emissions grew by a further 671 million tons between 2007 and 2008. Around half of the growth in global emissions during the past decade can be attributed to China, especially the rapid expansion of its energy-intensive industrial sector. Therefore, action by China in rebalancing development, curtailing the growth of energy use, and in effect carbon emissions, is critical both at a domestic level and at a global level. Unlike most other industrial economies, China has spent very little time debating the evidence behind climate change, but instead accepted the scientific consensus and responded with a raft of policy measures.[57] China's efforts to adopt a more sustainable use of energy are intimately linked into the nation's climate change and carbon emission policies. Beijing recently introduced a synthesised national-level Climate Change Program (NDRC, 2007).[58] The program was launched with the aim of building a resource efficient and environmentally friendly society, enhancing national climate change mitigation and adaptation and contributing to furthering global climate protection.

Energy efficiency is acknowledged as offering the lowest cost and most effective method of achieving energy conservation whilst reducing GHG emissions (see Figure 36). Energy efficiency can potentially provide over half the energy-related emission abatement potential within the next 20 to 40 years (IEA, 2006; IPCC, 2007c; McKinsey, 2009; Per-Anders et al., 2007; Stern, 2007; World Bank, 2007). As mentioned, China's top priorities in the 11th FYP (2006-2010) include sharply reducing energy consumption per unit of output and making energy production and use less damaging to the environment, while maintaining rapid development. It is estimated that if China can realise the 20% reduction in energy intensity during the Plan, then it will reduce carbon emissions by over 1 billion tonnes annually or four times the EU-15's commitments under the Kyoto Protocol (Chatham House & E3G, 2008). McKinsey (2009, 9) conclude that China can achieve energy intensity per unit of GDP reductions of almost 20% every five years for the next 20 years. Moreover, much of the mitigation potential for reducing carbon emissions can be effectively achieved through low cost and existing technological improvements.[59] The benefits of these energy efficiency gains will result in the abatement of GHGs from business as usual of around 7 billion tons of CO_2e. This is well in excess of the combined GHG emission commitments made by the EU, Japan and the US during the COP15 meeting in Copenhagen. In a further strengthening of energy policy, China announced the extension of its energy

[57] There has been some debate on climate change, especially around the issue of responsibility. For instance, after the 'collapse' of the Copenhagen climate negotiations, one of China's leading climate negotiators and NDRC vice-chairman, Xie Zhenhua, argued that "uncertainties" remain over the cause of global warming, and therefore an "open attitude" towards different understandings are necessary (Kazmin, 2010). According to Xie, climate change is a "solid fact" and the main cause is "the unconstrained emissions of developed countries during the industrialisation process …, but there are some uncertainties".

[58] The full-text of the National Climate Change Program is available: http://www.china.org.cn/english/environment/213624.htm

[59] According to the China Environmental Service Industry Association, energy efficiency projects can provide up to a 200% return on investments with an average of around 30%.

efficiency targets in 2009 into a carbon intensity target. These decisions reflect the gradual convergence of climate policy and energy policy in China during the past five years. It is hoped that this plays an important role in ensuring a higher level of compliance and implementation of policies at the sub-national level.

China's Climate Change Program acts as a guiding document for more specific policies and approaches to climate change both domestically and internationally, including China's existing GHG emissions, the impact and challenges of climate change on China, various policy measures for tackling climate change and China's guiding position, principles and objectives on commitments to climate change. At the same time, the State Council established the National Leading Group on Climate Change Strategy (NLGCCS) led by the premier.[60] The NLGCCS consists of 27 agencies and is responsible for making decisions and coordinating national actions on climate change. Equivalent groups have been immediately established at the provincial, prefectural, municipal and county levels[61] to:

> *Organize implementation of the national strategies and policy on climate change; to design provinces' actions on climate change, energy saving, and pollution reduction; to review plans on international collaboration and strategies on negotiation; and finally to coordinate key provincial actions on climate change, energy saving, and pollution reduction.* (Qi Ye et al., 2008, 295)

As a result of these initiatives, a hierarchy of leading groups on climate change and/or energy saving and pollution reduction has emerged for the formation, implementation and coordination of energy policy in China. The speedy formation of these agencies at all levels of government signals the priority afforded to this issue (Qi Ye et al. 2008).

In 2008, the government published its *Climate Change White Paper* (2008). China's position on climate change is clearly set out in the *Five-Year Plan*, the NLGCCS, the *Climate Change Program* and the *White Paper*. These policies focus on achieving national energy efficiency gains through a broad range of policy measures. A consistent theme within China's climate change strategy focuses on the role of cleaner production and energy efficiency for mitigating emissions.

In 2009, Premier Wen Jiabao announced that climate change considerations would be incorporated into the medium- and long-term development strategies and plans of every level of the Chinese government. The accompanying State Council announcement also called for increasing investment in low carbon industries as well as the construction and transport sectors. At the same time the National People's

[60] The NLGCCS replaced the National Coordination Group on Climate Change (NCGCC), which was headed by a Vice Premier and had been established by the State Council in October 2003. The NLGCCS works along with another companion body namely the National Leading Group on Energy Saving and Pollution Reduction (NLGESPR). The composition of NLGESPR is basically the same, as both groups are lead by the Premier and consist of the same agencies: 'They are one group of agencies and officials but work under two different titles' (Qi Ye et al., 2008). Because of their different goals and objectives, the secretariats of the two groups are located in different agencies.

[61] Naughton (2009b) describes a similar rapid administrative response to the global financial crisis in late 2008 when the hierarchical structure of the communist party was utilised to rapidly marshal the lower level governments into action.

Congress passed a resolution on climate change with the aim of restructuring the existing carbon intensive development model whilst still promoting growth by maximising efficiency, lowering energy consumption and minimising carbon emissions.[62]

In September 2009, President Hu Jintao announced that China would convert its energy efficiency targets into reductions of carbon emissions per unit of GDP. Such an approach tackles the dual goal of reducing both energy and carbon intensity. More importantly, this switch to reporting CO_2 emissions will align China with developed economies on providing measurable, reportable and verifiable (MRV) emissions (WRI, 2009).

> *In the years ahead, China will further integrate actions on climate change into its economic and social development plan and take the following measures: First, we will intensify effort to conserve energy and improve energy efficiency. We will endeavor to cut carbon dioxide emissions per unit of GDP by a notable margin by 2020 from the 2005 level. Second, we will vigorously develop renewable energy and nuclear energy. We will endeavor to increase the share of non-fossil fuels in primary energy consumption to around 15% by 2020. Third, we will energetically increase forest carbon sink. We will endeavor to increase forest coverage by 40 million hectares and forest stock volume by 1.3 billion cubic meters by 2020 from the 2005 levels. Fourth, we will step up effort to develop green economy, low carbon economy and circular economy, and enhance research, development and dissemination of climate-friendly technologies.*
>
> *President Hu Jintao at the UN Climate Change Summit*

To fully appreciate these comments by President Hu, it is necessary to briefly articulate the political context behind China's position and response to climate change. In so doing, it becomes more apparent how China plans to implement a low carbon economy through divergent yet parallel strategies.

China's official position on climate change rests firmly within the United Nations Framework Convention on Climate Change (1992) and the Kyoto Protocol (1997) which state that action on climate change should be in accordance with each nation's "common but differentiated responsibilities and respective capabilities and their social and economic conditions". Moreover, developed economies "should take the lead in combating climate change and the adverse effects thereof". China's position that the mitigation of carbon emissions is the responsibility of the developed world is predicated on several arguments.

Firstly, the developed world wields a sizeable historical debt with significant emissions since the industrial revolution. For example, between 1805 and 2005, the US and UK have each produced 15 times the amount of GHG emissions compared with China (see Figure 28). Even if examined from a more recent historical perspective, China's cumulative contribution to CO_2 emissions from 1900 to 2005 is 8% of total global emissions or less than one-tenth that of the United States, which contributed around 30% of emissions (IEA, 2009a).

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[62] Xinhua (2009) China's Legislature Endorses Climate Change Resolution, *Xinhua*, 27 August online: http://www.chinadaily.com.cn/china/2009-08/27/content_8625536.htm

Figure 28: Accumulated Carbon Emissions, 1805-2005, gigatons of CO_2-e

UK	1121
US	1110
Germany	959
EU27	762
France	528
Japan	335
Korea	190
China	71
China (2030)*	194

Note: * Estimate
Source: CEACER, 2009

Even if the period 1960 to 2005 was examined, China's total emissions are only one tenth of those produced from the US.

Secondly, while China is now the largest source of GHG, much of these emissions are generated by manufacturing industries that shifted production to China from the West and have helped developed economies reduce their own emissions. Moreover, these factories and industries are producing goods for export to feed the demand for consumer items and materials in the West (Weber et al. 2008). According to research by Davis and Caldeira (2010), China is the largest exporter of emissions, mostly to the US, Europe and Japan. If trade embedded emissions were included in the global GHG calculations, then the US would remain the largest emitter and China's emissions would be reduced by 20%. As such, China argues that the West needs to share some responsibility for such emissions.

Figure 29: Global GHG emissions, 2007

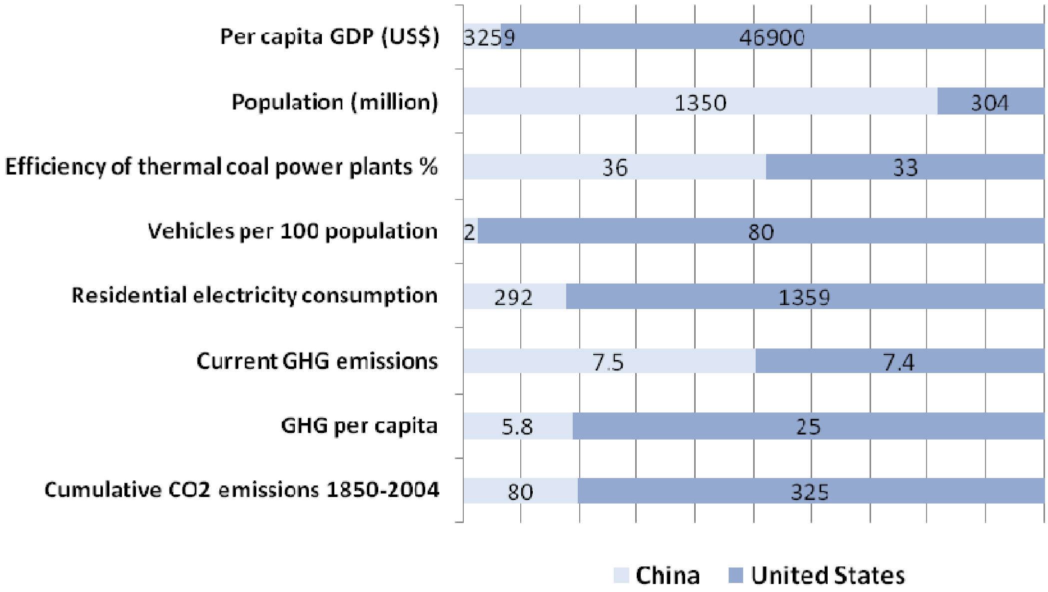
	GHG emissions (Gigatons CO_2-e)	Annual growth rate (1990-2007)	Total per-capita emissions (tons per capita CO_2-e)	GHG intensity of domestic production (2005) Tons CO_2-e per US$1000 GDP
China	7.6	4.7	5.2	3.6
United States	7.2	1	24.3	0.7
Indonesia	3.5	12.7	14.1	12.8
Brazil	2.6	3.1	13	
Russia	2.1	-2.4	14.6	
India	2.1	3.6	1.5	3.7
Japan	1.3	1.3	12	0.4
Germany	0.9	-1.3	12	0.5
Canada	0.8	1.9	24.9	0.8

Source: IEA, 2009; WRI,2009; McKinsey, 2009

Thirdly, on a per capita basis China's emissions are 5.2 tons of CO_2 per capita or around one fifth of America's 24.3 tons or Australia's 28.7 tons per capita (McKinsey, 2009).[63]

[63] Based upon 2005 figures.

Figure 30: Comparison of Chinese and US Energy Statistics



Source: Seligsohn et al., 2009

While Figure 29 shows China as the world's largest anthropogenic CO_2 emitter and the US the second largest, producing more emissions than the combined total of the next four largest emitters: India, Russia, Japan and Germany. While China and the United States' are the largest global emitters, the discrepancy in each nation's emissions is more obvious from a per capita or historical perspective. For example in 2008, despite US emissions declining by almost 192 million tons or around 3% following the global financial crisis, the US remains the main GHG emitter amongst the large economies producing almost 25 tons of carbon dioxide per capita compared to the world average of 5.3 tons. A more detailed comparison of energy statistics between China and the United States is instructive (Figure 30), especially given the high level of tension in negotiations during and following the 2009 Copenhagen meeting and the apparent gap in understanding. China's per capita emissions remain well below the United States as highlighted by the disparity in residential energy consumption, which reflects the developmental gap between the two nations.

Fourthly, as China still remains a developing economy it argues that it should not have to limit its level of development due to something beyond its responsibility. China remains a low to middle developing economy with a per capita GDP of around US$3259 in 2008, which according to the IMF (2009) ranks it 104th among 180 countries and regions. Moreover, it argues that its share of emissions will continue to grow to meet the social and economic needs of its people. Therefore, any actions it takes will be dependent upon progress in tackling poverty as well as efforts to raise the level of the populace's development.

Finally, in terms of preconditions for action on climate change, China returns to the 1992 UNFCCC and 1997 Kyoto Protocol which both clearly articulate the responsibility of the developed economies to: lead on cutting emissions; and provide financial assistance as well as share energy efficient and carbon reduction technologies with developing economies.

It is clear that China remains sensitive to being seen as framing carbon emission commitments within its clearly articulated position that the developed world should lead and as a low to middle income developing economy its growing carbon emissions do not need to be curtailed until it has attained a reasonable level of wealth. Moreover, it hopes that through the process of developing a global agreement on climate change, China will receive both technical and financial assistance from the West. Ironically, despite all the conservative pronouncements at the global level during the past decade, China has already dramatically shifted its stance on the domestic front due to a growing acknowledgement that unrestrained carbon emissions, environmental pollution and inefficient resource utilisation will not lead to prosperous development. Instead, China's structural rebalancing program has received a further boost following the realisation that the challenges of climate change can provide additional economic development opportunities by embracing a low carbon economy. China recognises that improving energy efficiency and reducing carbon emissions is not only critical to its national security but provides an enormous opportunity for future economic prosperity.

Carbon Emissions and Carbon Intensity

Due to the combination of the global economic slowdown and positive government steps in tackling energy efficiency in China, by the end of 2008 China's CO_2-e emissions slowed to an annual increase of 6%, which is the lowest annual increase since 2001 (PBL, 2009). The slowdown in China's emissions growth contrasts with a trend since 2004, when its emissions increased by 17% largely due to the aforementioned rapid growth in heavy industry.

Figure 31: Carbon Efficiency and GDP Growth Comparison, 2007

	GDP carbon efficiency improvement	GDP growth rate
China	4.9	10.1
India	1.3	6
Indonesia	4.4	-1.4
Australia	3.5	1.3
Saudi Arabia	3.1	-2.5
United States	3	1.7
France	1.9	1.5
Germany	2.7	1.6
Japan	0.3	1.3
Russia	2	-0.7

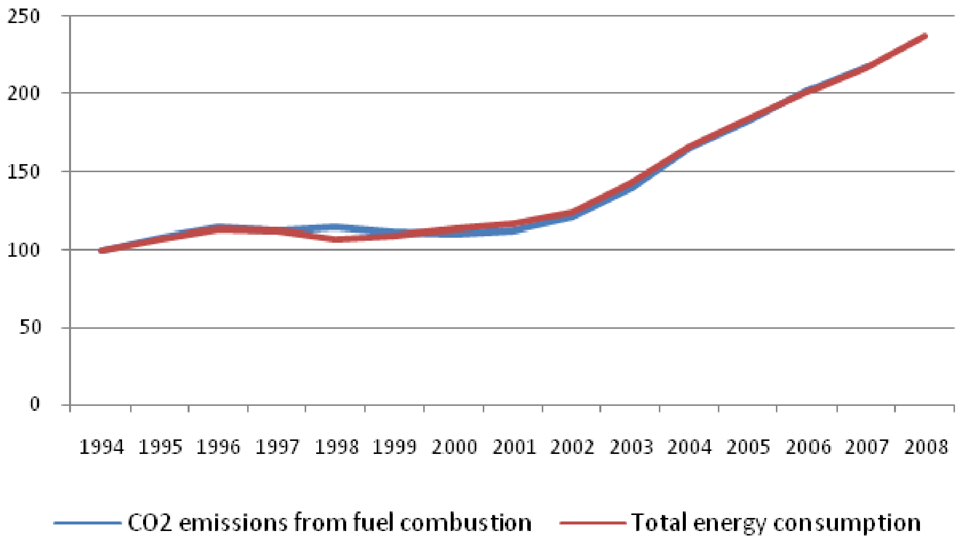
Source: McKinsey, 2009

During the past 20 years, China has achieved significant improvements in reducing its carbon intensity as a unit of GDP. According to McKinsey (2009, 35), China had the highest carbon efficiency improvement rate in the world between 1990 and 2005. While annual growth averaged 10% during this period China's carbon intensity per unit of GDP reduced by 4.9%. In other words, for every increasing 10% of GDP growth, China has been able to reduce its carbon footprint by nearly 5% (see Figure 31).

As mentioned, President Hu announced that China would extend the national energy intensity targets into a carbon intensity figure. This significant cut was later announced as a 40-45% reduction in carbon intensity by 2020 based upon a 2005 base year.[64] It is expected that China will incorporate a carbon efficiency target in the 12th and the 13th FYP between 2010 and 2020, which will be backed up by legislation and targeted policy and implementation programs. The carbon intensity targets correlate with the energy efficiency targets as well the timeframe matching China's increasing renewable energy commitments and expectations for a peak and decline of its carbon emissions by 2030 (see Figure 35).

According to CSES analysis, China's carbon intensity is set to decline by 42.5% on a BAU scenario in 2020 relative to 2006, with annual emissions growing by 4.3% over 2006-30 and annual GDP growth of 8.1%. State media also reported that China's CO_2 emissions per unit of GDP had reportedly decreased between 2007 and 2008 by 10%.[65] Therefore, the carbon intensity reduction announcement was greeted with a certain level of cynicism by those expecting a reduction of at least 50% or more.[66]

Figure 32: CO_2 Emissions from Fuel Consumption and Total Energy Consumption, China, 1994-2008 (indexes 1994=100)



Source: IEA database (for details see Appendix)

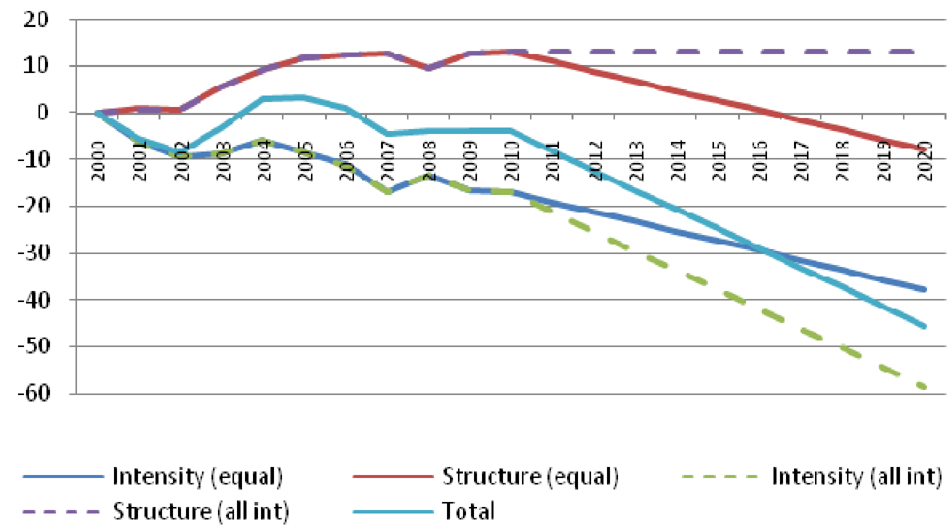
However, it should be appreciated that for China to hold itself to the BAU scenario, significant challenges remain. First and foremost, energy use and energy intensity figures have once again diverged from national policies due to the 2008-2010 economic stimulus package. Moreover, the BAU scenario is

[64] According to Professor He (Director of Tsinghua University's Low Carbon Energy Laboratory), China is currently developing its national GHG emissions inventory for the UNFCCC Second National Communications with some international assistance (cited in Seligsohn, 2009)
[65] China Daily, 23 September 2009 http://www.chinadaily.com.cn/bizchina/2009-09/23/content_8724671.htm
[66] China's commitments to reducing its energy intensity are often met with scepticism, yet it is rarely acknowledged that their efforts will reduce global GHG emissions by a more significant amount than the combined reductions promised by the wealthy developing nations of Europe, Japan and the United States. Implementation will however remain the key indicator.

largely based upon new policies introduced since 2007, such as the intensification of the policy measures for achieving the energy efficiency targets and new support for renewables and low carbon energy. However, it is still unclear how successful these policies will be or what implementation resistance they will encounter at the local level. Finally, emissions per unit of energy use change only slowly (Figure 32), as this requires changes in the energy supply mix and an increase in the emissions efficiency of energy production (for example, by the introduction of carbon capture and sequestration). Thus we take it that China's Copenhagen commitment implies a reduction in emissions intensity of at least 40% by 2020, relative to 2005. On our estimates this implies a reduction of about 36% on 2010 levels.

As the previous discussion implies, such a reduction can be achieved by either reducing the energy efficiency of individual industries or by shifting the structure of GDP to a less energy intensive one, or both. In Figure 33 we explore two alternative paths: one in which the adjustment is equally shared between the intensity and structure effects, and the other in which industry structure is held fixed and the reduction is achieved by reducing the energy intensity of industries within that structure.

Figure 33: Achieving a 40% Reduction in China's Energy Use Per Unit of GDP by 2020: Intensity and Structural Contributions on Two Separate Paths, 2000-2020, thousand tons of SCE per billion RMB at 2005 values



Source: China National Statistical Bureau; CEIC database and estimates of the authors (for details see Appendix)

These estimates indicate that, if the composition of China's GDP remains fixed at 2009 levels, very rapid adjustment in industry-specific intensities is required to achieve the 40% reduction target, and that the pace of reduction needs to accelerate markedly from that achieved over 2000-09. On the other hand, if the burden of energy reduction is shared equally between structural and intensity factors, achieving the 40% reduction target is consistent with a continued fall in energy intensities in line with 2002-09 trends. The balance between these two factors is ultimately a policy choice, but it is evident that changes to the structure of GDP can make an important contribution. China's policy stance in the 11th Five Year Plan period has been to pursue action on both fronts: to reduce energy emissions by aggressive action to reduce energy intensities within industries but also to attempt to change the structure of GDP.

The energy efficiency and carbon intensity targets will remain challenging for China to maintain (particularly beyond 2020), especially considering the re-intensification of energy intensive industrial production following the government's stimulus package and existing policy commitments.

Attaining an Emissions Peak and Decline Scenario

Notwithstanding the global financial crisis and the constraints of climate change, the outlook for China's energy demand is for continuing high rates of growth for many years to come. It is estimated that if current patterns of economic growth and energy consumption continue, China's total annual primary energy demand would increase from 1297 million tons of coal equivalent (Mtce) in 2000 to 3280 Mtce by 2020. While coal consumption is expected to increase by 3% per annum between 2005 and 2030, the share of coal in China's energy mix would decline from 69.9% in 2000 to 63.2% by 2020, and its CO_2 emission would reach 1940 Mtce by 2020 (IEA, 2009a).[67] Acknowledging the growing levels of development in China, strong growth in demand for energy and rapidly rising carbon emissions are critical domestic and international issues.

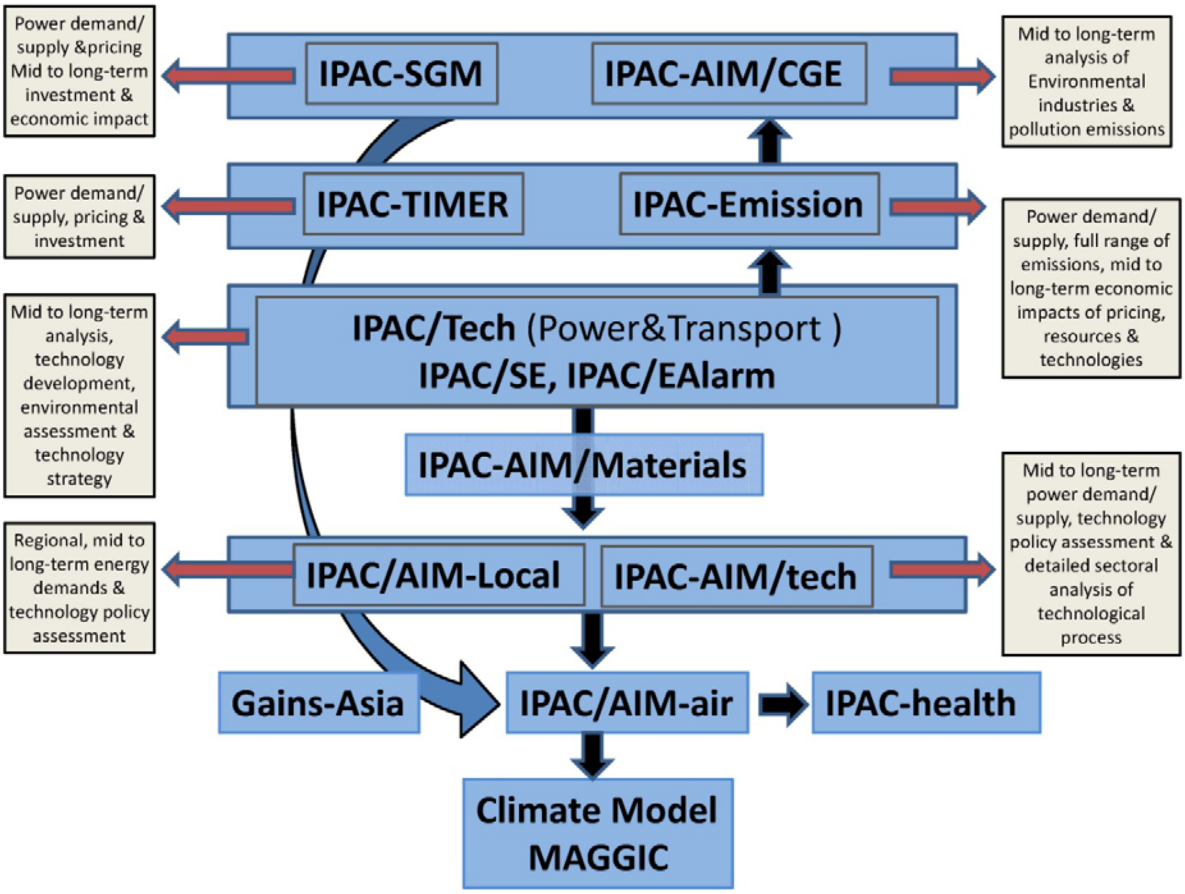
The gravity and complexity of fully understanding the drivers and implications of such changes in China have been a strong focus of the central government for over a decade. One of the key outputs of China's effort in this area has been the formulation of the IPAC-AIM modelling framework (China Energy Environment Integrated Assessment Model; 中国能源环境综合评价模型 IPAC 框架).

This framework is one part of a complicated quantitative model utilising global IPCC (2007a) methods for incorporating economic, social and technological aspects at the local and provincial levels to determine a variety of emission pathways and energy use scenarios for China. The model provides useful background into China's complex economic situation as well as incorporating global economic factors, such as trade. The framework has been gradually developed by ERI together with literally hundreds of domestic and international research collaborators over the past 15 years. This section of the report includes some of the scenarios and modelling results for projected economic activity and carbon emissions through to 2050 emanating from the 2009 report titled '*China to 2050: Energy and* CO_2 *Emissions Report*. The report is a joint publication by members of the China Energy and CO_2 Emissions Report Group (CEACER, 2009), which includes the Energy Research Institute of the National Development and Reform Commission, the State Council Development Research Centre's Industrial Economics Research Department and Tsinghua University's Institute of Nuclear and New Energy Technology.[68]

[67] The IEA reduced its estimates of annual coal demand in China from 3.2% to 3% following the policy success I closing down small, inefficient coal-fired power plants and replacing them with more efficient supercritical coal plants.

[68] The report is published in Chinese, titled: 2050 中国能源和碳排放报告, Beijing, Science Press, but it is expected that most chapters will be available in English shortly following their publication in international journals.

Figure 34: Integrated Policy Assessment Model used by CEACER



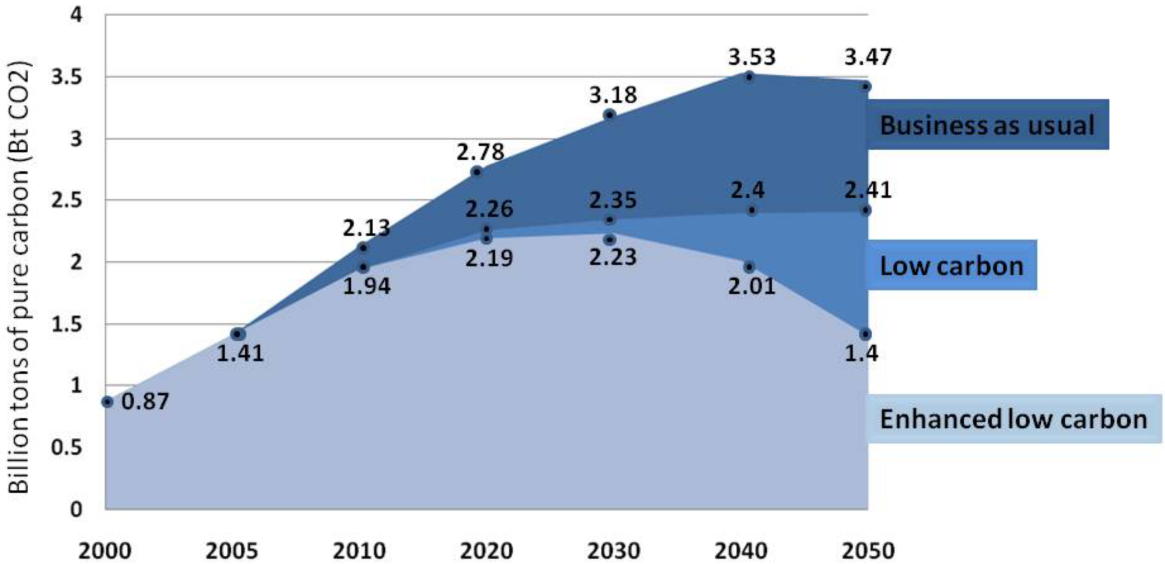
Source: CEACER, 2009

Figure 34 provides details of the modelling for the CEACER report, which incorporates several components. Firstly, the IPCC's IPAC-emissions model was adopted, including global energy demand and supply, GHG emissions, targets and burden sharing relationships, energy imports and exports, energy prices and reduction costs. Secondly, an energy and computational general equilibrium economic model (IPAC-CGE) was used covering major industries and sectors including future economic sector details, energy intensive industries and a reduction cost. Thirdly, an energy technology model was incorporated following the IPAC-AIM approach to analysing the impact of a range of different technologies (up to 600) and includes China's energy and emissions scenarios, energy demand by sectors, energy supply and reduction costs.

Several key considerations are included in the model, including: the issue of burden sharing (equity); structure of the economy, especially the role and impact of manufacturing; and, identifying broad government policy perspectives and measures required to bring about emission reductions of 50% by 2050. A key focus of ERI's research for the report has included examining a peak and decline approach for China's GHG emissions and "back-casting" the necessary reductions in the various sectors based upon technological and behavioural estimates.

The ERI IPAC-AIM model includes 6 scenarios, however due to the media's emphasis on only three scenarios, ERI have generally limited themselves to just three scenarios in public discussions including: the baseline (BAU), a low carbon policy (LC) and an enhanced low carbon scenario (ELC) (see Figure 35). In terms of CO_2 emissions, the focus is on a peak and decline approach with a 2030 peak of 2.23 Btce following the ELC scenario, whereas emissions continue to grow until 2040 to around 3.53 Btce under BAU. The ELC scenario then suggests a steady decline in emissions returning to 2010 levels by 2035 and 2002 levels by 2050. Following a low carbon policy approach, CO_2-e emissions stabilise by 2030, but fail to achieve a decline by 2050 when emissions continue to grow; reaching 2.41 Btce. The key finding in the report is that China's emissions could begin to slow from 2020 with a peak around 2030. Such a scenario is even more ambitious than the commitments from most developed economies and would therefore be favourably viewed in international negotiations.

Figure 35: ERI IPAC-AIM Model of CO_2 Emission Scenarios



Source: CEACER, 2009

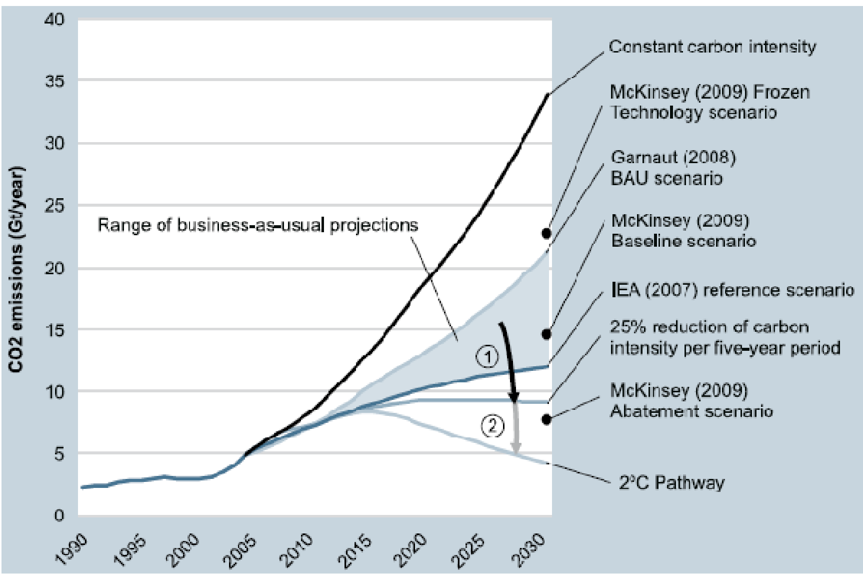
The key outcomes of the ERI modelling for embracing a low carbon approach compared to business as usual by 2050 is a reduction in primary energy demand and CO_2 emissions of 26.8% and 44% respectively. This will require an optimisation of the nation's energy structure away from coal (declining from 44% to 37.4%) and oil (declining from 27.6% to 20.2%) and towards nuclear (increasing from 9% to 14.2%) and renewables (increasing from 9.4% to 13.8%) as well as a reduction in overall energy demand. According to ERI, additional assumptions arising from the scenarios in Figure 35 include: per capita income is expected to increase ten-fold from RMB20,000 in 2010 to RMB200,000 by 2050; and China's CO_2 emissions will reach 5.5 billion tons in 2010 with a peak scenario in 2035 of 8.8 billion tons. In summary, the key conclusions of the ERI study found that:

- the most significant gains in energy efficiency will come from the industry and transportation sectors;

- China's per capita GHG emissions will rise from 3.58 tons in 2004) to 4 tons in 2010 and 6 tons in 2050, which is equivalent to a 50% increase from 2010 to 2050;
- CO_2 reductions remain dependent upon the application and widespread penetration of existing and new low carbon technologies;
- the costs are not much higher for a low carbon approach, but the opportunities and benefits are significant especially in the global context; and
- timing is critical and there remains an urgent need for the State Council to adopt climate and energy planning, including carbon emission targets, within the Five Year Plans (FYP), including the forthcoming 12th FYP or at least the 13th FYP at the latest.
- Challenges remain, especially for managing the growing demand for oil and gas as well as adopting carbon capture and storage (CCS) by 2030.

The Stockholm Environment Institute (SEI, 2009) provides a useful comparison (Figure 36) of different emission pathways based upon a variety of recent analyses of possible abatement scenarios (Garnaut, et al., 2008; IEA, 2007; CEACER, 2009; McKinsey, 2009- see SEI, 2009). SEI divides the pathways into three groupings. Firstly, the higher emission scenarios based upon business as usual with little or no technological improvement and retention of existing energy intensity figures. Secondly, a status quo low carbon policy approach achieving 25% improvement in carbon intensity every five years through to 2030. Thirdly, the enhanced low carbon scenario based upon 'backcasting' to keep global temperature increases to below 2 degrees Celsius. The different scenarios highlight the enormous gap between BAU and low carbon policy scenario (arrow 1) and the enhanced low carbon scenario (arrow 2). It is important, however, to keep in mind the difficulty in terms of the accuracy of these models, which make enormous assumptions in terms of parameters and weighting. Therefore, caution and careful considerations is necessary as Figure 37 highlights in relationship to the problems with estimating the contribution of the steel industry.

Figure 36: Schematic Overview of Possible Future Emission Pathways for China



Source: SEI, 2009, 5

Prior to discussing the key drivers for China's projected increase in emissions, the basic economic and population characteristics for China going forward to 2050 are introduced. Understanding the underlying trends of population growth, future industrialisation, economic development and urbanisation are essential in appreciating both the opportunities and constraints for achieving more sustainable energy use and realising a low carbon economy.

Figure 37: Note on CEACER Model and Scenarios

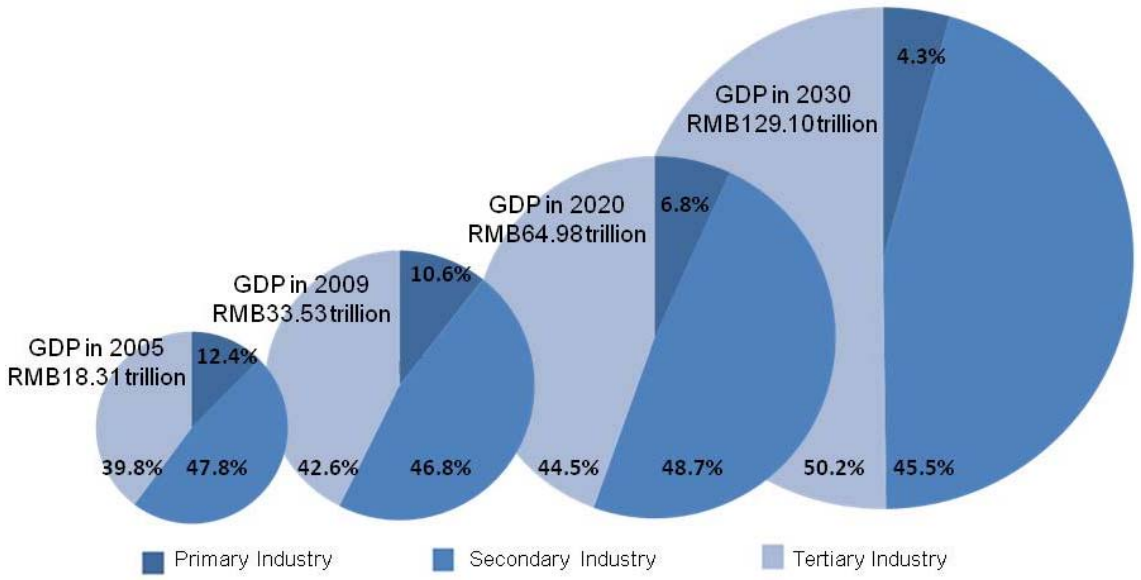
The assumptions and projections in the CEACER report (2009) scenarios have been challenged somewhat due to the rapid economic growth of the past few years and the rising steel and energy figures. The strong growth experienced between 2005 and into 2008 requires some of the baseline data to be reviewed.[#] This is especially important following the central government's stimulus program which resulted in a massive economic rebound, especially in the energy intensive heavy industries. For example, steel production rose significantly in China during 2009 by 14% compared with 2008, despite the global economic slowdown that resulted in the global production of steel declining by around 25% in countries other than China. According to the CEACER BAU scenario, steel output doubles between 2005 and 2020 from 355 to 710 million tons respectively. China publicly claims to already have the capacity to produce 700 million tons of steel.[##] By the end of 2008 steel output reached 530 million tons, rising to 568 million tons in 2009, equivalent to half the world's steel. Based upon recent growth figures, China's steel production could reach over 3500 million tons by 2020 or 400% over the CEACER BAU estimates. Such discrepancies in baseline figures and growth forecasts questions the reliability of projections for 2020, especially assuming that under the projections growth in steel output flattens out post 2020. And yet, all signs show that steel will in fact continue to grow to meet strong demand, especially in the infrastructure and housing sectors. Following discussions between CSES and ERI, ERI argued that this growth in steel production was considered unsustainable in the medium to long term and is expected to eventually slow down after 2010. The initial 2010 projections are now being left out of publications due to recent central government policy measures and industry consolidation. A further consideration in reviewing production figures and arguments about efficiency in the steel industry are concerns that the apparent 'inefficiencies' are being used as a means by central government line agencies to consolidate industrial production within the state-owned sector (Naughton, 2009c).

It is important to stress that the CEACER report is largely focussed on modelling and analysis of alternative emission projections, rather than the policy making processes and implementation. This critical second stage is now the key focus of the researchers involved in the report with collaboration between ERI and CSES contributing to these dimensions through the three case studies (see separate Final Report). Presently, a key focus of research is on developing feasible and realistic targets developed in cooperation with other developed nations. A remaining constraint exists relating to China's access to comparable international data and global trends, including an examination of the structural issues of the economy. Some of these issues were recently addressed during the 2009 US-China engagement on energy and the resultant cooperation agreements. For example, see the US-China Electric Vehicle Initiative (White House, 2009), which included proposed collaborative activities such as discussions and development on 'joint standards development', 'joint demonstrations' and 'joint technical roadmap'.

[#] The CEACER report is not alone in underestimating growth projections for China. The World Bank, IEA, IMF and OECD predictions for energy consumption in China have all needed to be adjusted regularly. While such adjustments are made in the short-term, very few projections include sustained growth forecasts beyond 2020.

[##] China has rapidly risen up the global steel production ladder from 2000 when it produced a sixth of all steel to now producing almost half of all steel in 2009.

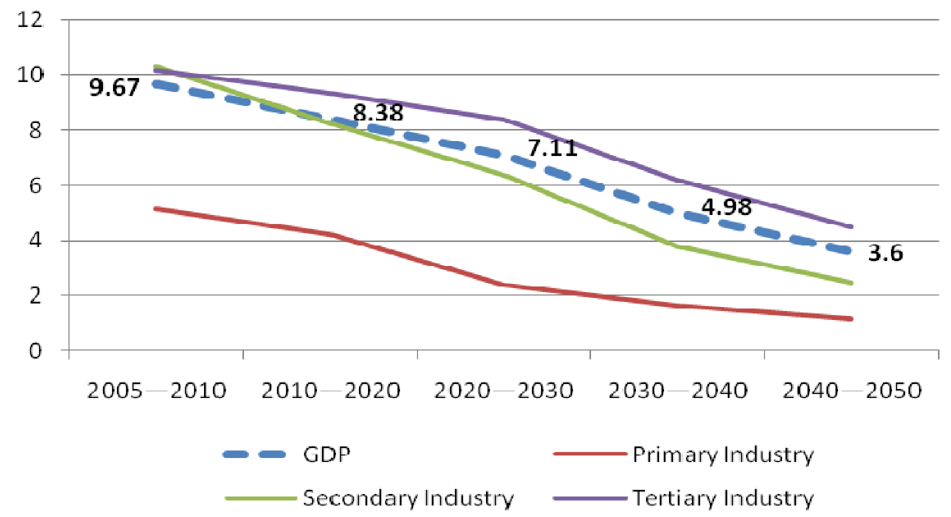
Figure 38: Growth of China's GDP by Sector, 2005-2030



Note: amounts are set at constant 2005 prices.
Source: CEACER, 2009

Rapid GDP growth driven by industrial expansion and urbanisation are the key drivers for China's continuing rapid growth in GHG emissions. According to CEACER modelling, China's GDP is expected to continue to grow at or near 10% per annum for the next decade despite the recent global economic crisis which is predicted to slow its growth to around 8-9% in the short term (see Figure 38 and 39). By 2020, GDP growth may slow to between 6-8% per annum, yet China will account for a quarter of total global economic activity to become the world's largest national economy. This shall increase China's role as the source of global economic growth, especially in driving the demand for resources.

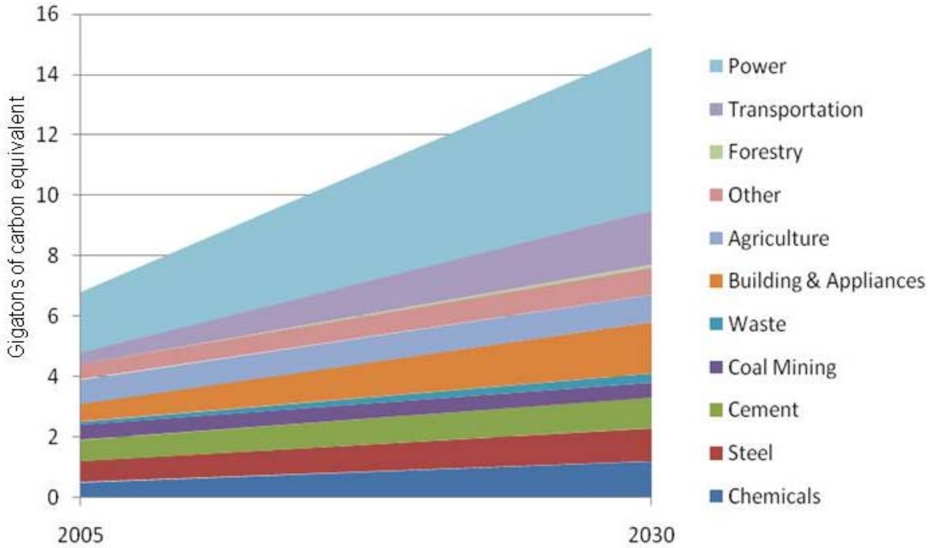
Figure 39: Rate of Growth by Sector of China's GDP (%)



Source: CEACER, 2009

A key consideration for this report is the speed of adjustment within the structure of the economy. For structural rebalancing to take place, the expansion of the service sector needs to be above the growth of the industrial sector. However, predictions that this would occur during the 11th FYP have been premature. By 2020, China will reach middle income status and yet the industrial sector is expected to retain a key role in boosting growth. The pre-eminence of industry will gradually be supplanted by the rapid expansion of the service sector. By 2020, the service sector is likely to gradually increase its share of economic growth from around the present 41.8% to nearly 45%. The shift, as shown in Figures 17 and 18, however, will most likely remain gradual. And yet according to Figures 16 and 18, secondary industry retains its preeminent hold on GDP growth until 2030 when it accounts for over 40% of total GDP compared to around 48% in 2005. By 2030, the service sector is expected to contribute to more than half of the nation's economic value. The gains in the tertiary sector occur as primary industry's share steadily declines to around 4.3% in 2030.

Figure 40: CO_2 Emissions by Sector, BAU Scenario, 2005 & 2030



Source: CEACER, 2009

Figure 40 illustrates the growth in emissions by different sectors of the economy. It shows that the largest growth in China's emissions will come from the three sectors of power generation, transportation, and buildings and appliances. Clearly, power generation remains the most important contributor to emissions – almost tripling between 2005 and 2030. GHG emissions from power generation are estimated to rise from 2.0 Gigatons of CO_2-e per year to 5.4 Gt in 2030; a 170% increase. However, what is also evident is the expansion of the building and appliances, and transport sectors, which make up for much of the rest of the growth. Buildings and appliance are set to triple from the existing 1.1 Gt of CO_2-e per year to 3.2 Gt in 2030; a 190% rise. Whereas the transportation sectors annual contributions are set to rise 350% by 2030. This dramatic rise is due to the existing low base level in China today. For example, in 2005 China's vehicle penetration rate was only 3% compared with 60% in Japan and 80% in the United States. As a result, the transportation sector only contributes around 8% of China's total GHG emissions compared with 22% in Japan and 29% in the US. However, penetration rates are shifting dramatically in recent years with the doubling of vehicle ownership rates between 2004 and 2009 and they are expected to double again by 2015 (Credit Suisse, 2010). Furthermore, expectations of a ten-fold increase in vehicle numbers to 337 million vehicles by 2030, mostly private light-duty vehicles, will dramatically alter this balance. Based on an average annual mileage of 10,000 km, vehicles will emit 1.8 Gt of CO_{2}-e by 2030 up from existing emissions of 0.4 Gt CO_{2}-e (McKinsey, 2009, 39).

As a result of the combination of existing policies with the burgeoning growth in the urban population and their insatiable appetite for household appliances, primary energy demand in China is expected to more than triple between now and 2030. According to the IEA (2009a), China shall account for 39% of the global increase in primary energy use between 2007 and 2030 with its share of total global demand increasing from 16% to 23% respectively. According to Figure 41, primary energy demand will grow at just under 3% annually between 2007 and 2030 to reach 3,827 Mtoe by 2030. Final electricity consumption will rise by 4.5% annually during the same period and reach 7,513 TWh.

Figure 41: Energy Scenarios for China

	2001	2007	2015	2020	2030	2007-2030
Primary energy demand (Mtoe)	603	1 105	1 970	2 783	3 827	2.9%
Final electricity consumption (TWh)	259	1 081	2 717	4 723	7 513	4.5%

Source: IEA, 2009a; CAECER, 2009

Regardless of the scenario or predictions for China's future energy use, much of the increase in energy demand through to 2030 remains coal-dependent. China already doubled coal consumption between 2001 and 2007 with expectations it will double once more by 2030 to 3424 Mtce, accounting for around 65% of the global increase in coal use between 2007 and 2030 (IEA, 2009a).

Figure 42: Projected Energy Capacity, Baseline Scenario

	Coal	Petroleum	Natural Gas	Hydro	Nuclear	Wind/ Solar	Biomass	Total (GW)
2000	70.62%	3.01%	0.49%	24.83%	0.71%	0.17%	0.18%	309.04
2005	71.44%	2.54%	0.44%	23.50%	1.66%	0.23%	0.19%	516.24
2010	73.01%	1.86%	1.03%	21.11%	1.39%	0.66%	0.93%	937.45
2020	72.51%	1.64%	2.54%	18.91%	2.02%	1.20%	1.19%	143.01
2030	70.10%	1.35%	4.58%	16.52%	3.33%	2.78%	1.35%	182.75
2040	55.92%	1.36%	8.54%	16.66%	9.04%	6.67%	1.81%	211.91
2050	53.41%	1.38%	10.22%	14.53%	11.83%	6.79%	1.84%	236.12

Source: CEACER, 2009

At the same time, according to the CEACER's (2009) business as usual (BAU) scenario for China's future energy mix, total renewable energy capacity actually declines as a percentage of the total energy capacity due to the growth of low carbon energy sources such as natural gas and nuclear power (see Figure 42). For example, between 2000 and 2020 the proportion of renewables reduces from 25% to 21%. By 2050, nuclear and natural gas increase their capacity to 11.8% and 10.2% respectively while coal's growth stabilises from 2020 above 72% and eventually declines to 53% by 2050.

Figure 43 illustrates the enhanced or aggressive low carbon scenario calculated by the IPAC-AIM technology model, whereby total energy generation capacity peaks around 2030 and eventually declines due to the expansion of nuclear and wind. Hydro power generation capacity peaks by 2020 due to limitations on new capacity when it reaches nearly 30% of total capacity. By 2050, renewables contribute over 43% of China's total energy capacity, but when combined with the low carbon fuels of nuclear and natural gas reaches 70% with coal reduced to around 27%.

Figure 43: Energy Generation Capacity, Enhanced Low Carbon Scenario (billion kWh)

	Coal	Petroleum	Natural Gas	Hydro	Nuclear	Wind	Solar	Biomass	Total
2000	70.62%	3.01%	0.49%	24.83%	0.71%	0.17%	0.00%	0.18%	3090.4
2005	71.44%	2.54%	0.44%	23.50%	1.66%	0.23%	0.00%	0.19%	5162.3
2010	68.12%	1.44%	1.92%	22.59%	2.10%	3.09%	0.05%	0.67%	8431.7
2020	49.46%	0.93%	5.14%	28.95%	5.41%	8.21%	0.12%	1.78%	12743.3
2030	37.66%	0.72%	6.63%	26.85%	9.24%	15.98%	0.59%	2.34%	16604.8
2040	31.30%	0.55%	7.83%	24.81%	12.89%	18.56%	1.69%	2.37%	19653.3
2050	27.19%	0.47%	9.22%	21.57%	17.51%	18.31%	3.48%	2.25%	22184.5

Source: CEACER, 2009

Energy and Development under a Low Carbon Economy

The characteristics of China's reform experience highlight the complex patterns and variations between regions and within various sectors of the economy and society. Such a predicament ensures that making predictions or outlining trends and patterns in such a divergent context very difficult. The ongoing oscillations in the direction and pace of the reforms and the incremental, adaptive and reactive nature of policy developments challenge narrow and linear predictions and projections of future change in China. What is obvious to the state, however, is the implication of ignoring the current imbalances in the economic structure, especially the serious environmental and resource constraints arising from energy-intensive industrial expansion. Moreover, the state perceives an opportunity to tackle the economic and social imbalances through a development path that minimises environmental and resource costs. One suggested approach for resolving the existing economic imbalances and developmental contradictions is a low carbon economy (LCE). This section of the report explores some of the key characteristics of a low carbon economy, as well as how this so-called 'new economy' differs from traditional patterns of development and economic principles. The final part of the report assesses the feasibility of China successfully decoupling economic development from increasing energy and carbon emissions, and concludes with a brief summary of the key issues.

The debate on the low carbon economy has given rise to three sets of issues about its meaning, its significance and its implementation. This section introduces the role of a low carbon economy as a vehicle for rebalancing the structure of China's economy. The significance of a low carbon economy is then discussed prior to discussing the impact of the government's response to the global financial crisis in the form of the economic stimulus package, including the implications of this package for energy sue and economic rebalancing.

The Concept of a Low Carbon Economy

For some the concept of a low carbon economy involves a new economic paradigm, whilst for others it entails a complete social transformation of which the economy is only a part. There is additional debate about the timing and intensity of implementing a LCE with some calling for a gradual adoption of measures, whilst others call for a complete and rapid paradigm shift. Whichever path towards a low carbon economy is chosen, there is a growing recognition that the concept can play a leading role in rebalancing the economic structure of a nation towards a more sustainable development path (CAS, 2009a; GERF, 2008; NEF, 2009; Royal Society, 2009; SEI, 2009; UK Government, 2007; Vivid Economics et al., 2009; Zhuang Guiyang, 2008).

The low carbon economy concept first emerged in the UK government's energy white paper as part of a strategy to reduce GHG emissions and improve energy security (DTI, 2003). A key focus of the concept is the decoupling of carbon outputs and economic development. In other words it aims to reduce the ratio of carbon in energy production and consumption, especially through energy efficiency improvements and is often measured as the level of energy consumption per unit of GDP. Implicit in adopting a low carbon economy is that early action on climate change can mitigate the extreme negative impacts of climate change whilst reducing the economic, social and environmental costs of inaction or delay.[69] Generally, a low carbon economy encompasses several principles, including:

- waste minimisation;
- maximise the adoption of low carbon energy sources and methods, especially renewable and alternative energy sources and fuels;
- ensure the efficient utilisation of all resources, especially energy, through the retrofitting and adoption of leading energy efficiency measures and techniques;
- expand the support for research and development, early stage technological development and the necessary human skills to realise such developments; and
- raise the level of awareness and compliance with environmental and social responsibility initiatives amongst industry, commerce and individuals.

The concept of a low carbon economy emerged in China due to a growing acceptance that the traditional development strategy based upon heavy industrialisation is environmentally and socially unsustainable and economically insufficient to deal with the demands of an increasingly competitive global economy. It is increasingly apparent that China is not likely to continue down the traditional path

[69] Delays in adopting world's best practice in energy efficiency and low emissions technology pose serious challenges for China's energy security as well as for global climate change. McKinsey (2009) argue that a delay of only five years in failing to realise the energy efficiency savings arising from mainly the energy, transport and housing sectors would reduce the potential abatement of carbon emissions through to 2030 by 30%. A delay of 10 years would increase the lost abatement to 60%. Therefore, more aggressive policy measures need to be adopted in China in terms of the transition to a low carbon economy, including strategic planning of cities, promoting renewables and low carbon energy generation, tighter building energy efficiency standards as well as higher fuel economy standards for vehicles.

of economic development, nor will it progressively adopt the institutions, systems and policies prevailing in advanced economies. Instead, new and distinctive approaches to development, which take into account China's local circumstances and the new global realities, need to be urgently implemented. A low carbon economy (LCE) is seen as offering a good mix of policies for rebalancing China's economy towards achieving more sustainable growth (CAS, 2009a; CEACER, 2009). Key arguments for supporting the adoption of the low carbon economy are based upon the premises that it will:

- provide a new competitive advantage for China's manufacturing and industrial sectors within a fundamentally different global context;
- grow employment through productivity gains from quality enhancing process technologies rather than labour-saving technologies;
- rebalance the existing unsustainable use of resources and environmental degradation;
- offer alternative income streams for rural communities and improve rural output;
- significantly contribute to mitigating China's rapidly growing GHG emissions; and
- strengthen China's capacity to adapt to a climate changed globe.

Therefore, the growing calls for adopting a LCE development pattern are well received by government due to the concept fit with the broader desired goals of structural rebalancing.[70] However, much remains unclear in terms of the meaning, scope and implications of a LCE for China, including whether LCE is a development strategy that is compatible with rapid, balanced and sustainable long-term growth. This report shall address some of the key questions that have arisen within the Chinese debate, and in particular explore the relevance of the low carbon economy to China's development strategy.[71] While each aspect of the structural rebalancing issues is of critical importance and interconnected, it is not possible to explore all of the issues in any depth in this report. Therefore, this report is limited to focusing on one major aspect critical to the implementation of such a revised approach – the role of sustainable energy use and its relationship to a low carbon economy.

The Significance of a Low Carbon Economy

An enormous number of decisions about China's future path of development are being made everyday throughout the country relating to the types of buildings erected, the preferable mode of transport, the sources of energy used to power the economy and the types of household appliances to purchase. The decisions made today in China hold significant implications for the nation's development path. Moreover, the world is increasingly aware that decisions made today in China have implications not just for China, but more generally for the globe in terms of the environment, especially climate change, resource availability and prices and developmental opportunities. Given the current state of China's economic structure and projections for future growth, the significance of China embracing a low carbon economy is obvious. Nevertheless, China is set to benefit from this transition beyond achieving a more

[70] There are some vagaries, however, about the similarities and differences between LCE and other concepts in China such as circular economy, sustainable development, ecological civilisation and harmonious and scientific development (Bina, 2009).

[71] See for example Xin Hua (2009), Zhou Shouxian (2009), Huang and Li (2009), Guo and Wang (2009), Hu Ning (2009), Hu Zhenyu (2009)

sustainable path of development, but in attaining new competitive advantages through innovation and technology whilst mitigating its GHG emissions.

Climate change is one of the key challenges of the twenty first century. In response, a global consensus now supports structural economic changes to reduce greenhouse gas (GHG) emissions. According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007a), a common but differentiated responsibility for implementing this transformation rests largely with the wealthy governments, firms and citizens of developed nations. The IPCC has called for global action to reduce GHG emissions by 50% to 85% of 2000 levels by 2050 to cap warming by 2 degrees Celsius above pre-industrial levels. Such a rise provides the best chance of avoiding dramatic ecological, economic and social damage from occurring (European Commission, 2007; IPCC 2007b; Stern, 2007). While global action is critical for achieving success, there are growing concerns that if rapidly developing economies, such as China, are excluded from binding reductions, then there is little likelihood of achieving the 2 degree target. According to the U.S. Assistant Secretary of Energy, Sandalow (2009):

> *Even if every other country in the world cut its emissions 80% by 2050 … China's business-as-usual emissions alone would cause global average temperatures to increase by 2.7 degrees centigrade.*

Achieving the 2 degree target will mean changing the way that business is done. The Chinese government is well aware of the need to conserve resources and improve energy efficiencies, but it is similarly committed to rapid economic growth through the quadrupling of per capita GDP between 2000 and 2020 (Hu Jintao, 2007). China has already made serious commitments to improve its energy structure and energy efficiency with targeted reductions of 20% by 2010, the introduction of clean technologies in the energy sector and a reduction of the economy's carbon intensity by 40-45% between 2005 and 2020.

In spite of all the talk, current economic growth remains both energy intensive and carbon intensive (World Bank, 2008; Chatham House & E3G, 2008). Pan Jiahua (2009) warns that 'energy-saving and emissions-reduction are not the same as greenhouse-gas curbs' and that 'different methods of production and lifestyles' are needed in order to have a major impact on emissions:

> *China needs to choos[e] a low-carbon path with improved energy efficiency and a better energy infrastructure, developing clean energy and preventing greenhouse-gas emissions from becoming a barrier to China's economic growth.*

President Hu Jintao, recently echoed these ideas when he argued for the need to tackle climate change on the basis of economic development, and that China must "proactively participate in global cooperation to fight climate change" as well inculcate the whole of Chinese society with the importance of saving energy, reducing emissions and being environmentally aware (Reuters, 2010a).

In recognition of the urgent need to decouple China's growing GHG emissions from amount of resources used, waste generated and pollution produced per unit of production, the Chinese government adopted the concept of a low carbon economy. Although the Chinese government acknowledge the economic, social and environmental risks of not responding to climate change, significant implementation gaps remain in turning the rhetoric into implementable policy reality. A recent review of current government and business responses argues that real change is slow to materialize despite strong commitments to future emissions reductions (Economy, 2007b). There is now a broad consensus that without more aggressive and increased policy and market interventions by government, energy efficiencies and carbon reductions are unlikely to be implemented at a rate necessary for meeting global emission reduction targets.

Competitive Advantage

> *China will accelerate the development of a low carbon economy and green economy so as to gain an advantageous position in the international industrial competition.*

This quote from Wen Jiabao's (2009) speech at the World Economic Forum China highlights the increasing realisation of the competitive benefits of adjusting China's economic structure by investing more in higher value added manufacturing as well as reducing the country's heavy reliance upon coal as a source of energy. A LCE is seen as offering China not only the opportunity for rebalancing but for decoupling its heavy reliance upon coal and energy intensive industry as a driver for economic growth. Moreover, China is highly vulnerable to the impacts of climate change (economically, socially and environmentally) and needs to make significant investments in mitigation and adaptation strategies. China can accelerate the transition away from carbon intensive growth as well as strengthen and consolidate its competitive advantages through innovation, science and technology and research and development in new energy developments. There is a growing realisation of the asymmetry between China's current stage of development and a low carbon economy.

> *Humanity can solve the carbon and climate problem in the first half of this century simply by scaling up what we already know how to do.*

Pacala and Socolow (2004) argued that existing technologies offer the best and lowest cost options for decarbonising the economy and reducing GHG emissions. The global pressure to adopt these so-called clean technologies (cleantech) has provided a boost to nations already strong in the application and production of high technology equipment and processes, such as Germany and Japan. According to Ellen Carberry of the China Greentech Initiative (Ford, 2009), "China sees [green technology] as an enormous market that is not claimed or controlled by any one nation, and there is an opportunity for them to do it … The combination of urgency; the enormous needs; a focused, systematic planned government; an army of engineers; and access to capital may define China as the platform for the green- technology industry globally". Moreover, according to Wan Gang (2009), the Minister of Science and Information Technology, China can seize the opportunity arising from the "dual crises" of climate change and global economic recession through a new industrial revolution based upon new energy technologies and industrial structural adjustment with new energy sources and a low carbon economy (China Energy Network, 2009). Similarly, the director of the China Environmental Protection Research Institute, Zhou Guomei, argued that the global financial crisis provides China with an opportunity to consolidate measures in reducing GHG emissions, readjusting the industrial mix, changing the mode of growth and strengthening China's environmental protection measures.[72]

In recent years, China has announced a string of policy initiatives aimed at shifting towards to a low carbon economy. However, it is not guaranteed global market leadership in the manufacturing of such products or technologies. It will need to maintain strong policy support and market incentives to compete for both hard and soft technological development against a backdrop of state-led investment in so-called ‘cleantech’ investment. The motor vehicle industry is a case in point with large government assistance programs taking place in the US ($11 billion), Japan ($200 million between 2009 and 2014) and France (over €400 million between 2009 and 2013) for promoting electric vehicles and new battery technologies. As a result, in 2009 the head of China’s National Energy Administration, Zhang Guobao said, China attaches great importance to the development of the new energy industry and will closely track the new global trends in this field (Hu Shaowei, 2009). According to Zhang, “China will increase investment in the new energy industry, strengthen scientific research in this field and raise its development to a strategic position". Without such investment, Zhang argued that China would fall behind other nations in this emerging economic sector if it fails to see this issue from a strategic perspective. To increase its international competitiveness, China views the development of the new energy sector as an effective method to boost the manufacturing sector, increase employment and investment and generate higher domestic demand. This has led some to assert that China is in the early stages of a new energy revolution with plans to leap frog from the middle of a heavy industry phase of development into a new technology and low carbon phase (Friedman, 2009).

China can benefit from global technological developments over the past three decades for minimising and managing environmental problems. By gaining access to these technologies, China can skip the intermediate stages in technology and achieve greater short-term improvements than would otherwise be possible. Similarly, advances in policymaking capabilities in the environmental area in rich countries, including better data, management systems, institutional developments and the use of market instruments, can benefit China.

A key component of the development of the cleantech market is that it not only benefits China, but offers significant global benefits, beyond reducing global emissions from China, but reducing the costs and advancing technological development and expansion. China is expected to focus on maximising the competitive and growth potential of climate change more than most other nations. China is already emerging as the largest manufacturer and market for clean tech industries including renewable energy production, such as wind turbines and solar panels. According to a recent industry report (Volans, 2009), China's clean tech market may be worth as much as US$500 billion to US$1 trillion per year by 2013. The Chinese Renewable Energy Industries Association claims the renewables sector employed over one million workers in 2008 and is expanding by 100,000 a year (Bradsher, 2010). According to ERI director, Jiang Kejun, "only by using advanced low carbon technologies can China's greenhouse gas emissions peak around 2030; otherwise, the peak will be delayed and we don't want to see the latter scenario" (Fu Jing, 2009) Moreover, China’s strategic economic and developmental interests are at the heart of

[72] http://english.people.com.cn/90001/90781/90879/6727384.html

embracing a low carbon economy, according to Jiang, who believes the world should be sharing the necessary technologies to facilitate this transition.

As part of its overall development plan, China is seeking to achieve global leadership, or at least parity with the leading advanced economies, in science, technology and education. To this end, investment by the Chinese government and other Chinese parties in these areas continues to be very substantial.

Figure 44: Research and Development Spending

	2003	2004	2005	2006	2007	2008
R&D spending as % of GDP	1.13	1.23	1.34	1.42	1.44	1.54
Total R&D (billion RMB)	154	196.6	245.0	300.3	371	462

Source: China Statistical Yearbook, 2009

China's economy is both basic and sophisticated. Basic in terms of low overall income levels and consumption levels, but sophisticated in terms of human and technical capacity. In the period 1995-2006, the gross expenditure on R&D (GERD) in China grew at an annual rate of 18%. According to an OECD report (Schaaper, 2009), in the four years to 2008, China added 666,000 personnel to its skilled researcher base, an increase of 71%. China has around 17000 institutions of higher education with a student population of 25 million, which has increased from 5 million in 2000. The path of spending on R&D in China is provided in Figure 44, both in real terms and as a share of GDP. Given the rapid growth of GDP at about 10% per annum, even a stable GDP share implies that R&D spending is rising rapidly in real terms. After being relatively stable at about 0.6% of GDP between 1987 and 1998, R&D as a share of GDP more than doubled to 1.34% by 2005. The outcome of this growth in R&D is that China currently ranks third on GERD, behind the US and Japan.

Similar exponential growth outcomes have occurred in terms of research output. A decade ago, China's research output was around 20,000 articles. By 2006, it had quadrupled, exceeding publications from Japan, the UK and Germany. Then in 2009, more than 120,000 articles were published by Chinese scholars (Thomson Reuters, 2009). Questions about quantity versus quality are often raised regarding China. And yet, an increasing number of the articles are based upon international collaboration in an ever widening range of areas, especially in areas important for the development of a low carbon economy.

In its long term plan for science and technology for 2006-2020, the Chinese government has declared an intention to double the proportion of China's GDP spent on R&D from 1.23% in 2004 to 2% in 2010 and 2.5% by 2020. Using CAECER GDP forecasts above, Chinese R&D by 2020 will be about RMB4.6 billion in 2000 purchasing power parity prices if China achieves an R&D spending level of 2.5% of GDP, implying an average annual growth over 2004-2020 of 13.6%. Based upon these estimates, China will be a research superpower with R&D spending in 2020 over 45% greater than that of the USA, 60% above that of EU-15 and four times that of Japan. Perhaps more importantly, over 50% of the increase in R&D spending in these four countries/regions between 2004 and 2020 will take place in China. While, remarkable gains have been made during the past decade, it is estimated that R&D spending will reach around 1.58% of GDP in 2009, falling short of the 2010 target. But it seems beyond doubt that, if China's R&D spending continues to increase rapidly over the next decade as planned, then China will displace the historical dominance of North American and European research to play a leading role in global science and technology development.

Given the scale of the expansion of China's R&D capabilities, it is useful to note China's national science and technology research priorities, as expressed in the national plan to 2020. The top ten areas of national focus and priority are shown in Figure 45.

Figure 45: Top Ten Areas of National Focus and Priority, 2006-2020

1.	Energy
2.	Water and mineral resources
3.	Environment
4.	Agriculture
5.	Manufacturing
6.	Transportation
7.	Information technology and modern service industries
8.	Population and public health
9.	Urbanisation and municipality development
10.	Public security

Source: MOST, 2006

In 2009, the Chinese Academy of Sciences (CAS, 2009b) sponsored the development of a long-term strategy for R&D and science and technology. This strategy provides direction in eight areas of R&D with 22 key points emphasising the role of international competitiveness, sustainable development and national security. The document also highlights the development of "new energy" industries and products.[73] The notable feature of the priorities in these two plans, in the context of the present study, is their alignment with the current focus towards a low carbon economy. The question remains however, of how this move is to take place and will it be substantial enough to displace the preeminent role of coal and the energy intensive industries it fuels.

Low Carbon Cities

In 2007, Shanghai and Baoding participated in a low carbon cities program supported by the WWF aimed at reducing energy consumption and carbon emissions whilst supporting economic growth. Baoding has utilised its human and technical resources as a major power industry manufacturer for attracting renewable energy manufacturers, such as Yingli Solar and Guodian Wind Turbines. It has also opened up a so-called new energy industrial park called "Power Valley" (following the Silicon Valley model) with incentives, such as reduced taxation and access to soft loans. According to local officials, 500 MW of solar and 5.1 GW of wind power capacity were manufactured in Power Valley by 2008. By 2009, around 20% of the city's GDP was produced by the so-called "new energy sector', which also experienced a 40% growth rate. As a result, local officials declared a new industrial revolution focused on low carbon energy. Following the success of Baoding, a dozen other cities, including Shenzhen, Tianjin, Zhuhai, Nanchang and Wuxi have declared themselves as 'low carbon' to capitalise on the rapid growth in the demand for renewable energy generation components, such as wind turbines, power

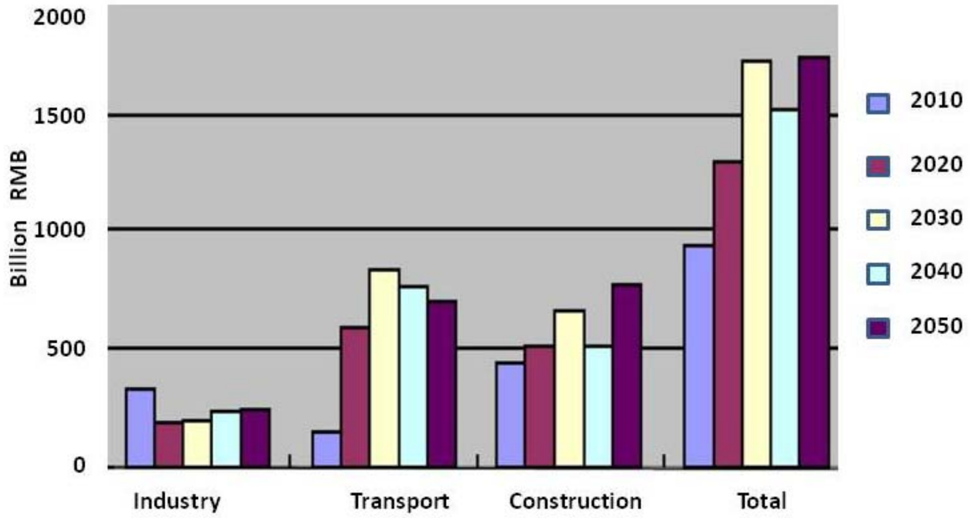
[73] The CAS (2009b) strategy is called: *Innovation 2050: Science and Technology and China's Future* or in Chinese 《创新 2050：科学技术与中国的未来》

generators and solar cells both internationally and domestically. Since the global financial crisis, concerns have been raised about over capacity arising from the rush into renewable and low carbon manufacturing (Dyer & Lau, 2009).

Financing a Low Carbon Economy

According to CEACER estimates of the necessary investment for implementing the 2050 low carbon scenario path, ERI concludes that China needs to spend RMB40 trillion from 2010 to 2050 on advanced technology and energy efficiency measures to reach the targets in the enhanced low carbon economy. This is equivalent to a figure of around RMB1 trillion annually from 2010, incrementally rising to just under RMB2 trillion by 2050 (see Figure 46). According to the modelling, the highest levels of initial investment are necessary in the construction and industry sectors, whereas transportation requires the highest levels in the period 2020 to 2050.

Figure 46: Additional Investment Required to Achieve the Low Carbon Scenario



Source: Jiang Kejun, 2009

When comparing investment levels between the CEACER low carbon and business as usual scenarios there is surprisingly very little difference. For example, investment in the energy industry is around 5-10% higher under a low carbon scenario compared with BAU.

The 2009 *IEA World Energy Outlook* conferred with the CEACER report's conclusion. The IEA estimated that the expected extra energy demands requires an estimated RMB20 trillion investment to build a further 1326 GW of power generation capacity through to 2030. Similar outcomes are reached in the analysis for national energy costs. To provide a cost comparison, McKinsey (2009) analysis estimated that to readjust the energy mix and achieve comparable reductions in CO_2 emissions with ERI's low carbon scenario by 2020, China will need to incrementally invest RMB1.5-2 billion annually over the next two decades. A Renmin University study reported the higher figure of around RMB3.2 trillion annually by 2030 if China continues along its current policy trajectory.[74] The report found that the cost of curbing

[74] China Daily 2009 China's green bill, 3 Sept, 8: Accessed 3 November 2009 online: http://www.chinadaily.com.cn/opinion/2009-09/03/content_8649589.htm

China's GHG emissions will amount to around 7.5% of the country's annual GDP. More modestly, the IEA's *World Energy Outlook* estimated the cost at around RMB280 billion annually through the period 2010-2020 (IEA 2009a). Jiang Kejun et al. (2009) found that investment levels are overall higher in the BAU scenarios than the low carbon scenarios due to the savings made in achieving energy efficiency improvements as well as in realising the lower abatement and adaptation costs. Moreover, Jiang argues that introducing new energy and clean technology industries will be cheaper than upgrading old, inefficient ones, as well as provide greater social and environmental benefits.

The Role of the Global Financial Crisis

> *The unprecedented global financial crisis has taken a heavy toll on the Chinese economy. Yet we have risen up to challenges and dealt with the difficulties with full confidence... However, the stabilization and recovery of the Chinese economy is not yet steady, solid and balanced* .
>
> Wen Jiabao, 2009

In response to the economic turmoil created by the Global Financial crisis, China launched what is widely acknowledged as a 'timely', 'substantial' and 'effective' fiscal stimulus package in November 2009 (Naughton, 2009b; World Bank, 2009; ADB, 2010). The government's RMB4 trillion stimulus package is equivalent to approximately 15% of China's GDP.[75] The stimulus plan contains four strategic goals, which generally reinforce the goals of the 11th FYP:

1. Rebalancing the economy: develop a long-term growth strategy increasingly led by domestic consumption rather than exports.
2. Efficiency: modernise and restructure industry to achieve higher productivity and efficiency.
3. Social balancing: strengthen and expand social welfare and employment.
4. Stability: maintain the broad goals of the economic reforms.

Spending was to be spread over two years, but has been frontloaded with RMB120 billion in spending during the fourth quarter of 2008, a further RMB110 billion in the first quarter of 2009 followed by RMB908 billion in mid-2009. The World Bank (2009c) estimated that government-directed spending lifted GDP growth by over 4% points or more than half of GDP growth in 2009. In contrast, the State Council estimated that the stimulus contributed to between 1.5% and 1.9% to national economic growth. The cost of the plan is expected to produce a record budget deficit of nearly RMB1 trillion in 2009 (less than 3% of GDP) compared with Y180 billion in 2008.

Key aspects of the stimulus could be summarised in three points.

- Firstly, undertake aggressive fiscal stimulus, especially in rural areas, with lower taxes on motor vehicles, property sales and household appliances.
- Secondly, loosen monetary policy to increase access to credit, especially for small and medium companies (SMEs) and individuals. For example, in the property sector, banks have been instructed to accept smaller deposit requirements and lower loan rates for first-time buyers. The

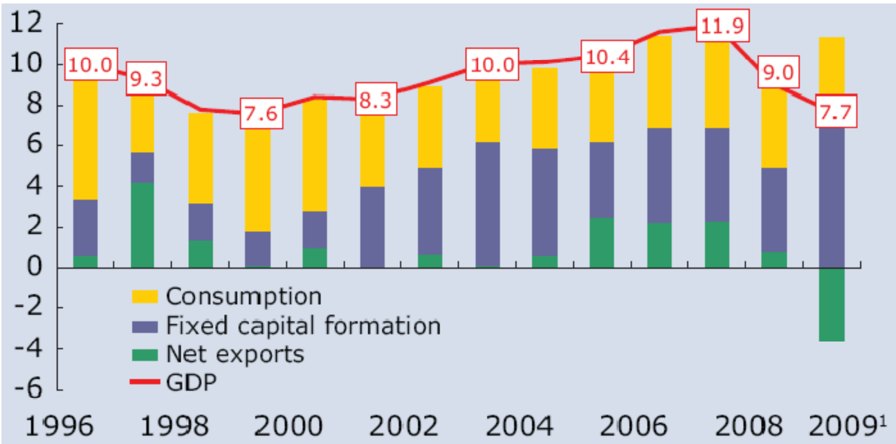
[75] According to Naughton (2009a), direct central government allocations are projected to be equal to around RMB1.18 trillion allocated over 2009-2010, which is equivalent to around 2% of additional fiscal allocations. The remainder of the RMB2.82 billion is expected to come from local governments and banks.

monetary policy resulted in a dramatic expansion of credit. In the first quarter of 2009 bank lending increased to about RMB5 trillion (US$732 billion), almost three times the levels reported during the same period of 2008. By the end of 2009 new bank loans reached nearly RMB10 trillion or more than doubling the RMB4 trillion in 2008. The World Bank (ibid) expects overall loan growth for 2009 of around RMB10 trillion or 40% of GDP. It was reported that in the first week of January, bank lending totalled RMB600 billion due to concerns that the government was planning to reverse the loose monetary policy to avoid a lending bubble.[76]

- Finally, instruct state-owned enterprises to boost production. The package has so far resulted in China avoiding a serious economic downturn with its economy rebounding faster than any other large economy. In November 2009, the World Bank (ibid) raised its forecast for China's GDP growth in 2009 to 8.4%, which is up from its earlier prediction of 6.5%. The main driver for the rebound, as illustrated in Figure 47, has been a "surge in bank lending and vigorous fixed-assets investment" (ADB, 2009).[77]

In early 2010, China's deputy Prime Minister Li Keqiang argued that during the financial crisis China 'spared no effort in rebalancing the structure of the economy' (Pilling, 2010). If we accept this argument, then the Chinese government will need to review its current suite of policy measures, because the economic stimulus program appears to have reversed early gains in structural economic rebalancing. This is particularly obvious in terms of investment levels in energy intensive industries, such as steel, cement, chemicals and manufacturing, which have locked the economy into a cycle of ongoing investment commitments so as to avoid the emergence of crisis levels of bad debt and overcapacity (Yu Yongding, 2009).

Figure 47: Contributions to GDP Growth, y-o-y, %



Note: 1. 2009 figures are for first to third quarter results only.
Source: Cited in ADB (2009) from NBSC

[76] In fact in mid January 2010, the Chinese central bank raised the reserve requirement half a percentage point to 16% for large banks and 14% for smaller banks. The decision to require banks to hold more internal assets was apparently in response to concerns of a stock and housing bubble (Wines, 2010).

[77] According to the National Bureau of Statistics (http://www.stats.gov.cn), between January and November 2009, China's industrial production increased 10.3% year-on-year. This suggests that domestic demand remains robust.

Accompanying every financial crisis is a revolution in technology that serves as an engine for economic development. This time, new energy technology will probably be the new driving force.

China's Science and Technology Minister, Wan Gang April 2009[78]

According to the Science and Technology Minister, China should emerge from the global economic crisis greener and more advanced than it went in. Despite powerful statements about the "greenness" of China's stimulus with the government's initial allocation of RMB350 billion or 9% of the stimulus for the environment, it seems that around RMB21 billion had been disbursed by June 2009 or just 0.5% (Horn-Phathanothai, 2009). The key issue in the stimulus is not in fact the environmental component, but the potential opportunities of "greening" the broader stimulus, in particular the infrastructure programs including the Sichuan reconstruction, housing scheme, railways and power grid spending components. Utilising the stimulus package to foster innovation, research and development as well as science and technology for strengthening the new energy economy would have not only strengthened the momentum for rebalancing development but provided the economy with a competitive advantage. If, for example, the new buildings and homes being built incorporated energy and water efficiency benefits, or the power grid linked up renewables into the electricity network and the railways funding boosted public transportation systems, then HSBC estimates the stimulus could be 37% green (HSBC, 2009).

It appears that the stimulus package has been fundamentally utilised for boosting economic growth rather than as a catalyst for redirecting the economic structure away from high-levels of investment in export-orientated manufacturing and heavy industry. Despite the apparent lessons arising from the last major economic stimulus program following the Asian Financial Crisis, local governments and bankers have returned to what they understand best - maintaining rapid economic growth.

Disappointingly, a large portion of the stimulus funding seems to be cyclically rather than structurally focused. As a result, much of the stimulus package is being funnelled into the "old economy" with infrastructure and project funding supporting projects initially rejected due to their negative environmental and resource implications.[79] For instance, NEA head, Zhang Guobao (People's Daily, 2010), noted that "some local governments approved energy-guzzling projects during economic crisis". Moreover, due to the 'hard wiring' of the financial system, much of the new lending has gone into supporting energy-intensive SOE construction, manufacturing and infrastructure industries (Horn-Phathanothai, 2009). This is obvious in the recent production data for steel, iron and cement which have expressed strong growth throughout 2009 despite the global economic downturn.[80] All three products have been boosted by the rebound in the property market, the strong infrastructure component of the

[78] Cited in http://www.guardian.co.uk/environment/2009/apr/02/china-e6-electric-car

[79] This is epitomised by the scaling back of the EIA process through a fast-tracking system, ironically described as the "green passage" 绿色通道 (Wang Xiaojun, 2009). This was a major set-back for the newly promoted Ministry of Environmental Protection which was only just granted vetting powers over major investment projects as part of the 2008 administrative reforms. This was a strategic shift away from the local-level environmental protection bureaus which were heavily influenced by local government priorities.

[80] According to Horn-Phathanothai (2009) "crude steel output in China rose to a record 266.6 million tonnes in the first half of 2009, as the stimulus spurred demand from the construction and automobile sectors".

stimulus and the rapid growth in automobile sales. For example, new lending investment to the property sector in 2009 increased by 40% over 2008 figures. Ironically, in response to concerns about investment resulting in asset bubbles and non-performing loans, in late 2009 China's Banking Regulatory Commission adjusted lending rules to discourage speculative lending and stabilise bank risks. Concerns about over capacity in the industrial sectors affecting energy efficiency targets, emission forecasts, stable economic growth projections and falling prices have been raised by the State Council which issued a new plan to reduce overcapacity in seven key industries (Dyer & Lau, 2009). However, it is still too early to see if the adjustments to monetary lending will curtail the speculation or effective curtail lending to and investment in "sectors with overcapacity and high-energy-consuming and high-emission industries".[81] According to Huang Yiping (2010), China's monetary policy remains constrained in several ways, including: the absence of a special policy-formation mechanism with clearly defined responsibilities; a lack of consistent targets; an over-utilisation of 'irregular' policy tools and measures, such as 'moral persuasion' and credit controls; and a reluctance to utilise conventional tools such as exchange rates and interest rates. What is clear however, is that the ongoing tweaking of the economy is primarily targeted at providing "a stable and relatively fast" economic growth[82] through the "continuity and stability" of macroeconomic policies, including loose monetary policy. The implication for economic structure and the rebalancing program is, on the one hand, offering reassurance that national policy priorities will remain focussed on achieving rapid economic growth, whilst gradually adjusting the economic structure to shift the key driver of the economy towards the service sector. Due to inherent and ongoing weaknesses in the global economy, it is most likely that earlier calls for more ambitious rebalancing policies during the 12th FYP will be restrained. At the same time, there is a growing acknowledgement within China that policies promoting domestic consumption are concomitant to strengthening growth and rebalancing the economy. The question remains, however, whether such adjustments are sustainable from a resource and environmental perspective.

[81] Statements made in late 2009 by the NDRC revealed a growing transparency and level of detail in industrial policy, especially in making clear statements about closing down new investments in areas experiencing over capacity and the promotion of other industrial sectors such as nuclear, bio-technology, IT and bio-pharmaceutical (People's Daily, 2009; BoA & Merrill Lynch, 2009)

[82] This was the message emerging from the Central Economic Work Conference (CEWC) in Beijing in late 2009 and echoes the same message in 2008. The CEWC is an annual gathering of the nation's top leaders to map out economic policy measures for the following year.

Implementing a Low Carbon Economy: From Inertia to Realising Opportunities

The domestic and international significance of China making the transition to a low carbon economy is considerable. However, the task in shifting the economy is enormous and therefore for it to be successful there is a need for both aggressive policy action combined with international assistance, particularly in the area of sharing best practice policies and energy efficiency and affordable low carbon technologies. The preceding sections of this report have explored the reasons for rebalancing China's economic structure including the remaining challenges; the relationship between China's energy use and current and future emissions; and, the role of low carbon economy in decoupling economic growth from increasing carbon emissions, whilst providing China with a new opportunity for sustainable economic development.

> *We should make carbon reduction a new source of economic growth, and change the economic development model to maximize efficiency, lower energy consumption and minimize carbon discharges.* (NPC, 2009)

As articulated in this NPC (2009) resolution, the key is realising the benefits and opportunities arising from a low carbon economy, especially through implementation at the local level. However, before this is possible, China needs to adjust the current pattern of economic development, including the key drivers and incentives for the ongoing unsustainable mode of emphasising quantitative growth over quality development. It is increasingly apparent that the rebalancing of China's development requires deeper reforms beyond structural economic adjustments and new technology. Instead, it should extend to reviewing the concept of development itself.

China needs to redefine development beyond existing simple measure of economic expansion, which externalises many economic, social and environmental costs. The current attachment to GDP is not a problem in itself, however the political imperative of this indicator in prioritising government decision-making is inappropriate, especially considering its weakness in measuring overall social development and economic health. GDP is further limited in its ability to incorporate medium to long-term economic considerations, such as the value of pulped timber versus forests for water protection, biodiversity and as a carbon sink. Moreover, GDP fails to clearly distinguish between productive investment and extravagant squandering, nor account for over-valued property and fuzzy derivative values. Previous attempts at adopting alternative measures, such as a Green GDP were too confronting for a regime that prefers no news, to bad news. The Green GDP figure revealed negative development in some areas due to the high costs of the previously hidden pollution and health (Bjureby, et al., 2008; Economist, 2008c). The recent global financial crisis has reinvigorated the debate about the limitations of GDP as a measure of development. Recent international-level work on reviewing developmental indicators and statistics to try and formulate a better measure of progress has been undertaken by French Government,[83] the European Commission[84] and the OECD.[85] However, moving away from GDP's paramount role will remain

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[83] The 'Commission on the Measurement of Economic Performance and Social Progress' report is available at: http://www.policyinnovations.org/ideas/innovations/data/000144/_res/id=sa_File1/economicperformancecommissionreport.pdf

[84] In 2009, the European Commission set up the 'Beyond GDP' initiative (http://www.beyond-gdp.eu).

difficult especially in China where most local governments and industries prefer the illusion of economic growth, because a clearer indication of social, environmental and economic progress may not be in their interest. Naughton (2009a, 7) provides a sobering warning about the challenge of departing from existing mode of development and more specifically the role of local governments in particular in not just slowing down the rebalancing program through the stimulus program, but in fact bringing it to a halt:

> *The problem is that so far there is little evidence of any significant political will to really change the patterns embodied in last year's growth. On the contrary, there are strong political forces that benefit from government patronage and extension of government power, and those interest groups do not show the slightest sign of being in retreat. The Chinese government, headed by Premier Wen Jiabao, has made many statements about their intention to move toward more balanced growth, since at least 2004. But it hasn't happened.*

This report has introduced a wide range of comprehensive and significant steps China is making towards adjusting its economic structure, especially in regard to energy generation, use and conservation. Shifting away from a coal-based energy and resource intensive pattern of development will require time and significant structural adjustments for alternative pathways to be realised. These efforts have been globally recognised as the most ambitious in the world and for transforming China into a green economic giant and global leader in alternative energy investment (The Climate Group, 2009; UNEP, 2009; Ford, 2009). What is evident is that the Chinese government has been seeking a cleaner less-polluting and less intensive pattern of development for the past thirty years. In general, it has successfully reduced pollution, waste and energy as a unit of GDP. While the post-WTO entry period witnessed a reversal of the steady improvements in reducing the energy intensity of the country's economy, what is increasingly apparent is that China has commenced the transition towards a low carbon economy. In summary, this section firstly introduces several of the key policy measures that stand out in this regard prior to highlighting ongoing structural and implementation challenges and finally offering some suggestions for strengthening existing measures.

China has initiated a comprehensive process of substantial and comprehensive policy support for a low carbon economy. This is probably most apparent in the renewable energy sector. The rapid growth in the manufacture and installation of renewable and low carbon energy production, especially wind, hydro, biomass, solar, nuclear and natural gas, reveals the momentum behind China's transition to a low carbon economy. Initially ambitious targets for low carbon energy generation, such as wind, solar, hydro, biomass and nuclear, have all been met and then raised even higher. At current growth rates, low carbon energy sources are expected to represent over 15% by 2020 and around 30-40% of the energy supply by 2050.[86] In addition, the target of installing solar hot water systems on one third of houses by 2020 is likely to be met early. The growth in the renewable sector has taken place following targeted government investment as well as supportive policy measures, such as feed-in tariffs and the direct payments covering grid connectivity for setting up wind, solar and biomass power plants. As a result of

[85] Since 2007, the OECD has hosted the Global Project on 'Measuring the Progress of Societies' (www.oecd.org/progress).
[86] http://english.peopledaily.com.cn/90001/90778/90857/90860/6650353.html

these policies, China is now the leading manufacturer of solar cells and wind turbines (Bradsher, 2010) and by 2009 was the global leader in terms of spending in the cleantech sector, including renewable generation capacity and manufacturing.

The expansion of the renewables sector has not just focussed on manufacturing and expanding markets, but has involved the investment of resources in expanding the skills base and environment for innovation. Premier Wen Jiabao (2009) recently promised to “make China a country of innovation” with science and technology leading development. Today, China is once again a global research and scientific leader. The past decade has witnessed, exponential growth in research and development spending from both the public and private sectors based upon domestic and international collaboration. This has resulted in China utilising and developing world’s best practices and state of the art technology in energy production, generation and use. Highlights include the manufacture of highly efficient solar cells, the building of third generation nuclear power plants, the operation of super-ultracritical coal fired power plants, trialling of commercial carbon capture and storage, construction of ultra-high voltage transmission lines for the national grid, the widespread use of cogeneration heat and energy systems in industry and the power sector, and the development of new energy storage devices. The commercialisation of new energy sector innovation continues to be a key focus of government policy and an attractive incentive for the private sector. For example, the sale of over 100 million electric bikes in China during the past five years has provided essential support and commercial opportunities for expanding the battery and electric vehicle sector.

The failure to price the economic, social and environmental externalities of resources and their use is considered as one of the main drivers of energy intensive industrial expansion. However, during the past five years price adjustments to energy and key natural resources have gradually commenced promoting energy conservation and waste reduction. For example, the perverse subsidies and soft pricing of goods produced in resource intensive industries is being phased out. The electricity scheduling reforms for electricity grid companies also prioritise sources of low carbon energy generation. Further reforms to price controls on resources and energy are gradually occurring, including a greater role for the market in determining prices. Raising electricity prices to industrial users and reducing natural gas price subsidies for fertiliser production are two recent initiatives. Such price adjustments need to be gradual due to the risks of inflation affecting social stability. On the demand side, lower taxes for smaller more efficient vehicles has shifted the sales and production of vehicles away from large to small vehicles. Furthermore, the recent introduction of a fuel tax and trialling of an environmental tax offer the opportunity for consideration of a carbon tax in the next few years.

The inclusion of energy efficiency targets in the 11th FYP and local government performance evaluations have been a key focus of government efforts. The arrangements for incorporating energy conservation programs and targets within the performance evaluation of government officials will ensure a higher level of policy implementation. In contrast to most developed economies, China is targeting the major energy-intensive sectors and individual energy users for significant reductions in energy use, energy intensity and carbon emissions. Policy measures include a broad range of incentives and penalties to increase implementation and compliance. The successful and early implementation of two key industry policies, the Top 1000 Program and the Top Ten Energy Conservation Projects are good examples of such an approach and highlights the government's focus on maintaining the economy's global competitiveness whilst achieving energy efficiency. However, ensuring the reliability of statements of compliance with industrial energy efficiency programs has been an ongoing challenge in China. However, more regular and tighter monitoring and auditing of energy use and waste levels including the use of online publication of results as well as increased penalties for the failure to comply or supply of inaccurate data have had a noticeable impact upon higher compliance and implementation rates. Additional improvements in the collection, processing and reporting of energy data though would be beneficial for strengthening compliance.

The government has also revealed a high-level of flexibility and adaptation to policy weaknesses, especially in light of fluctuating domestic and global conditions. The post-2007 strengthening of the programs for meeting the 20% reduction in energy intensity during the 11th FYP epitomizes this approach. Far from being a 'business as usual' policy measure (as argued by some), the success of the energy efficiency targets have compensated for failures in readjusting the economic structure away from energy-intensive industry and high levels of investment in fixed capital. From 2010, China's energy efficiency policy translates into reducing China's annual CO_2 emissions by 1 billion tons from BAU. In contrast, the EU will only reduce its carbon emissions by 300 million tons under the whole period of the Kyoto Protocol. Moreover, the 2009 announcement of extending this program into achieving a 40-45% reduction in carbon intensity by 2020 should also be seen as a significant policy move given the failure to achieve global consensus beyond the Kyoto Protocol. Based upon current policies it appears likely that China will be able to strengthen this target and may even be able to meet a GHG emissions peak and decline scenario from 2030.

A key prerequisite of reaching an early peak and decline scenario is tackling structural change and energy use in the industrial sector. Therefore, continued sectoral programs to meet sector and product targets for energy efficiency as well as the closure of smaller, inefficient modes of industrial production are of critical importance. Ongoing government and banking sector financial support in offering soft loans and other incentives for the upgrading of equipment and retrofitting to achieve energy conservation and waste reduction are important. As are social considerations, especially improvements in the occupational health and safety in manufacturing and mining sectors, with a focus on coal. But critically, central government measures to reduce the growing levels of investment in expanding industrial capacity in energy-intensive sectors needs to be tightened.

China still has some work to go before meeting world's best practices in energy use, but significant steps have been made towards alignment with world leading (EU and Japanese) energy efficiency and pollution standards for industrial production, energy generation, buildings, household appliances and fuel emission standards. Since 2007, industrial programs have improved the energy efficiency of China's coal power generation fleet beyond the equivalent efficiency of US plants. In addition, building energy efficiency codes have resulted in almost 100% of new city-based buildings complying in the design stage and around 80% of newly built buildings meeting the codes. The 150 million compact fluorescent light bulb program is another successful example that has met its targeted goals early. Combined with the enforcement of the indoor heating and cooling program to keep winter heating to 20 degrees and summer cooling at 26 degrees, China has significantly reduced the energy demands and waste in the buildings sector. These programs have been especially successful in the government sector.

Ongoing state-led interventionist programs combined with mandatory targeted reductions in energy intensity and energy efficiency seem to be more successful since 2007. Ongoing strong national monitoring and auditing of local government progress is necessary though to convince China's current and emerging leadership of the importance of the low carbon economy. Local governments and the SOE industrial sector have noticeably shifted the priority of decision making towards energy conservation following the inclusion of energy intensity targets in their annual performance reviews. A key driver behind this shift is a realisation that failure to meet energy goals will now affect their career opportunities (Xinhua, 2010).

Local governments have also been proactive in signing up to the eco-city concept to improve land use and planning so as to reduce energy consumption and strengthen environmental protection. One aspect of this program has been the establishment of low carbon zones across the country to attract investment in the rapidly growing 'cleantech' sector, such as the manufacture of renewable energy generating equipment and R&D in new energy industries. To date, over 40 Chinese cities have announced eco-city or low carbon development zones. These cities have committed high-levels of investment in, and the prioritisation of, rapid mass transit as well as inter-city express rail for passengers and freight. Another important aspect of transport policy has been the new energy motor vehicle program, which offers clear industrial policy priorities with plans for the production of half a million hybrid and electric vehicles by the end of 2011. The roll-out of new energy vehicles is supported by 20 major cities, which are committed to the initial piloting of the program by rolling out the necessary infrastructure, such as new bus, government and taxi fleets or battery charging stations for private vehicles.

Despite these significant steps towards improving energy efficiency and embracing a low carbon economy, China remains at the early stages of the transition. The pattern of development continues to be driven by rapid growth, especially in the heavy industry sector of the economy, which is energy and resource intensive. As this report argues, significant limitations and impediments remain pertaining to changing the fundamental economic structure of growth as well as the institutional system that supports the pattern of growth. Such changes will only be forthcoming if they are in line with the Chinese social, economic and political reality; a reality that is primarily concerned with maintaining stability and the ongoing rule of the Chinese Communist Party. In the short-term context, global commitments to reducing GHGs are secondary considerations and will only occur if they complement the nature of domestic priorities for economic growth. In fact, it is increasingly apparent that such a rebalancing is unlikely to occur until 2020 due to the ongoing gap between the rhetoric of central leaders and their national policy on the one hand, and local implementation and existing lock-in effects of current economic, social and political commitments.

Current economic policies commit China to another decade of rapid construction of new highways, railways, electricity generation capacity, distribution and grid systems, and commercial and residential buildings. Much of the required steel, cement, chemicals and glass will continue to be sourced from an ever expanding energy and resource intensive domestic industrial production base. The industrial expansion in the coming decade will occur side-by-side manufacturing growth for new and existing export markets as well as rapidly growing domestic demand for household items and motor vehicles purchased by the growing incomes and lifestyle expectations of predominantly urban consumers. Combined with a strong reliance and commitment on a carbon-based economy, energy efficiency gains will reduce intensities, but not curtail the rapidly increasing GHG emissions. One of the most significant constraints for adjusting China's energy policy remains the dominant presence of coal in China's energy mix. For instance, China consistently states that its dependence on energy derived from coal will not alter in the near future and that reductions in GHGs will be "rather difficult" to achieve (State Council, 2008). In line with estimates for a tripling of GDP, China expects to double its energy demand to reach around 5.5 to 6 billion tce by 2030. It is expected that coal will remain the key ingredient in China's energy mix. Due to the prevalence of coal in China's energy mix, the nation's carbon dioxide (CO_2) emissions per unit of energy are much higher than the world average level. However, the gradually increasing presence of non-carbon and low carbon energy sources is noteworthy. In addition, the low carbon energy sector has received a significant boost in recent years from supportive domestic policies and rapidly growing domestic and international markets.

As always, the real challenge for China remains delivering actual results through effective policy and program implementation. This is clearly illustrated by the poor progress in achieving energy efficiency improvements during the past four years. Therefore, the implementation of energy efficiency policies must be accompanied by credible systems of monitoring and review, which are based on standard definitions, data classifications and reporting procedures. Unless the output generated by these systems is utilised in designing reform proposals, the participants would soon lose interest in maintaining such systems and the commitment of government leaders would diminish. It is important, therefore to keep the policy cycle (for instance, formulation, implementation, monitoring, review and reform) fully operational in all dimensions.

While China has made increasingly strong political commitments to changing the economic structure and rebalancing the economy, the challenge of implementation remains dependent upon local circumstances as well as the unforeseen changing social, political and economic context at a domestic and global level. The commencement of this project coincided with one of the most disruptive and unanticipated financial dislocations of the past sixty years. If anything has been learnt from this so-called 'global financial crisis', it is the need for a more humble approach to modelling, scenario building and predicting change. Moreover, many of the energy and economic forecasts produced over the past decade pertaining to China have been consistently inaccurate in underreporting future economic growth and emissions.[87] While one positive feature of the GFC has been a slow-down in global carbon emissions, the same cannot be said for China. Beijing's economic response to the GFC has been both swift and comprehensive in form and content. The outcome it appears has been an intensification of China's 'old'

[87] Economic, energy and emission forecasts for China since 2001 from the World Bank, International Energy Agency, United States Energy Information Administration, OECD and Asian Development Bank have largely under estimated the resilience and strong growth of China's economy. As a result, many of the models and scenarios have needed regular updating, but also remind China watchers of the need for caution when accepting predictions for the direction of China's economy.

economic paradigm: high levels of investment in energy intensive heavy industry and infrastructure. Therefore, further, and more aggressive, structural economic change is necessary.

In order for China to realise the low carbon economy, it needs to continue to strengthen measures in five key areas, namely: optimise the economic structure in line with concepts such as clean production and circular economy; embrace low carbon technologies; improving governance and decision-making processes; adjusting social expectations for low carbon living standards; and, strengthening international agreement and cooperation.

1. *Optimising the economic structure to support sustainable energy use and transition to a low carbon economy.*

This involves several considerations:

a. Continuing energy efficiency gains across all sectors through tightened energy and emission standards, targets and intensities, as well as the expansion of cogeneration, waste recovery and recycling requirements and processes.
b. Balanced investment in hard and soft infrastructure. Hard refers to the transport system, water provision and treatment, energy grid and housing. Soft infrastructure is the human resources, such as the education, research and development, health, employment conditions and social welfare.
c. Continue to increase investment levels in research and development spending as well as focus on assisting the commercialisation of new technologies and innovation.
d. Advance the concept of circular economy for products and modes of production by reducing waste and measuring the full life cycle costs and benefits.

2. *Embracing low carbon technologies*

Policy and technological measures, both in the short and the medium term, need to be better linked. Low carbon technologies should be embraced through industrial innovation, research and maintaining global competitiveness and global market integration. In addition, the utilisation of existing low carbon technologies in industry, buildings and transportation sectors as well as the development of new technologies needs to be further promoted. Rhetoric is strong in this area, but practice on the ground continues to lag with increasing risks of the 'lock-in effect' of buildings and transport systems requiring increasing levels of imbedded energy and for utilisation. The shift towards renewables and low carbon energy generation, including wind, hydro, biomass, nuclear, natural gas and ultracritical and super ultracritical coal fired power plants requires further strengthening at the local level, including support for the export of these technologies to other developing economies.

3. *Improving governance and decision making*

This report has highlighted the gap between central and local governments as one of the most persistent challenges for achieving the rebalancing of development and structural economic adjustment. Moreover, it is expected that the greatest resistance to changing the status quo will continue to come from local governments, which for the most part operate on a simple strategy of seeking rapid levels of GDP growth as a driver of development. Therefore, strengthening local and regional institutional capacity is an important aspect of achieving structural adjustment and facilitating the transition towards a low carbon economy. Under the current political system, the role of leadership is central, especially the system of performance evaluation of local governments, state firms and their individual leaders. Better informed and skilled leaders are therefore needed to be involved in higher levels of integrated decision making and policy development as well as ensuring compliance. Further gradual reforms to the administration of the policy and regulatory system would be beneficial, as well as greater scope for the use of market-based mechanisms in achieving a low carbon economy and removing existing impediments, such as perverse subsidies.

4. *Adjusting expectations for* low carbo*n living standards*

Improving the application of energy efficient technologies and setting up supportive policies for the sustainable use of energy are critical ingredients in shifting to a low carbon development pathway, but due to the size of China's population and the growth of its economy more fundamental changes will be necessary. For example, China may have the largest electric car fleet on the planet by 2030, but can its cities transport system, air quality and energy systems cope with 400 million vehicles. The average quality of life of most households is set to double in the next decade. Therefore, there is an urgent need to emphasise the importance of behavioural change by adjusting lifestyle expectations and raising the level of awareness of energy efficiency and the benefits of low carbon development. Such behavioural change will require an increasing willingness to involve the general public in urban planning, awareness campaigns and behavioural changes through consultation, engagement, monitoring and the media. But critically, effectiveness in shifting expectations requires strong behavioural signals reinforced through pricing systems to promote energy conservation and the responsible purchase and use of energy efficient appliances and products, such as motor vehicles and air conditioners.

5. *International agreement and cooperation*

China's strong actions on adopting a comprehensive range of measures for achieving sustainable energy use provide a clear indicator of the country's priorities. While rapid economic growth will remain the number one goal of government, what has changed is the development pathway. No longer are environmental degradation, energy wastage, air pollution and carbon emissions acceptable corollaries of economic growth. The key driver for change is the acknowledgement that achieving energy security and competitive economic advantage are two sides of the one coin. The bonus is that the low carbon pathway will provide both of these goals together with improved environmental protection and reduced carbon emissions. No doubt, many challenges remain in shifting China's massive economy away from the current energy intensive, industry and investment led growth pattern and onto a low carbon pathway. Much of this will depend upon the successful implementation of broader, integrated and more aggressive social, economic and political reforms than are currently underway to ensure that future growth is more equitable, balanced and sustainable. It is important to recognise the importance of the current shift in China's pattern of development. The nation is at a critical turning point with critical domestic and international implications. The reforms being carried out in China today not only provide guidance for the rest of the world, but they offer greater confidence that development and growth can be achieved progressively, whilst reducing the footprint on the planet.

Further Research

- Develop detailed industry sector roadmaps that include the broad economic impacts of government intervention and technological developments relating to energy intensity, production, employment, productivity and levels of competitiveness.
- Generate energy use matrices for different sectors and products to assess the costs and benefits of different policy measures, such as the impact of tightening standards, introducing rebate programs and price adjustments as well as technological and behavioural changes on cost, energy use and carbon emissions.
- There needs to be more detailed localised assessments of the effectiveness and level of implementation of the structural rebalancing, especially the current energy policies, in particular the role of local support and resistance for the concept of the low carbon economy. Undertaking a regional or city-based analysis of the implementation of a low carbon economy would provide important insights into this policy's social and economic impacts and relationship to the rebalancing program. The shape and form of current aggregated data on energy consumption at a sectoral level makes detailed analysis difficult to undertake at the national level. Moreover, very few studies to date have examined the social and economic role of labor, firm, finance and employment relations following climate-policy related structural adjustment. It is envisaged that such a study could be undertaken on a comparative basis to examine a range of geographically distinct locations.
- Examine the economic structural issues relating to trade and investment flows, especially in energy intensive industries. For instance, understanding the implications and practices of Chinese manufacturers either exporting products or shifting production to the developed world to determine energy and environmental practices would be beneficial. As such, a study determining the reach of China's low carbon economic policy, for example, are they spreading energy efficient and leading edge technologies, exports and investments to other developing economies? An extension of the existing project focus on motor vehicles and air conditioners could be undertaken.
- Improved understanding of the relationship between innovation and R&D and new product commercialisation is developing rapidly in China. Recent government funding programs, greater international collaboration and stronger private sector interest may be shifting the balance towards China's role as the leading generator of new innovation and intellectual property. The role of universities, private companies and venture capital continues to play a key role in the US in developing and commercialising leading edge technologies, but it would be useful to better understand how such investments and decisions are developing in China. China has embarked on a low carbon research and development funding program to support private and commercial spin-offs from its leading research centres, but it will still take some years before the innovative and entrepreneurial environment of the US can be matched in China. However, there is a need to better understand this process and assess its potential.
- Assess the resource risks for the development of new energy technologies, for instance the relationship between competing uses of resources and policies. The role of rare earth elements and the development of battery technologies, such as lithium ion cathodes or the relationship between natural gas and renewables under a carbon tax system could be examined for example.

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Appendix: Methods and Data

Methods for measuring structure and intensity

The measures used for the structure and intensity effects are derived as follows. Total energy use in period *t* is given by:

$$E_t = \sum_i y_{ti} \, . \, \varepsilon_{ti} = \sum_i (y_{0i} + \Delta y_{ti}) \, . \, (\varepsilon_{0i} + \Delta\varepsilon_{ti}), \qquad (1)$$

where Δy_{ti} and $\Delta\varepsilon_{ti}$ are the change in value-added in sector *i* (y_i) and in the energy intensity of sector *i* (ε_i) in period *t* relative to the base period (t_0).respectively. This implies:

$$\Delta E_t = \sum_i (y_{0i} \, . \, \varepsilon_{0i} + \Delta\varepsilon_{ti} \, . \, y_{0i} + \Delta y_{ti} \, . \, (\varepsilon_{0i} + \Delta\varepsilon_{ti}) - \sum_i y_{0i} \, . \, \varepsilon_{0i}$$

$$= \sum_i (\Delta\varepsilon_{ti} \, . \, y_{0i} + \Delta y_{ti} \, . \, \varepsilon_{0i} + \Delta y_{ti} \, . \Delta\varepsilon_{ti}) \qquad (2)$$

The first term in the summation represents the change in total energy use due to changes in energy intensity in the industry sectors, for opening levels of GDP in the sectors. The second term represents the change in energy use due to changes in GDP in individual sectors, for opening energy intensity levels within the sectors, and the third is that due to interaction effects between changes in GDP and in energy intensity at the industry level.

Let s_{ti} be the share of sector *i* in total GDP at time *t*, and Y_t be total GDP at *t*, so that:

$$\Delta y_{ti} = s_{ti} \, . \, Y_t - s_{0i} \, . \, Y_0 = (s_{0i} + \Delta s_{ti}) \, . \, (Y_0 + \Delta Y_t) - s_{0i} \, . \, Y_0 = s_{0i} \, . \, \Delta Y_t + \Delta s_{ti} \, . \, Y_t \, . \qquad (3)$$

Thus, substituting (3) into (2),

$$\Delta E = \sum_i \Delta\varepsilon_{ti} \, . \, y_{0i} + (s_{0i} \, . \, \Delta Y_t + \Delta s_{ti} \, . \, Y_t) \, . \, (\varepsilon_{0i} + \Delta\varepsilon_{ti})$$

$$= \sum_i \Delta\varepsilon_{ti} \, . \, y_{0i} + s_{0i} \, . \, \varepsilon_{0i} \, . \, \Delta Y_t + \Delta s_{ti} \, . \, \varepsilon_{0i} \, . \, Y_t + s_{0i} \, . \, \Delta Y_t \, . \, \Delta\varepsilon_{ti} + \Delta s_{ti} \, . \, \Delta\varepsilon_{ti} \, . \, Y_t$$

$$= \sum_i s_{0i} \, . \, \varepsilon_{0i} \, . \, \Delta Y_t + \Delta\varepsilon_{ti} \, .(y_{0i} + s_{0i} \, . \, \Delta Y_t) + \Delta s_{ti} \, .\varepsilon_{0i} \, . \, Y_t + \Delta s_{ti} \, . \, \Delta\varepsilon_{ti} \, .Y_t \qquad (4)$$

Given that $E_t = E_0 + \Delta E_t = \sum_i s_{0i} \, . \, \varepsilon_{0i} \, .Y_0 + \Delta E_t$

$$E_t = \sum_i s_{0i} \, . \, \varepsilon_{0i} \, . \, Y_t + \Delta\varepsilon_{ti} \, .(y_{0i} + s_{0i} \, . \, \Delta Y_t) + \Delta s_{ti} \, .\varepsilon_{0i} \, . \, Y_t + \Delta s_{ti} \, . \, \Delta\varepsilon_{ti} \, . \, Y_t \text{, and}$$

$$E_t/Y_t = 1/Y_t \, . \sum_i s_{0i} \, . \, \varepsilon_{0i} \, . \, Y_t + 1/Y_t \, . \sum_i \Delta\varepsilon_{ti} \, .(y_{0i} + s_{0i} \, . \, \Delta Y_t) + 1/Y_t \, . \sum_i \Delta s_{ti} \, .\varepsilon_{0i} \, . \, Y_t$$

$$+ \; 1/Y_t \, . \sum_i \Delta s_{ti} \, . \, \Delta\varepsilon_{ti} \, .Y_t$$

$$= E^* + \sum_i \Delta\varepsilon_{ti} .(y_{0i} + s_{0i} . \Delta Y_t)/Y_t + \Delta s_{ti} .\varepsilon_{0i} + \Delta s_{ti} . \Delta\varepsilon_{ti} \quad (5)$$

where $1/ Y_t \sum_i s_{0i} . \varepsilon_{0i} . Y_t = \sum_i s_{0i} . \varepsilon_{0i} .Y_t = E^*$ is the level of energy use, for a given Y_t, that would occur if the shares and energy intensities were fixed, that is if the overall energy intensity were fixed.

Thus the last three components in (5) represent the intensity, composition and interactive effects respectively, in terms of contributions to changes in overall energy intensity. Here we follow the principle of 'jointly created and jointly distributed' (Ang & Zhang, 2000) and allocate the multiplicative effect equally between the composition and share effects. As a result we decompose the *change in total energy use* into two components:

- The intensity effect: $\sum_i \Delta\varepsilon_{ti} . y_{0i} + \Delta y_{ti} .\Delta\varepsilon_{ti}/2$ and
- The structure effect: $\sum_i \Delta y_{ti} . \varepsilon_{0i} + \Delta y_{ti} .\Delta\varepsilon_{ti}/2$.

Equivalently, we compose the change in total energy intensity into two components:

- The intensity effect: $\sum_i \Delta\varepsilon_{ti} .(y_{0i} + s_{0i} . \Delta Y_t)/Y_t + \Delta s_{ti} . \Delta\varepsilon_{ti}/2$ and
- The structure effect: $\sum_i \Delta s_{ti} .\varepsilon_{0i} + \Delta s_{ti} . \Delta\varepsilon_{ti}/2$.

Data Issues

The key requirements for an energy decomposition analysis by industry are real value added and energy consumption by industry. Most of the studies referred in the literature to date use the gross value of production as the output variable, because of the difficulties of obtaining data on value added by industry (for a review see Sheehan and Sun 2007). But value added, which excludes inputs to the production process, is much to be preferred as the output variable, as the energy embodied in inputs to production is not counted as energy consumption by the industry in question, and may change significantly over time as the structure of production changes. The Chinese national accounts data provide consistent real value-added series for six sectors (agriculture, industry, construction, transport, storage and post, wholesale and retail trade, and other tertiary industries) for the full 1980-2008 period, consistent with the revisions to the national accounts as a result of the First National Economic Census in 2004 (NBSC, 2005) but not yet consistent with the Second National Economic Census in 2009. But with over 70% of China's energy use taking place in industry (excluding construction but including mining) it is important to disaggregate this sector, and here problems arise.

Value-added data by detailed industry are available only from 1994, in current prices and for 'designated enterprises', the criteria for which changed in 1998. Prior to 1998, this description covered all enterprises with an independent accounting system which were owned or regulated at or above the township level, whereas from 1998 it covered all state-owned enterprises (SOEs) with an independent accounting system and all non-SOEs with an independent accounting system and annual sales revenue in excess of 5 million yuan (Holz and Lin, 2001). The independent accounting system test is common to both periods, so the critical change is from being owned or regulated at the township level or above before 1998 to being either an SOE or having sales over 5 million yuan after 1998. As Holz and Lin point out, the gross value of production of designated firms by the pre-1998 test amounted to over 90% of that overall all industry in 1980, but fell to only about 60% in 1997, prompting the change. While there seems to have been little impact of the change on this share in 1998, the effect of moving to a fixed monetary limit was to increase the coverage of 'designated enterprises' as both inflation and rapid growth eroded the impact of that limit. By 2004 this ratio had recovered to be over 90%, and a similar pattern is evident for value added.[88] This means that studies that use either gross value of production or value added for designated firms in relation to total energy use by industry may generate seriously misleading results. For the last three years (2007-09) the NBS has published the percentage change in current price value added by industry relative to the same month of the previous year (on both a single month and at year to that month basis). As there is no reference to 'designated enterprises', we take this to refer to each industry as a whole.

The methodology adopted to assemble real value added by detailed industry for 1994-2009 is as follows. The starting point is three data sources: the current price series on value added by industry for designated enterprises for 1994-2006; total industry value added for all enterprises from the national accounts for 1994-2006, together the implicit price index for this aggregate for 1994-2009; and gross industry output value (GIOV) data for all industries for 2004 and for designated enterprises in 2003 and 2005.[89] The relationship for individual industries between the output data for designated enterprises and for all enterprises in 2003-05 is used to gross up the value-added data for designated firms over 1994-2005 to create industry value-added estimates consistent with the national accounts total. For the last three years we apply the percentage change in the year to December (accumulated, and for 2009 so far only for November) to the industry estimates from the previous year, starting with 2007.

The question of the price index to be used to obtain real value added is also important. Whereas different industries will be subject to a range of different factors affecting both input and output prices for example, changes in raw materials or energy prices), the costs incurred in the value-adding process should mainly reflect common cost factors within China. For this reason we use the overall price deflator for industrial value added from the national accounts to convert value added for each industry into constant values.

Data on energy consumption by industry is available from the *China Statistical Yearbook for 1994-2007* while an aggregate figure for 2008 has also been published by NBS. This allows the series for energy consumption per unit of real value added to be constructed by industry for 1994-2007, with an aggregate figure only for 2008.

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[88] Being data collected from a specific group of enterprises, it must be assumed that these data do not reflect the additional industrial output detected in the 2004 National Economic Census. As the denominator of this ratio incorporates the post-2004 adjustments, the value of the ratio in recent years will also reflect these adjustments to the aggregate data for industrial value added. The major part of the increase in value added detected in the 2004 Census was, however, in the services sector.

[89] GIOV for designated enterprises has not been published for 2004, so the average of 2003 and 2005 is used.

PART 2: IDENTIFYING POLICIES AND IMPLEMENTATION STRATEGIES FOR IMPROVING ENERGY EFFICIENCY

More Sustainable Energy Use in China: Economic Structure and the Application of New Technologies Project

IDENTIFYING POLICIES AND IMPLEMENTATION STRATEGIES FOR IMPROVING ENERGY EFFICIENCY

CASE STUDY 1

High Fuel Efficiency Motor Vehicles

May 2010

Centre for Strategic Economic Studies

Victoria University, Australia

With the assistance of the

Energy Research Institute,

National Development and Reform Commission

Beijing, P.R. China

Report for the Australian Department of Climate Change

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1. Introduction

This case study reports on the implications for the Chinese automotive industry and the economy more broadly of a move by the Chinese government to promote a greater use of motor vehicles that produce less greenhouse gases and other pollutants and are more fuel-efficient. This transition is occurring against a background of increasing knowledge of the impact of greenhouse gases on climate change and the desire to improve air quality within China's cities. Concerns about resource security and the rising real cost of fossil fuels is another important motive for improving fuel efficiency. A further more recent consideration is the desire to establish a globally competitive motor vehicle industry in China that shares market leadership in terms of fuel economy.

This report provides background on both the rapid rise in the number of motor vehicles in China during the past decade and the corresponding rapid growth in the output of the domestic automotive production industry. It describes how national, regional and municipal governments within China have promoted the growth of the industry through joint ventures among foreign automotive manufacturers, domestic manufacturers and government, and more recently have encouraged the development of automotive technology, such as electric cars. The government has introduced policies and programs to address pollution, congestion, fuel costs and climate change associated with motor vehicle use and these are described in terms of their impact on the industry and consumers.

Although established in automotive component export markets for some time, the Chinese motor vehicle industry is poised to make a serious attempt to become a global presence in the automotive trade. As the Japanese and Korean examples illustrate, this is necessarily a long-term program which will require Chinese manufacturers to meet environmental, safety and engineering and other standards in developed economies as well as the quality and other expectations of consumers. Manufacturers will increasingly therefore need to adopt world's best practice manufacturing and supply chain management techniques and invest in the innovation necessary to achieve this either within their own organisations or in collaboration with private and public technology organisations.

The challenges faced by the Chinese Government in reducing carbon emissions from transport are illustrated by comparing growth in the Chinese passenger vehicle fleet with that in Australia as an example of an advanced economy. The anticipated strong growth in the number of cars in China highlights why the Chinese Government is giving priority to the development of electric and hybrid diesel vehicles.

There are range of policies that can be adopted to encourage low carbon transport suggested including stronger emissions standards for vehicles, fuel taxes, vehicle purchase taxes, support for infrastructure for electric vehicles and encouragement of alternative transport modes.

The concern about carbon emissions from transport has prompted governments and other bodies to develop roadmaps setting out goals and timelines for achieving lower emission vehicles. These are reviewed and illustrated using the UK Consensus Technology Roadmap.

Appendix A provides a review of technology options for reducing carbon emissions from transport based on the information contained in the initial report of this project. Appendix B provides a summary of the detailed review of policies for reducing carbon emissions undertaken by the UK Energy Research Centre. Appendix C provides a review of fuel efficiency and emission standards in various countries

2. The Chinese Automotive Sector

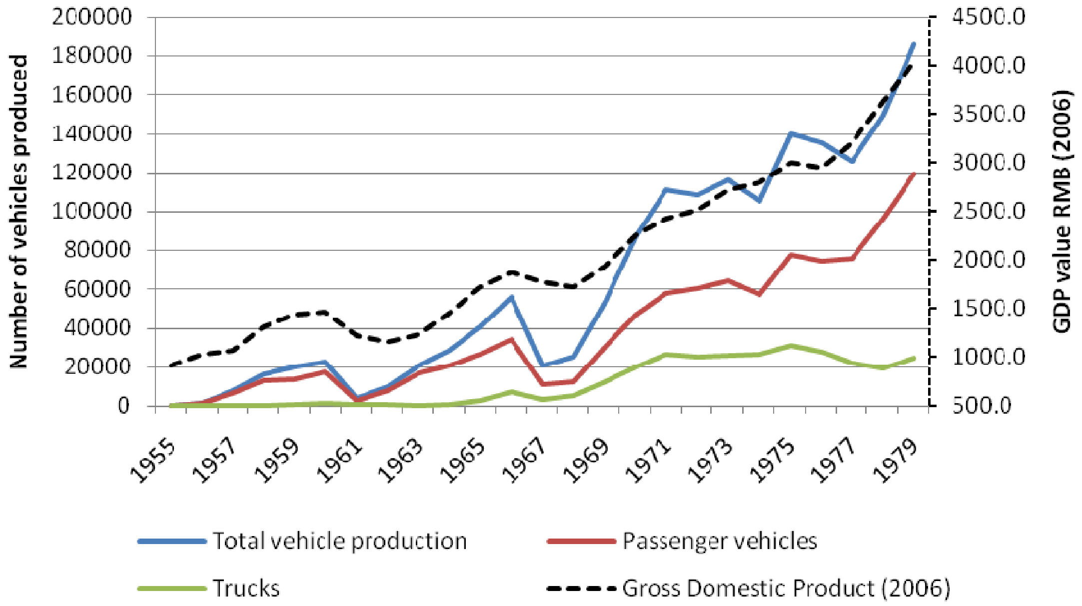
2.1 Historical Background

Although China had a modest automotive manufacturing sector prior to the Second World War, the industry is usually described as originating with the establishment by the national government in 1956 of the First Automobile Works (FAW) in Changchun in Jilin Province, North-East China. Producing medium-size trucks, the FAW factory was based on a Soviet design and was built with the help of Soviet technicians. In the following few years, automotive manufacturers were set up by provincial and municipal governments in Nanjing (now the Nanjing Automobile (Group) Corporation), Shanghai (now the Shanghai Automotive Industry Corporation – SAIC), Jinan (China National Heavy Truck Group) and Beijing (Beijing Automotive Industry Holding Corporation). The first passenger car, the 'Hongqi' (Red Flag) was launched by FAW in 1958. However bicycles provided the chief form of personal transport for much of the period after 1949.

Following the difficulties of the Great Leap Forward and the demise of Soviet-China friendship, the central government set up the Second Automobile Works (SAW, later Dongfeng Automotive Group) with the support of the Shanghai municipality and FAW. For strategic reasons however, the plant was located in Shiyan, a remote location in Hubei province.

During the Cultural Revolution regional authorities set up new factories in Tianjin, Shenyang and Wuhan, all of which became major producers. However the isolation of China and the turmoil during the period of the Cultural Revolution meant that the growth of the local automotive industry was constrained and consisted overwhelmingly of trucks rather than passenger vehicles.

Figure 1. Vehicle Production and GDP, China, 1955-1979



Source: NBSC, 2009

Figure 1 shows that the average annual growth from 1955 to 1979 was nearly 12% (Liu and Yeung, 2008) and production rose rapidly between 1967 and 1971 before reaching a plateau and then rapidly growing after 1974. Vehicle production grew from 61 vehicles in 1955 to 185,700 vehicles in 1979 (Arnold, 2003; NBSC, 2009). The growth in vehicle production mirrors the changes in China's Gross Domestic Product (GDP) during the 25 year period.

The economic reforms and greater openness beginning in 1978 provided a major stimulus to the Chinese automotive industry. There was strong growth in the importation of cars and the Government responded by promoting joint ventures between domestic and foreign manufacturers to increase local production. The first of these was a small venture involving American Motors Corporation and Beijing Automotive called Beijing-Jeep to produce a local version of the Jeep Cherokee.

In 1987 the Government decided as part of its overall industrial strategy to nominate the automotive industry as one of its key 'pillar industries'. An important aspect of this was the decision to divide the leading manufacturers into major and minor assemblers. The three major joint ventures were:

- Shanghai Automotive Industry Corporation and Volkswagen (1985)
- First Automobile Works and Volkswagen (1990)
- Dongfeng Motor Corporation and Citroen

The three smaller ones were:

- Beijing Automotive Industry (BAI) – AMC (later Chrysler, then Daimler Chrysler, then Hyundai)
- Guangzhou Automobile Industry Group and Peugeot (later Honda) (1985)
- Tianjin Automotive Industry and Daihatsu (later merged with FAW and Toyota joint venture)

Of these early joint ventures, the most successful were those involving Volkswagen which took advantage of its first-mover status and through its Santana and Jetta models quickly reached a dominant position in the market. Guangzhou-Peugeot was closed in 1997 while Beijing-Jeep never flourished.

From their beginnings in 1983, joint ventures proliferated and now involve all the major international automotive manufacturers, including the Japanese car companies that had earlier been reluctant to commit to joint ventures because the initial ones had many teething problems. The more recent and key joint ventures include: Jinbei-General Motors, Chang'an-Suzuki, Nanjing-Iveco, Changhe-Suzuki, Shanghai-General Motors, Guangzhou-Honda, Nanjing-Fiat, Yueda-Kia, Tianjin-Toyota (later FAW-Toyota), Chang'an-Ford, Beijing-Hyundai, FAW-Toyota, Dongfeng-Nissan, Guangzhou-Toyota, BMW-Brilliance and Beijing-Benz (Liu and Yeung 2008).

While initially concentrated heavily in Changchun and Shiyan and later in Beijing, Nanjing and Shanghai, the creation of new companies and factories lead to a decentralisation of production and spread the geographical distribution of the industry to other cities such as Chongqing, Haerbin and Tianjin.

The Government's policy to build the local automotive industry through the transfer of technology, skills and capital from foreign car companies via majority ownership of joint ventures was formally recognised in the 'Automotive Industry Policy of China' in 1994. This policy aimed at tripling local production over a 15 year period, beginning the process of making the automotive industry internationally competitive. It instituted some formal protection barriers by raising the import duty on completely built-up vehicles and components and provided subsidies for exporters. The policy required the industry to reach 80% local content within three years or face higher import duties. Importantly it permitted only one major new venture during the period of the 9th Five Year Plan (FYP) from 1996 to 2000 (SAIC-General Motors) and promoted the rationalisation and consolidation of domestic manufacturers. From this emerged the major producers in the market today (Figure 2).

China's decision to seek membership of the World Trade Organisation (WTO) which took place in December 2001, necessitated a change in some of the protectionist aspects of industrial policy. The 10th Five Year Automotive Development Plan (2001-2005) included a number of measures stimulating the vehicle market in China, including reducing tariffs on imported complete built units (CBUs) and vehicle components, as well as abolishing local content requirements. The Plan reiterated the policy of favouring selected large firms both among the assemblers and parts manufacturers and encouraging further consolidation among smaller producers.

In 2008, the top five manufacturers accounted for 40.7% of output while the top 10 made up 65.3%. Figure 2 lists the 20 top car makers in China in 2008, which hold a combined market share of 91.9%. The remaining 8% of the market is divided amongst a further 100 or so manufacturers. At the end of 2008 there were some 117 car manufacturers in China (China Association of Automobile Manufacturers, 2009).

While joint ventures with foreign manufacturers producing domestic versions of foreign cars dominate with a 56% market share, an interesting feature of Figure 2 is the presence of a number of private domestic manufacturers – namely Zhejiang Geely Automobile, Chery Automobile and BYD. These companies began producing cars quite recently in 2000 (Geely), 1998 (BYD) and 2002 (Chery) and in recent years, they have emerged to gain a significant market share without being a preferred manufacturer within the automotive industry plan. Domestic local brands make up around 44% of the market. More recently, BYD has made major commitment to electric and hybrid vehicles. Other independent producers include Great Wall Motors initially a truck manufacturer which began making SUVs in 1996, but is producing an increasing number of smaller private vehicles today.

Figure 2. Top 20 Car Makers in China, 2008

	Production	Sales	Share of production %
Shanghai Volkswagen Audi	481,730	478,059	9.6
FAW Volkswagen	480,800	498,908	9.5
Shanghai GM	403,939	408,470	8.0
FAW Toyota	366,512	347,663	7.3
Dongfeng Nissan	319,455	318,785	6.3
Chery	281,412	286,569	5.6
Guangzhou Honda	279,298	277,358	5.5
Beijing Hyundai	258,356	253,298	5.1
Zhejiang Geely	220,955	221,823	4.4
Chang'an Ford	197,366	200,756	3.9
BYD	192,971	170,882	3.8
Guangzhou Toyota	175,870	172,004	3.5
Shenlong PSA	172,720	178,060	3.4
Tianjin FAW	172,369	176,638	3.4
Chang'an Suzuki	123,389	124,123	2.4
Brilliance BMW	115,802	127,024	2.3
FAW Mazda	113,220	117,544	2.2
Dongfeng Kia	106,439	108,353	2.1
Dongfeng Honda	83,085	83,413	1.6
FAW Hainan	82,771	92,757	1.6
Top 20	4,628,459	4,642,487	91.9
All manufacturers	5,037,334	5,046,934	100.0

Source: China Automotive Industry Yearbook, 2009

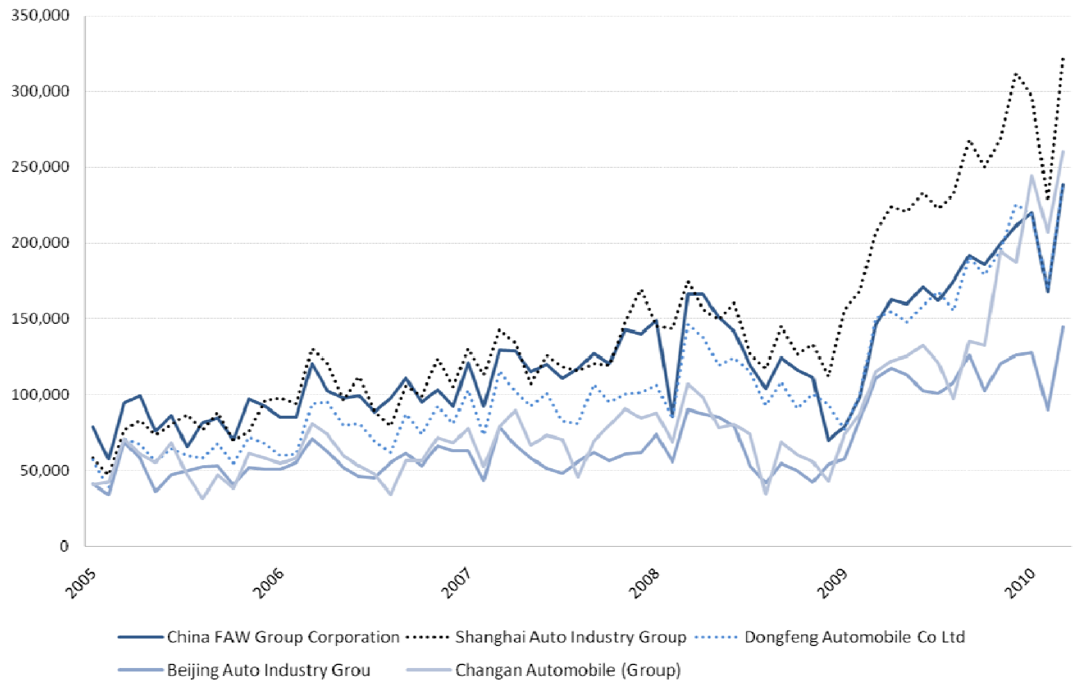
In summary, Chinese government policy with respect to the automotive industry has been to build a domestic production capability by encouraging joint ventures with foreign car companies and a few selected domestic manufacturers. The foreign car companies would have a minority share in such ventures but would transfer skills and design and manufacturing technology to China to form the basis of domestic capabilities in these areas.

In a review of the Chinese automotive industry, Liu and Yeung assert that this desired development of technological capacity in the favoured domestic manufacturers – FAW, SAIC and Dongfeng - has not occurred and they remain reliant on their foreign partners for new models and associated technology. They cite the case of Dongfeng which closed its technical centre for new car development in 2002. As noted earlier it is those manufacturers that emerged outside the formal automotive plan that have been successful in developing their own cars and technologies.

In January 2009, the Chinese Government announced a range of measures to stimulate the economy in light of the global recession and financial crisis. Included in this package was the Automotive Industry Restructuring and Revitalisation Plan which among other things called for a further rationalisation of the 14 major domestic manufacturers into around 10 which would account for 90% of the market and be organised into two tiers by 2012. The first tier would consist of SAIC, FAW, Dongfeng and Chang'an with annual sales volumes above 2 million units and another 4 to 5 companies including BAIC, GAIG, Chery and China Heavy Duty Truck Corporation with annual sales volumes above 1 million units. It is interesting to note that Chery is now acknowledged officially as a leading automotive company in China. Another outcome of the rationalisation plan has been an acceleration of overseas acquisitions in 2008 and 2009. However, domestic mergers are expected to dominate 2010 and 2011 (Yu, 2010).

Figure 3 shows the monthly production figures of China's top five automobile manufacturers between January 2006 and March 2010. The past three years clearly highlight the role of domestic policy and economic conditions on vehicle production. For example, in early 2008 there is a brief slowdown in car production, due to the government's monetary and fiscal policy tightening, followed by a rapid surge in production following the RMB4 trillion stimulus package, which was released in January 2009. Production was only possible to grow so rapidly, because the manufacturers have been building up the manufacturing capacity of their plants since 2005 as well as consolidating their control of the market by merging smaller plants.

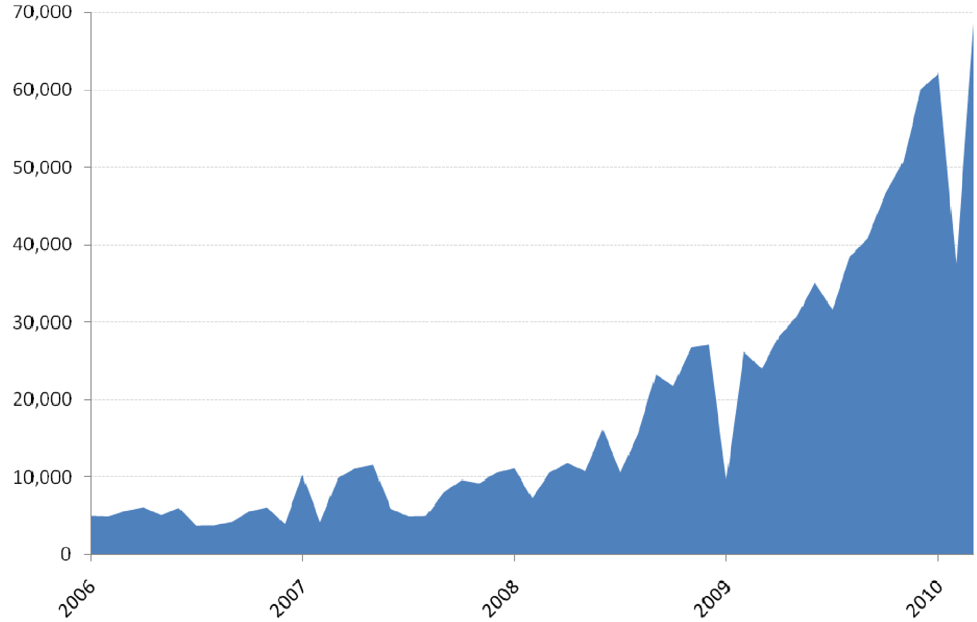
Figure 3. Monthly Production of China's Top Five Automobile Makers, number of vehicles



Source: CEIC Data (2010) from China Association of Automobile Manufacturers; January 2005- March 2010

One of China's motor vehicle stand-outs is the sudden rise and success of the Shenzhen-based BYD. Figure 4 highlights the dramatic increases in BYD vehicles from 2008 when it introduced its low cost F3 model, which has gone on to become the most popular small car on the domestic market in 2009. The company plans to sell 800,000 vehicles in 2011. BYD has been very successful in marketing its brand both domestically and internationally and will be one of China's first vehicle manufacturers to sell hybrid and electric vehicles on the international market. The company grew on the back of its cell phone components and laptop battery plant, but today auto sale revenues have soared to the front. In 2010, BYD announced plans to spend US3.3 billion on battery development over the next five years. BYD's plug-in E6 entered the Chinese market in 2010 and was planned for launching in the US market late in 2010.

Figure 4. Monthly BYD Automobile Production, number of vehicles, 2006-03.2010



Source: CEIC Data (2010) from China Association of Automobile Manufacturers

2.2 Market Characteristics

During 2009 and 2010, China's motor vehicle market has realised a shift away from the traditional dependence upon foreign branded to a more diverse market. The largest market share is still held by global automaker joint ventures, such as Volkswagon (16%), Hyundai (10%) and GM (9%). And yet, privately-owned indigenous manufacturers are increasing their share with Chery Automobiles holding 5.5%, closely followed by the private BYD at 5.1%. In total, China's domestic brands hold a 32% market share with predictions this will rise to 37% by 2015. Assisting this transition is a greater level of dispersed control of the industry with the top-five companies making up 50% of market share compared with 87% in Japan and 65% in the US.

Figure 5. Automotive Output in China, 1978-2009, thousands

Year	Motor vehicles	Passenger cars
1978	149	100
1980	222	135
1985	443	237
1990	509	269
1995	1,453	572
2000	2,077	618
2001	2,342	704
2002	3,251	1,092
2003	4,444	2,071

2004	5,091	2,276
2005	5,705	2,770
2006	7,279	3,869
2007	8,889	4,798
2008	9,346	5,037
2009	13,795	7,485

Source: NBSC, 2009

The reduction in tariffs and duties to 10%-13% for components and 25% for cars has reduced the price of both imported and domestic cars contributing to a major expansion in the market for cars in China. In the first quarter of 2009, the number of automobiles sold in China exceeded that in the United States for the first time, making China the largest automotive market in the world. In 2009, passenger cars accounted for about 72% of both output and sales (NBSC, 2010). The total number of motor vehicles on the road in 2009 grew by 45% to reach 76.2 million, including over 13 million low-speed trucks and tri-wheel motor vehicles. Private vehicles totalled 52.2 million, half of which are private cars (NBSC, 2010). During the first quarter of 2010, passenger car sales continued to rapidly expand by 72% (YoY) to 3.52 million units (Bloomberg, 2010).

Figure 6. Output of Trucks and Cars in China, 2004-2008

	Trucks million units	Trucks US$ billion	Cars million units	Cars US$ billion
2004	1.5	42.7	2.5	39.8
2005	1.5	39.5	4.0	59.9
2006	1.8	47.1	5.2	73.8
2007	2.1	60.5	6.3	85.8
2008	2.4	74.6	7.4	98.0

Source: Datamonitor 2008

Over the period 2004 to 2008 the average annual growth rate for passenger cars was 31.1%, while for trucks it was 12.1% (Figure 6). Datamonitor (2008) predicts further growth of about 12% per annum in both categories to 2013.

Figure 7. Automotive Market in China, Share of Market by Country of Origin of Manufacturer, 2000 and 2007

Year	2000	2007
China	19.8	30.0
Germany	46.5	18.1
Japan	17.1	27.2
Korea	0.0	7.2
USA	6.7	13.1
Others	9.1	4.4

Source: Liu and Yeung, 2008

While domestic manufacturing provides most of the supply for the Chinese automobile market, China does import some vehicles – about 314,000 units in 2007 with a value of about $10 billion with Germany, Japan, the USA and South Korea being the principal suppliers.

Figure 8. Chinese Automotive External Trade, Trucks, Cars and Parts, 2000-2008

Year	Trucks		Cars		Parts	
	Import No.	Export No.	Import No.	Export No.	Import US$m	Export US$m
2000	3,085	7,093	21,620	523	2,112.8	1,125.4
2001	3,138	8,527	46,632	763	2,617.7	1,632.2
2002	6,692	10,520	70,329	969	2,312.4	1,661.3
2003	9,862	26,142	103,017	2,849	7,384.3	5,420.4
2004	8,078	52,796	116,085	9,335	8,679.6	7,946.0
2005	3,032	100,153	76,542	31,125	7,684.9	9,889.5
2006	5,582	163,064	111,777	93,315	10,525.2	19,248.4
2007	7,980	260,311	139,867	188,638	14,215.2	28,691.2

Source: Liu and Yeung, 2008

Figure 8 shows the composition of Chinese external trade in vehicles and automotive parts from 2000 to 2007. While imports of trucks have remained relatively constant, there has been a major expansion of truck exports to other developing nations particularly since 2004. Similarly while imports of cars jumped in 2002 and 2003 the growth since then has been modest. Again however exports have increased rapidly from a low base and now outnumber imports. Imports of automotive parts have been increasing – doubling in recent years but this has been more than outweighed by a rapid rise in the export of parts.

The principal destinations for the export of motor vehicles from China have been relatively unsophisticated markets in the Middle East and elsewhere (Figure 9) although some exports have occurred to developed countries. By contrast automotive components and parts have been sold predominantly to developed countries. This includes exports by foreign companies such as Bosch and Delphi producing parts in China through joint ventures.

Figure 9. Top 10 Destinations for Chinese Automotive Exports, 2008

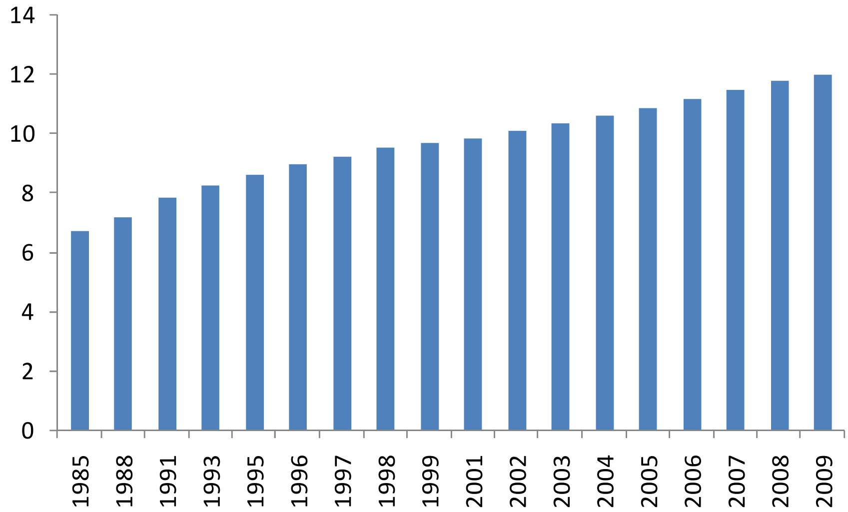
Auto parts		Motor vehicles	
Destination	US$m	Destination	US$m
US	7,873.2	Russia	1,294.5
Japan	4,595.4	Iran	599.6
Korea	1,766.7	Algeria	595.2
Germany	1,094.5	Vietnam	559.6
Canada	854.7	Ukraine	477.0
Holland	832.2	Angola	420.8
Russia	757.0	UAE	288.7
UAE	723.7	Saudi Arabia	282.6
Australia	654.8	Syria	250.6
UK	636.9	South Africa	246.1

Source: China Automotive Industry Yearbook, 2009

2.3 Projected Demand for Vehicles and Policy Challenges

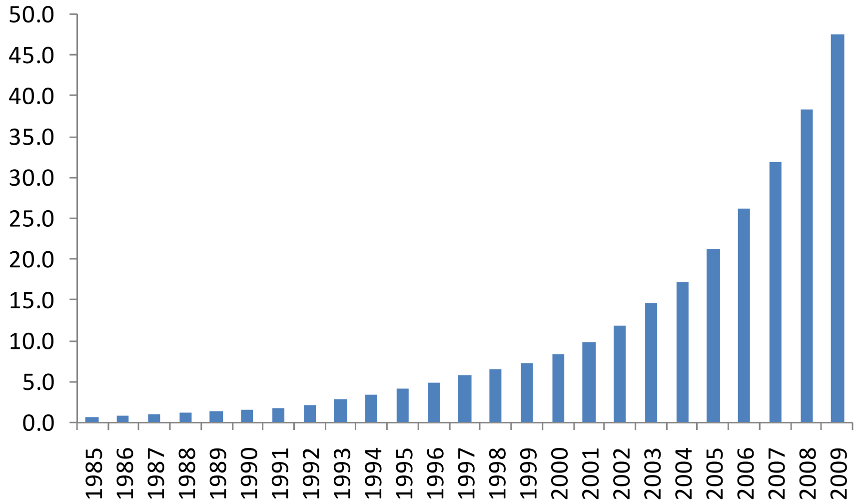
The strong growth in sales of motor vehicles, particularly for private passenger vehicles, in recent years has lead to a massive increase in the number of vehicles in the Chinese passenger vehicle fleet, as measured by vehicle registrations. Figure 10 demonstrate an almost exponential growth with the fleet of passenger vehicles more than doubling between 2005 and 2009. In most advanced industrialised countries, the market for passenger vehicles is virtually saturated with medium term growth approximating that of population growth. Figure 11 shows passenger vehicle registrations in Australia as an example of such a market with an average rate of growth in the fleet of about 2.5% over the past five years.

Figure 10. Passenger Vehicle Registrations, China, 1985-2009, million



Source: CEIC database, 2010

Figure 11. Passenger Vehicle Registrations, Australia, 1985-2009, million

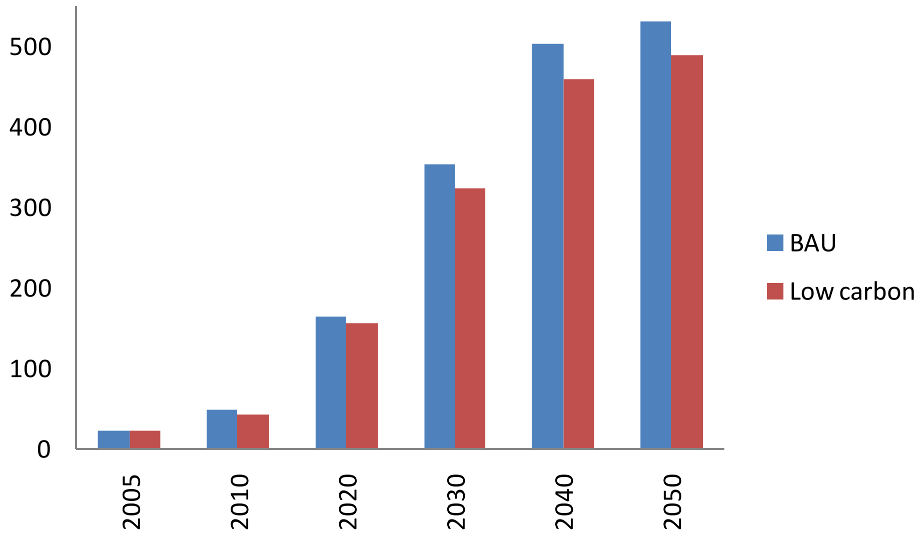


Source: ABS, 2009

If the Australian fleet continues to grow at its current rate then the number of cars in 2030 will be about 18.2 million or a rise of about 48%. On the other hand, the Energy Research Institute (ERI) predicts that the Chinese passenger vehicle fleet will increase from 48.7 million in 2010 to 353.8 million in 2030 a rise of 626.7% and reach 531.1 million by 2050 (Figure 12). This is based on their "Low Carbon" scenario which has overall emissions in China peaking around 2040 and remaining steady thereafter (ERI, 2009).

To maintain carbon emissions from Australian passenger vehicles at their levels in 2010 will require cars in 2030 to emit only about 67.6% of the carbon that is emitted by a car in 2010. This goal could be reached using currently available or predictable improvements to current ICE (internal combustion engine) motor vehicle technology.

Figure 12. Projected Passenger Vehicle Registrations, China, 2010-2050, million



Source: ERI, 2009

To achieve the same goal in China will require cars in 2030 to emit 13.8% of the level of car in 2010. This cannot be done with just improvements to ICE technology but will require a rapid adoption of alternative technologies such as hybrid and fully electric vehicles and associated infrastructure.

3. Current Policies to Reduce Emissions from Transport in China

The rapid growth of the automotive fleet in China was accompanied by increasing concern for the impact of air pollutants both locally in terms of their influence on population health and globally in terms of the contribution of car emissions to atmospheric carbons levels and climate change. A further concern of the Government was to reduce the level of fuel imports particularly against a background of rising fuel prices coming from strong international demand for oil. Prior to 1993, China was a net oil exporter. However, since then it has become the second largest global importer with the dependency on imports growing steadily.

Presently, 16 of the 20 most polluted cities in the world are in China. About 79% of the nitric oxide and particulate matter pollution in Chinese cities arises from automobile use (Kearney 2009). As a result, a number of cities have implemented controls on emissions from cars. For example, in the run-up to the Olympic games in Beijing in 2008, the city banned the sale of new cars that failed to meet the China IV Emission Standard, which is equivalent to the Euro IV standard to help reduce air pollution. The estimated economic costs of air pollution in China vary between 2-7% of GDP.

National and local governments have introduced a broad range of policy measures aimed at promoting energy efficiency in the automobile sector, including industrial strategies and supporting initiatives. More recently the government has introduced economic incentives with lower taxes for the production and consumption of compact vehicles and raised taxes for larger vehicles.

One of the most effective policy measures for controlling oil demand and GHG emissions has been the introduction of vehicle fuel standards. China's first fuel efficiency standards were introduced in 2000 with the aim of encouraging foreign vehicle firms from introducing more fuel-efficient technologies into the Chinese market. In 2004 the National Development and Reform Commission announced it would introduce mandatory fuel efficiency standards for passenger cars in two phases. Phase 1 standards took effect from July 2005 for new models and from July 2006 for continued models. Phase 2 standards took effect from January 2008 for new models and January 2009 for continued models. Phase 3 is set to be introduced in 2015 with a target of 42.2 mpg (around 50% higher than current US fuel economy standards).

The standard set up maximum fuel consumption limits according to 16 categories of vehicle weight and by automatic or manual transmission. A study by the China Automotive Technology and Research Center (CATARC) (2008) found that Phase 1 increased overall passenger vehicle fuel efficiency by 9% from 9.11 litres/100 km in 2002 to 8.06 litres/100 km in 2006 despite an increase in average vehicle weight and engine size. CATARC estimates that since the implementation of the standard, 1.61 billion litres of fuel had been saved and 3.84×10^4 tons of CO_2 had been avoided. However, CATARC noted that local fuel consumption by passenger cars was only equivalent to European and Japanese levels of 10 years ago. By comparison fuel consumption for equivalent cars in China is about 50% higher than in Japan and 14% higher than the EU. Initially the government aimed to align itself with EU and Japanese vehicle fuel economy standards by 2011, but will more likely reach parity between 2015 and 2020. However, cities such as Beijing and Shanghai are accelerating the introduction of stricter fuel economy standards, which will act as a driver for local vehicle manufacturers to comply and tap into local as well as lucrative export sales.

The highest reduction in fuel use was recorded for vehicles based on Japanese technology (18%), followed by independent domestic producers (14%), South Korean and US technology (9%), and European technology (5%). The CATARC further reports that other benefits arising from the new standards are the elimination of 444 non-conforming vehicle types and a restraint in the growth of SUVs.

The overall aim of the standard's policy is for vehicles in China to meet Euro-III emissions standards in 2007 and Euro-IV standards by 2010. A survey of passenger vehicle fuel economy and emission standards by the Pew Center in December 2004 concluded that 'The new Chinese standards are more stringent than those in Australia, Canada, California and the United States, but they are less stringent than those in the European Union and Japan' (Feng An and Sauer 2004).

The Automotive Industry Restructuring and Revitalisation Plan released by the Chinese Government in January 2009 has been mentioned earlier in the context of moves to further rationalise the industry, but it also contained major initiatives to stimulate the market for cars in China following disappointing growth of 6.7% in 2008, to build a larger market share for domestic suppliers and to address concerns about energy security, competitive advantage, air pollution and climate change. In particular the Plan aims to:

- increase sales and production in 2009 to 10 million units and to keep growth at 10% per annum for the following 3 years;
- increase the market share of domestic brands from 34% to 40%; and
- increase the market share of cars with a capacity of 1.5 litres or less to 40% and for those with a capacity of 1.0 litres or less to 15%.

The measures to achieve this include:

- a lowering of the vehicle purchasing tax from 10% to 5% on cars under 1.6 litres capacity and an increase of the tax on larger cars, minivans and SUVs;
- an increase in the price of petrol and diesel following the introduction of China's first fuel tax in 2009;
- the establishment of a fund of RMB5 billion to help rural citizens upgrade 3-wheelers and low speed vehicles to small vehicles of 1.3 litre capacity or less
- increased subsidies to encourage people to scrap old cars and purchase new cars; and,
- efforts to remove 'any unreasonable rules' hampering car sales and to improve the process for obtaining finance for new car purchases.

Sales data for recent months indicates that the growth of smaller cars as well as minivans and mini-trucks have picked up considerably, while sales of larger vehicles have been sluggish (CHINAtalk 2009a).

While the emphasis on smaller cars will help control emissions of pollution and greenhouse gases, the stimulus to the whole industry and the strong growth targets will work against achieving better environmental outcomes. Through the recent Plan and by other measures, the Government has also encouraged consumers and manufacturers to move towards more fuel efficient and less polluting vehicles. By the end of 2011, the government has agreed with the automotive industry to establish the capacity by 2011 to produce 500,000 'new energy' vehicles (NEV), namely pure electric, hybrid and plug-in hybrid vehicles. This should be equivalent to around 5% of overall capacity within the industry.

The Government is aiming to have 10,000 such vehicles on the road by 2010 with the support of 20 large cities each promising to use government procurement policies to promote NEV in the initial development stage. The country's largest electric power company, State Grid Corporation of China has begun to install charging stations in larger cities such as Beijing, Shenzhen, Wuhan and Shanghai (CHINAtalk 2009b).

Supporting the move to electric cars the Government also announced that it would create capacity to produce 1 billion Amp/hr of high performance battery modules, or the equivalent of about 750,000 Chevrolet Volt battery packs; and create a fund of RMB10 billion to support domestic manufacturers to upgrade technology and develop new alterative energy engines.

This emphasis on alternative fuel vehicles technology was first flagged in the Science and Technology Middle- and Long-Term Development Plan (2006-2020) which highlighted hybrid, alternative fuel and fuel cell vehicles as priorities for research. It also announced the establishment of a State Key Laboratory of Automotive Safety and Energy within the Ministry of Science and Technology (MOST). This was followed more recently by the establishment by MOST of a Beijing New Energy Auto Design and Manufacture Base in December 2008.

In January 2009 the Government announced a program to provide subsidies for the purchase of hybrid, electric and alternative fuel vehicles in 13 pilot cities including Beijing and Shanghai. The program is largely aimed at buses and taxis and vehicles used by the government in areas such as the postal services. Zero emission and alternative fuel cars can receive subsidies of between RMB6,000 and RMB60,000 (KPMG 2009).

The control of the development of alternative fuel vehicles in China rests with the National Development and Reform Commission (NDRC) which issued the Administrative Regulations for the Approved Commencement of the Manufacture of New Energy Automobiles in October 2007. The regulations put NDRC in charge of approving companies wishing to manufacture alternative fuel vehicles. The regulations distinguish between: (a) 'initial' stage technologies, which may only be manufactured in small batches, (b) 'developing' stage, which can be produced in larger batches, and (c) 'mature' technologies, which can be mass produced. Manufacturers wishing to make these vehicles must possess at least one key technology involving energy storage, mechanical operation or system control.

The technologies covered by the regulations include hybrid vehicles, battery electric vehicles (including solar powered), fuel cell vehicles, hydrogen-powered vehicles and other technologies such as high-efficiency accumulators (Zhang 2008).

Several projects and initiatives are being undertaken to increase the use of alternative fuels and technologies. These include the following.

Natural Gas

The number of vehicles powered by natural gas is still small at about 200,000 and widespread uptake is likely to be constrained by the lack of infrastructure to supply this fuel. However for locations near natural gas pipelines the potential for greater use is considerable. The Dongguan local government in Guangdong province has announced it will invest RMB72 million in the construction of 60 natural gas fuelling stations by 2015 and will convert 90% of the local bus and taxi fleet to run on natural gas. Shanghai already has 400 gas-fuelled buses and plans to have 40,000 alternative energy vehicles by the 2010 Expo. Similar natural-gas fuelled bus programs are underway in Dalian and Chengdu.

Solar Power

There has been very little work on solar powered vehicles although Zhejiang 001 Group has produced 10 concept cars based on their electric bike technology. These vehicles have a limited range of 150 kilometres and require 30 hours for recharging. However work on solar power is being undertaken in universities and research laboratories.

Biofuels

The Government has set a goal of producing 10 million tonnes of ethanol and 2 million tonnes of bio-diesel by 2020 to replace oil consumption in rural areas. After a rapid expansion in the production of ethanol from biomass, the Government restricted further development in 2006 because of concerns about the use of food crops for fuel production. This has lead to a switch to non-food crops and several plants using feedstock plants have been set up in Guangxi, Jiangsu, Hebei and Hubei provinces. An R&D partnership between Royal Dutch Shell and the Qingdao Institute of Bioenergy and Bioprocess Technology has been established to investigate biofuels.

Fuel Cells and Hydrogen

While the economics of fuel cells in cars is still not favourable in any country, China has undertaken both research and demonstration projects with this technology. In 2002, the Government announced it would invest about USD$18 million in a three-year fuel cell development program, the majority of the funding going to the Dalian Institute of Chemical Physics. Both Beijing and Shanghai have had demonstration trials for fuel-cell powered buses. As part of its plan to develop advanced hybrid-electric and fuel cell vehicles, MOST provided funding for the development of 150kW fuel cell bus prototypes.

Some of the institutions involved in developing fuel cell technology are Fuyuan Century Fuel Cell Power Corporation, Shanghai Shen-Li High Tech Corporation, Dalian Institute of Chemical Physics, Hong Kong University of Science and Technology, Tongji University and Tsinghua University (Gordon 2004).

Electric and Hybrid Vehicles

While hybrid electric-petrol vehicles such as the Toyota Prius, the Honda Civic Hybrid and the Buick LaCrosse have been available in China for a few years, their sales have been small mainly because of their cost. Following the Government's emphasis on 'new energy' vehicles, however, several domestic manufacturers have begun to produce hybrid vehicles.

In 2008 BYD Auto released its F3DM plug-in hybrid electric vehicle sedan, the world's first production vehicle of this type, with a range of about 100 kilometres between charges. BYD Auto was set up in 2003 and is part of BYD Company Limited which was established in 1995 and produces about 65% of the world's nickel-cadmium batteries and 30% of the world's lithium-ion mobile phone batteries. BYD has attracted a lot of publicity because of the decision by Berkshire Hathaway to invest in the company. In April 2009, BYD announced a joint venture with Volkswagen to explore using BYD designed batteries in their future hybrid/electric vehicles.

In February 2009, Chery produced its first electric vehicle, the S8, with a range of 93 miles and 4-6 hours recharge time. Other companies such as Beiqi Foton and Chang'an have also produced prototype hybrid vehicles. FAW has set up a hybrid electric bus manufacturing plant in Dalian and in April 2009 the Renault-Nissan alliance in cooperation with the Ministry of Industry and Information Technology and the Wuhan municipal government agreed to build a pilot electric-car program in the city. The China Automotive Engineering Research Institute set up an electric car R&D facility in Chongqing in February 2009.

4. Policy Priorities and Options for Reducing Emissions in the Future

This section presents five major policy options which could be considered by ERI in its development of the Chinese Government's actions to reduce carbon emissions from road transport, recognising the importance given to the introduction of electric and hybrid diesel vehicles.

It draws upon CSES and other analysis of actual and proposed policy responses in China and other jurisdictions. The most comprehensive review of policy options identified to date is that undertaken by the UK Energy Research Centre (ERC) in the development of the United Kingdom's carbon reduction strategy for transport as outlined in its "Low Carbon Transport: A Greener Future" released in July 2009. A summary of this review is given in Appendix B.

The strategy, which sets out to largely decarbonise transport in the UK by 2050, contains a brief review of alternative technologies for air, road and sea transport and sets out policies and programs that could be implemented to achieve this goal.

Specific policies

The policies identified by CSES and other sources such as the ERC review identified the following major areas for action:

1. Carbon emission and fuel efficiency standards for vehicles

2. Fuel taxes and subsidies

3. Vehicle purchase taxes and registration fees

4. Development of alternative fuel infrastructure

5. Promotion of alternative transport modes

The Chinese Government has already developed policies and implemented programs in each of these five areas. It is suggested that the reduction of carbon emissions be given the highest priority in the future development of these policies.

Supporting context

These policies will have their greatest effect if complemented by more general macroeconomic, climate change, and planning policies, including:

- policies to reduce carbon emissions in the generation and distribution of electricity;
- policies to support public research organisations and industrial research and development addressing climate change goals; and,

- land use planning and associated infrastructure development designed to make low emission transport more attractive.

4.1 Carbon Emission and Fuel Efficiency Standards for Vehicles

(i) Proposed policy

Progressively tighten and redefine the carbon emission standards for road transport vehicles in China.

(ii) Rationale

Fuel efficiency and/or carbon emission standards for new vehicles have been set by the European Union (EU), the USA, China, Japan, Australia and many other countries. The stringency of these standards, as well as how they are defined, monitored and enforced varies considerably from country to country.

The current and proposed Chinese standards are relatively strict in comparison to other countries, including Japan and the European Union

The Chinese Fuel Economy Standards (FES) limits fuel consumption by weight category and does not differentiate between petrol and diesel vehicles. The standards do not apply to alternative fuel vehicles or imported vehicles.

Unlike the standards in Europe or the USA, every model produced by a manufacturer must meet the Chinese FES standard for that weight category; otherwise the model cannot be produced.

The Chinese Government is currently in the process of planning further improvements in fuel efficiency of the order of 18% by 2015. China currently achieves a fuel efficiency standard of about 150 g/km (6.3 l/100 km) and aims to achieve a standard of about 130 g/km (5.5 l/100 km) by 2015.

(iii) Policy details and implementation

It is proposed that future emission standards:

- cover all forms of road transport including passenger vehicles, vans, trucks and buses;
- use the current system of weight categories;
- be mandatory within each category;
- adopt the Japanese "Top Runner" approach to continual improvement;
- apply to locally manufactured and imported vehicles;
- be measured on a well-to-wheel (life cycle) basis including both production and usage;

- cover all technologies, including vehicles powered by alternative fuels and hybrid and fully electric vehicles;
- reflect the Government's agreed carbon emission goals in the period to 2050; and
- are implemented in the context of future five-year plans.

If the goal is to reduce emissions from say 150 g/km to 30 g/km by 2050 this could be achieved by a reduction profile as shown in Figure 13. From a current value of 150 g/km, the five year target would seek to achieve 135 g/km by 2015 and 120 g/km by 2020 and so on.

Figure 13. Proposed Future Emission Standards, CO_2-e

	Five -year plan target
Current	150
2011-2015	135
2016-2020	120
2021-2025	105
2026-2030	90
2031-2035	75
2036-2040	60
2041-2045	45
2046-2050	30

Source: CSES

Emission standards are only effective in lowering carbon emissions if they are properly designed and the system of testing vehicles is comprehensive, accurate and reflects real-world driving experience.

(iv) Advantages and limitations

The main advantage of controlling carbon emissions from transport using emissions standards is that it leaves the choice of technology to achieve the standard up to the manufacturer. If emission standards are known in advance and a path for reducing emissions over the longer term is made clear, then manufacturers and other participants can plan model development and research and development programs to meet the standard.

While setting an emission standard controls the amount of carbon per kilometre, it does not directly control the number of vehicles sold or the distance travelled in those vehicles.

(v) Consequences

Consumers will be affected if: (i) some models are no longer available because they do not meet the standards, or (ii) vehicle prices rise if the costs of producing cars to meet the standards increase.

Increasingly stringent emission standards might be expected to increase the price of vehicles deterring some consumers from buying cars and substituting public transport for private transport especially in situations where this is convenient and affordable.

The difficulty of meeting standards may force further rationalisation on the Chinese automotive industry and transition arrangements may be required from Government. Government support for automotive R&D and technology acquisition is likely to be necessary.

Experience with meeting emission standards in a large domestic market will be advantageous for Chinese manufacturers when they face similar standards in global markets such as Japan, the USA and Europe.

4.2 Fuel Taxes and Subsidies

(i) Proposed policy

Redesign fuel taxes with the main objective being to reduce carbon emissions.

(ii) Rationale

Taxes that increase the price of fuel will reduce its use and encourage greater use of alternative fuels or non-motorised forms of transport.

Governments around the world have imposed taxes on road transport fuels mainly to raise revenue either for general purposes or for the construction of road transport infrastructure. Many recent taxes on petrol and diesel together with incentives for the domestic biofuels industry have been used to reduce the reliance on foreign oil and to encourage greater use of alternative fuels.

Governments are beginning to change the basis for fuel taxes with a view to reducing carbon emissions. France has announced taxes of 4.5 and 4 Euro cents per litre for petrol and diesel respectively (equivalent to 17 Euros per tonne of CO_2) to be introduced in 2010. Denmark, Finland, Italy, the Netherlands, Norway and Sweden all have a carbon tax of some kind on petrol and diesel as do British Columbia and Quebec in Canada. The current Swedish tax is equivalent to 108 Euros per tonne.

Governments can differentially tax vehicle fuels according to their life cycle carbon emission characteristics. Increasing the price of petrol and diesel more than for fuels which create less carbon emissions will induce consumers to: (i) reduce the amount of travel undertaken and fuel consumed, (ii) move to public transport or non-motorised transport modes such as cycling and walking, and (iii) over the longer term to switch to more fuel efficient vehicles and to alternative fuel vehicles.

In the short term however the demand for fuel is relatively price inelastic so that large increases are necessary to reduce demand significantly. This is usually very unpopular with motor vehicle owners. An alternative approach in the short to medium term is to make available to each motorist an annual quota of petrol or diesel at the current or even reduced price and impose a much larger price for fuel once the quota is exceeded. Consumers could avoid any financial penalty by adopting a range of strategies to limit vehicle use to that dictated by the quota. If quotas were transferable, this would create a market in quotas rewarding consumers that use less than their annual allowance. The policy could be designed to be revenue neutral.

(iii) Policy details and implementation

Taxes on petrol and diesel should be set at levels to achieve targets for their consumption derived from targets for carbon emissions from road transport. Economic analysis is necessary to identify how high prices should be to meet the targets, taking into account the increasing fuel efficiency of vehicles as emission standards are tightened. Any taxes on alternative fuels should be set at levels that do not discourage switching from petrol or diesel.

If taxes on petrol and diesel result in prices for these fuels below that of alternative fuels it may be necessary to subsidise their price to achieve their required uptake.

The alternative policy suggestion is set out in the attachment.

Targets for fuel consumption could be set within the context of China's five year plans as was suggested for the emission standards policy. This means that fuel taxes and subsidies would be set within the same planning cycle.

(iv) Advantages and limitations

While the impact of increasing fuel prices is offset to some extent over time as more fuel efficient vehicles are introduced, in the short term large increases in prices are necessary to achieve significant reductions in demand for petrol and diesel. These increases in prices will be unpopular and Governments are reluctant to impose them.

The alterative policy may be more popular and achieve carbon emission targets more easily.

(v) Consequences

Increasing taxes on petrol and diesel will encourage the use of alternative transport fuels and more efficient transport modes, such as public transport, cycling and walking.

This ability of consumers to switch from petrol and diesel will depend on the availability of alterative transport technologies, alternative fuels and the capacity of the public transport network.

4.3 Vehicle Purchase Taxes and Registration Fees

(i) Proposed policy

Redesign vehicle purchase taxes and registration fees with the main objective being to reduce carbon emissions.

(ii) Rationale

At least 15 member countries of the European Union, including France, Germany and the United Kingdom have introduced passenger car taxes that are totally or partially based on a vehicle’s carbon emissions or fuel efficiency. These taxes are levied either at the time of purchase or as an annual registration or circulation tax.

Differential taxes on the purchase of vehicles and differential annual registration fees (circulation taxes) for vehicles can both reduce the demand for high carbon emitting vehicles and shift the demand towards more efficient transport modes. If vehicles are inspected for fuel efficiency each year as part of the registration process, this reinforces the effect of these policies. Subsidies for the purchase of low carbon vehicles act in the same way by reducing the price of these vehicles compared to conventional vehicles.

At least 13 countries, including Canada, France, Germany the United Kingdom and the United States have introduced programs aimed at replacing older, less efficient vehicles with newer models. The main reason for this has been the economic downturn but environmental concerns have also been important in the design of these programs in some countries. Programs typically consist of rebates to be used for the purchase of the new vehicle.

The Automotive Industry Restructuring and Revitalisation Plan released by the Chinese Government in January 2009 contained major initiatives to address concerns about pollution and climate change. In particular the Plan aims to increase the market share of cars with a capacity of 1.5 litres or less to 40% and for those with a capacity of 1.0 litres or less to 15%.

The measures to achieve this:

- include a lowering of the vehicle purchasing tax from 10% to 5% on cars under 1.6 litres capacity and an increase of the tax on larger cars, minivans and SUVs;

- the establishment of a fund of RMB5 billion to help rural citizens upgrade 3-wheelers and low speed vehicles to small vehicles of 1.3 litre capacity or less; and

- increased subsidies to encourage people to scrap old cars and made it easier to buy new cars.

In January 2009 the Government announced a policy to provide subsidies for the purchase of hybrid, electric and alternative fuel vehicles in 13 pilot cities including Beijing and Shanghai. This is largely aimed at buses and taxis and vehicles used by the government in areas such as the postal services. Zero emission and alternative fuel cars can receive subsidies of between RMB 60,000 and RMB 600,000.

(iii) Policy details and implementation

It is proposed that:

- Vehicle purchase taxes in China be based on the vehicle's carbon emission level as measured in g/km.

- A zero tax rate or subsidies on the purchase price be implemented for vehicles that achieve emission levels that fall below a certain percentage (say 75%) of the emission standard for that weight class.

- Annual registration fees be set on the same basis.

- Vehicles be checked annually to determine their fuel efficiency prior to registration renewal.

(iv) Advantages and limitations

For some consumers increasing purchase taxes will deter them from buying vehicles and encourage greater use of more carbon efficient modes of transport. For most consumers the effect will be to shift from higher to lower emission models.

As the Chinese vehicle fleet has been growing so fast, its average age is quite low. This means that programs that change buyer behaviour through changes to new vehicle purchase prices can have a larger effect more quickly than in other countries.

(v) Consequences

The ability of consumers to switch higher to lower carbon emission vehicles will depend on the availability of these vehicles and their fuels and the capacity of the public transport network.

4.4 Development of Alternative Fuel Infrastructure

(i) Proposed policy

Provide support for the development of electric vehicle recharging stations and other infrastructure requirements for alternative fuel vehicles.

(ii) Rationale

The uptake of electric and hybrid electric vehicles will be maximised if there is adequate infrastructure to support the provisions of alternative fuels required by these vehicles. Electricity charging stations and/or battery replacement should be designed so that their use is as convenient as current petrol and diesel filling stations. In the early stages of introducing this infrastructure, the upfront cost may need to be subsidised until there is sufficient volume of use to justify a commercial service.

While the Government could mandate the use of alternative fuel vehicles by Government agencies and provide appropriate infrastructure within Government facilities, it could also subsidise the development of this infrastructure by private fleet owners as well as provide charging stations in locations such as car parks, shopping precincts and within conventional filling stations.

Large scale government procurement policies of alternative fuel vehicles would: (i) encourage the development of these vehicles by manufacturers by providing sufficiently large sales to recoup development costs, and (ii) provide an economic justification for the development of alternative fuel infrastructure by electricity suppliers and other organisations.

(iii) Policy details and implementation

In the early stages, government support should be concentrated on providing charging stations in situations where a car is parked for a significant period of time, such as parking areas provided by large employers, Government agencies, shopping malls, airports, railway stations, and large apartment blocks. Organisations which have fleets where a significant proportion can be converted to fully electric or hybrid vehicles, such as delivery vans or taxis, should be given preference. Inner city areas where congestion is high could also be targeted for early introduction of infrastructure.

Close coordination with electricity grid and supply organisations and local government will be required.

(iv) Advantages and limitations

Government commitments to buying a certain number of alternative fuel vehicles would provide certainty for vehicle manufacturers and infrastructure providers. Risks remain for the government in allocating preferences to specific technologies, which may reflect biases towards local production rather than leading edge innovation or best practice.

(v) Consequences

The carbon emission benefits arising from the greater use of electric vehicles depends on how the electricity is produced and distributed. The effectiveness of this policy therefore depends on emission policies adopted for the electricity power industry.

4.5 Promotion of Alternative Transport Modes

(i) Proposed policy

Provide support for more fuel efficient modes of transport by increasing the capacity of public transport and through the systematic introduction of congestion charges in large cities.

(ii) Rationale

In general, private passenger vehicles such as cars are the most carbon intensive mode of transport, in terms of passenger kilometres travelled. Buses and trains have lower emissions, as do non-motorised modes of transport such as cycling and walking.

As policies are introduced to limit demand for private passenger transport, other modes must be made more available and attractive to meet the demand for transport.

For freight transport, rail and water transport have less carbon emissions per tonne kilometre than road transport.

(iii) Policy details and implementation

Lower carbon intensive modes of transport such as buses and trains can be made more attractive by subsidising their prices, and making them easier to use by providing more extensive networks and faster and more frequent services.

Dedicated lanes on roads can be provided to more fuel efficient modes of transport such as cycling and multi-passenger vehicles. Public transport, cycling and walking can be encouraged within inner city areas by preventing access from carbon intensive vehicles through licensing restrictions and congestion charges.

Use of public transport can be enhanced by the provision of more parking space at train and bus stations, and coordinated inter-modal services.

(iv) Advantages and limitations

In the longer term greater use of rail for passenger and freight transport will require a significant investment in providing infrastructure, such as new rail routes above and below ground, better control systems and logistics planning.

The ability to provide dedicated lanes is likely to be hampered within some cities because of legacy infrastructure and opposition from motorists.

(v) Consequences

The capacity to achieve greater use of alternative modes of transport is heavily influenced by land planning so policies in this area also need to be considered.

5. Automotive Technology Roadmaps

While the Chinese Government has given strong indications of its on-going support for the domestic automotive industry and provided assistance in the development of alternative fuel vehicles, it has not produced a comprehensive roadmap of how the industry should develop or the how the technology required to meet its objectives should be developed or acquired.

Roadmaps are common in industries that are reliant on the development of new technology to maintain their competitive positions. Thus roadmaps have been developed in the USA and elsewhere for the semiconductor, software, nanotechnology, aerospace, light metals and building industries. In Australia, the Department of Resources, Energy and Tourism published a Hydrogen Technology Roadmap 'to assess Australia's hydrogen research capabilities and strengths and to identify what actions Australia could take to prepare for the possible emergence of a hydrogen economy' (Wyld Group 2008). This roadmap however concentrated on stationary energy applications with little discussion of potential use in road transport.

The NRMA set up The Jamison Group to produce "A Roadmap for Alternative Fuels in Australia" (Jamison Group 2008) which sets out a series of recommendations to reduce dependence on fossil fuels in transport. However there is only limited discussion of how to develop alternative technologies for application in Australia. The CRC for Advanced Automotive Technologies has reviewed Technologies for Sustainable Vehicles (Albrecht et al 2009) as the first report of its project to determine the impact that electric vehicles could have on CO_2 emissions in Australia, and to determine the requirements for charging infrastructure, the impact on the electricity demand, and the need for additional renewable energy generation. Again however the report does not specify a technology roadmap for the introduction of electric vehicles in Australia.

For a number of years, Japan has had strategies and associated technology development programs to develop more fuel efficient vehicles and to reduce carbon emissions within the transport sector. In 2009 the New Energy and Industrial Technology Development Organization (NEDO) released the final draft of the "2008 Roadmap for the Development of Next Generation Automotive Battery Technology." This roadmap covers the development of batteries used in plug-in hybrid cars and electric cars, which are expected to play main roles as next generation vehicles. Performances and costs at present as well as those to be attained by 2010, 2015, 2020 and after 2030 are shown as target values. The overall aim is to develop innovative batteries that will have 7 times the performance of current batteries at 1/40 of current prices. The roadmap fits within the larger Next-Generation Vehicle and Fuel Initiative announced in May 2007 by the Ministry of Economy, Trade and Industry (Noda 2008).

In the USA the Department of Energy released its National Battery Collaborative (NBC) Roadmap in December 2008 (USDOE 2008). The NBC is a 6- to 8-year program with funding up to $4.5 billion. The aim of the NBC is to help ensure that the United States leads the world in current and next generation battery technology and establishes a robust and dominant U.S.-based battery manufacturing industry.

The United States Council for Automotive Research (USCAR) was founded in 1992 as an umbrella organization for collaborative research among Chrysler Group LLC, Ford Motor Company and General Motors Company. Its goal is to further strengthen the technology base of the U.S. auto industry through cooperative research and development. The United States Advanced Battery Consortium is part of USCAR and aims to develop electrochemical energy storage technologies which support commercialization of fuel cell, hybrid, and electric vehicles. The consortium has set long term goals for the cost and performance of advanced batteries for electric vehicles (USABC 2010).

The US state of California introduced its Zero Emission Vehicles (ZEV) Program in 1990 to promote the use of zero emission vehicles. The program goal is to reduce the pervasive air pollution affecting the main metropolitan areas in the state, particularly in Los Angeles, where prolonged pollution episodes are frequent. Although concentrating on pollutants such as NOX and SOX and particulates, the program has also incorporated California's greenhouse gas targets, namely to reduce these to 1990 levels by 2020 and by 80% by 2050. The program was subject to a review by staff of the California Air Resources Board and this involved a comprehensive review of electric and fuel cell vehicle technologies which set out development paths for these technologies (CARB 2009).

In recent months the International Energy Agency (2009) and the Canadian Government (Electric Mobility Canada 2009) have also released technology roadmaps for electric vehicles.

As noted earlier, the most comprehensive strategy for reducing carbon emissions from transport is that announced by the United Kingdom in 2009. The programs and policies making up this strategy have been supported by a range of technology and policy reviews such as the King Review of Low Carbon Cars (King 2007, 2008), the report of the New Automotive Innovation and Growth Team (NAIGT 2009) and other reports (eg Ricardo 2009). This latter report on the future of the automotive industry in the UK incorporates a comprehensive technology roadmap and research agenda for achieving low carbon transport. These recent reports build on an earlier major foresight exercise by the UK motor vehicle industry (SMTT 2004) which has recently been updated (KTN 2009).

The UK Energy Research Centre provides a review of energy technology roadmaps relevant to the UK including those for road transport and hydrogen and fuel cells (UKERC 2009).

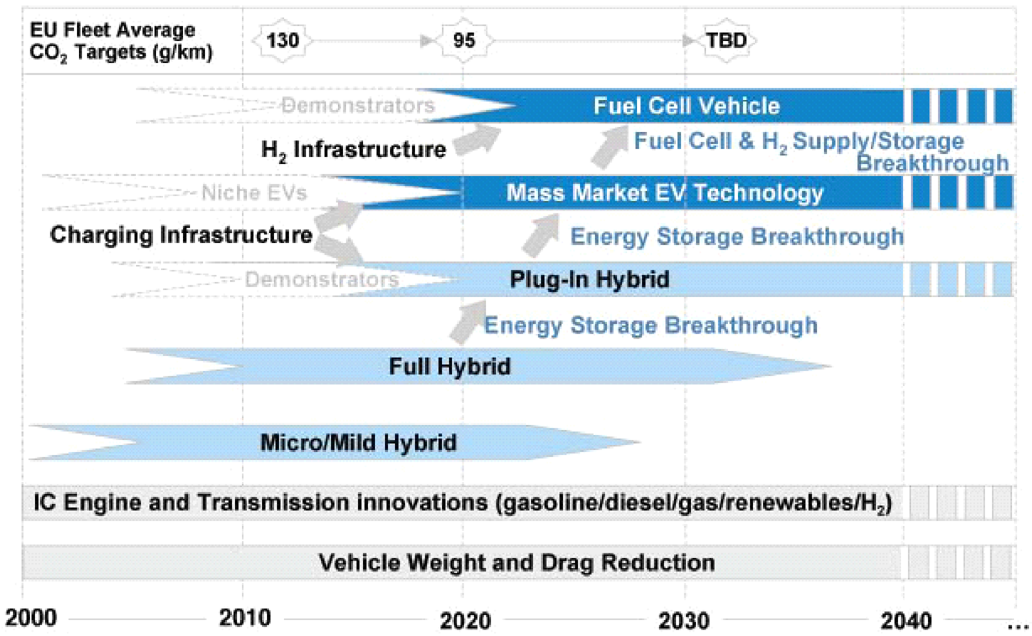
Most of the roadmaps referred to above set out goals and expected technology development paths for improvements to conventional transport technologies, emerging technologies and anticipated technologies. The UK Consensus Roadmap developed by NAIGT is a good example and an overview of this is reproduced as Figure 14.

The roadmap notionally covers the period from 2010 to 2040 and begins at the bottom of the figure with those efficiency improvements that are possible for any type of road transport vehicle such as reducing weight through the use of light metals and composite materials and improving aerodynamic design so designing vehicles so that drag is minimised. Improved tyre technology is also important in reducing rolling resistance.

The second level of the roadmap covers improvements that can be made with conventional fuel internal combustion engines either using existing fuels such as petrol and diesel or alternative fuels such as natural gas, biogas, biofuels derived from crops, cellulose or algae, and possibly hydrogen. The efficiency of engines can be improved with advanced turbocharging, better injection control, lowering engine friction, electrification of engine accessories and other known or near term technologies.

Figure 14. UK Transport Technology Roadmap

The Consensus Product Roadmap, mutually agreed by OEMs,
defines future direction to develop products that will benefit UK plc



Source: NAIGT, 2009

Hybrid vehicles using both ICE engines and electric motors are the next group of technologies on the roadmap and range from micro hybrid in which the electric motor drives accessories through to fully hybrid in which the engine creates electricity to drive the electric motor. Currently most emphasis is on plug-in hybrid electric vehicles (PHEV) which rely on recharging the batteries that provide power to the motor while the IC engine provides power on long distance trips. As noted on the figure, the full development of both PHEVs and fully electric vehicles require significant improvements in battery technology to match the performance of current vehicles at a reasonable price.

The other main option for low carbon vehicles is those powered by fuel cells which convert a fuel directly to electricity to drive electric motors. Although there are a number of fuels that can be used in a fuel cell, hydrogen is the one which has gained most support. There are however major obstacles to producing, transporting, and distributing hydrogen and in storing sufficient amounts on board which need to be overcome before fuel cell vehicles are competitive with conventional vehicles.

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Appendix A

Technology Options for Reducing Carbon Emissions from Transport

This section reviews those key technologies with respect to cars, trucks, buses that will form the basis of the technology roadmap to be developed in the remainder of this project.

A.1 Introduction

Substantial near-term improvements in the fuel economy of new light-duty vehicles can be achieved using available, cost-effective technologies. By 2015, new car fuel consumption can be reduced by up to 25% at low cost by fully exploiting available technologies. In some cases these have negative costs to consumers because the time–discounted value of fuel savings is greater than the cost of the technologies. Technologies include direct injection systems, other engine and drive-train improvements, lightweight materials, and better aerodynamics. Although stock-turnover considerations mean that the full effect of these improvements would not be realised until 2020-2025, they could still reduce the average fuel use per kilometre for the entire stock of cars by 10-15% over the next ten years.

The means for accelerated technological change in the automotive industry in the longer run will be advances in the application of information technologies, new materials technology, engineering breakthroughs in relation to advanced engine technologies, and the comprehensive utilisation of small scale technologies throughout the industry.

The scope of the changes ranges over every aspect of the car's design, ranging from engines, motor parts, transmission, ignition systems, exhaust controls, vehicle bodies, suspensions, brakes, wheels, vibration dampeners, tyres, filters, coolants, external coatings, windscreens and windows, seats, dashboard and instrumentation, on-board diagnostics, enhanced electronics for driver comfort and entertainment, and automated vehicle control systems. At the same time, the design and manufacture of automobiles will be revolutionised by the application of advanced virtual reality design technologies.

A.2 Alternative Fuels

One area of technological development of significance to sustainable transportation is that of alternative fuels. Transportation fuels that are alternative to refined petroleum products are: (i) natural gas-based fuels, and (ii) biofuels.

Alternative fuels do not necessarily emit less greenhouse gases than gasoline when used to power a vehicle. Most alternative fuels do contain less carbon per unit of energy than gasoline, but do not necessarily emit less total emissions *well to wheel* – including emissions from the extraction of the alternative fuel or feedstock, energy used in its production, distribution and storage, and its use in vehicles – in a life cycle analysis of fuel.

A few alternative fuels promise substantial reductions of greenhouse gases on a full fuel-cycle basis everywhere. These include ethanol and methanol under certain circumstances, namely when these alcohols are derived from cellulosic (woody) feedstock using advanced, low-energy production processes. However, current commercial alcohol production for transport does not use advanced processes and does not provide greenhouse gas reductions compared to gasoline.[1] Other low greenhouse gas fuels include highly efficient fuel-cell vehicles if produced from renewable or other low GHG feedstocks.

Short-term savings in well-to-wheel emissions can be gained through:

- the use of turbo-injection diesel engines running on low sulphur fuel (25%);
- the use of natural gas (LPG, CNG or LNG) as a fuel (around 20% for CNG);
- cellulosic alcohols (ethanol and methanol) and biodiesel promise larger reductions (50% or more); and
- hydrogen, although the net reduction of emissions depends on how the hydrogen is obtained – on current technologies it has substantially higher emissions, but it could be considerably lower with new, advanced technologies.

In the longer term, improvements in vehicular efficiency of 50% to 55% can be achieved for all fuels used in three-litre combustion engines. Some fuels, such as cellulosic ethanol, promise even greater long-run reductions relative to gasoline, due to expected advances in upstream processes.

Methanol and DME from Natural Gas and Coal

Alternative fuels currently subject of much interest are methanol and DiMethylEther (DME).[2] Both fuels could be produced from a wide range of feedstocks, including coal, natural gas and biomass. Methanol production from natural gas is an established technology. However, the bulk of this methanol is used for chemicals.

DME can be used as a fuel for power generation turbines, diesel engines, or as an LPG replacement in households. Current global DME production amounts to 0.15 Mt/yr. Its main use is as aerosol propellant for hair spray. Two coal-based DME plants are in operation in China, with a total capacity of 40 kt/yr. A rapid expansion of Chinese DME production is planned, to more than 1 Mt/yr.

Biofuels

In the future, ethanol and biogas have increased prospects for use in cars and trucks designed and built to be operable on different types of fuel. Piston engines in conventional motor vehicles can be adjusted to run on alternative fuels (such as ethanol and methanol) which reduce nitrogen-oxide emissions. A new technology known as the flexible-fuel vehicle has been developed which will detect which type of fuel its tank has been filled with and

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[1] Ethanol produced from grains using conventional harvest and distillation techniques has relatively high emissions (median estimates above gasoline).

[2] DME is non-toxic, contrary to methanol.

automatically adjust the engine; this would increase the flexibility of the vehicle for operational purposes.

Ethanol and biodiesel, as typically produced today in IEA countries, can reduce CO_2 emissions per litre of fuel by 20% to 50% compared with gasoline or diesel fuel, respectively, on a 'well-to-wheels' basis, but they are not near-zero-emissions fuels. Apart from fuel production facilities, the infrastructure investment required to support the use of advanced liquid biofuels may be relatively small, since these fuels can be blended with conventional fuels and transported using today's fuel systems in the future. In the future, synthetic diesel fuel should be blendable in any proportions with petroleum diesel and used in conventional diesel vehicles.

World fuel ethanol production is equal to about 0.5% of global oil consumption. The production is mainly concentrated in Brazil and the United States. It is based on sugar cane (in the case of Brazil) and corn (in the case of the USA). The resource base is gradually widening to cellulosic crops and even wood.

Various countries and regions are planning a rapid expansion of ethanol production. Some scenarios suggest that a tenfold increase by 2020 (to 280 billon litres and 3.3% of the market for transportation fuels) would be feasible, based on sugar can ethanol alone.

The production of ethanol and methanol from advanced processes using cellulosic biomass (wood, grasses and wastes) is also being examined. These alcohol fuels offer potential for use in pure form, in mixtures with other fuels, in hybrid vehicles, or as a chemical fuel in fuel cell vehicles. The advantage of these fuels is that production of their feedstock is not as carbon-or land-intensive as grain crops. Because wood and grass resources are renewable and store vast amounts of carbon, most of the CO_2 emitted during the use of cellulosic biofuel could be offset by the additional CO_2 removed from the atmosphere by the renewable wood and grass used as feedstock. An important consideration in the development of biofuels is the environmental and agricultural effect of feedstock production. Such feedstocks offer far greater potential for emissions savings than existing feedstocks such as sugar and grains. Their advantage comes from a broader range of potential feedstock, such as trees, grasses and forestry waste materials, and a more efficient chain of fuel production and use.

The IEA has studied the question of global potential for biofuels production. Their studies yield a wide range of estimates, but all indicate that it may eventually be possible for biofuels to provide a high share of transport fuel, with 50% to 100% well within the range of several studies. Such estimates depend on assumptions covering many factors, including population growth, food demand, demand for alternative uses of biomass, and demand for transport fuel.

The higher the future fuel demand, the harder it will be for biofuels (or any energy source) to fully meet this demand. The IEA projects that the range of biofuels production potentials could meet at least 20% of future transport fuel demand by 2050. Whether this can be done cost effectively is another matter. Other concerns include the effects of intensive biofuels production on ecosystems and the possible effects of developing genetically modified organisms. The latter might be important for improving productivity and lowering costs, but is controversial.

As liquid biofuels become a more important component of the transportation fuel supply, research collaboration has identified four key areas to address:

- bio-based ethanol processes such as pre-treatment and enzymatic hydrolysis of lignocellulosic feedstocks and end uses for lignin;
- potential volume and availability of liquid biofuels from the biomass industry;
- improved process economics (once feedstock availability and price are known); and,
- standards and policies for improved deployment.

A.3 Engine Technologies

The most exciting area, so far as potential for the increased energy efficiency of vehicles is concerned, is engine technology. An increase of 25% or more in the fuel efficiency of the internal combustion engine is readily attainable through the gasoline direct injection petrol engine, the use of engines in a low-load mode, and advanced diesel engines.

Among the new types of internal combustion engines likely to appear in the next decade or so is an advanced two-stroke engine accompanied by new electronically controlled fuel-injection techniques designed to both raise the efficiency of the combustion process and reduce emissions of unburnt fuel. Many of the two-wheeled vehicles which are prevalent in many developing countries are powered by two stroke engines. Two stroke motorcycles are a major source of white smoke and emissions of aromatic hydrocarbons and suspended particulate matter. Technological solutions to the smoke and unburned aromatic hydrocarbons associated with two stroke engines have now become available or are under development. They include catalytic exhaust conversion, direct cylinder electronic fuel injection and electronic computer control.

Hybrid Engines

Hybrid electric vehicles combine two power sources with at least one powering an electric motor. The range of alternative power sources includes batteries, flywheels, ultracapacitors, and heat engines. Hybrid systems come in a variety of configurations. One would use a small, constant speed internal combustion engine as a generator to power high-efficiency electric motors at the wheels, with a high-power-density battery or ultracapacitor used to provide a current boost to the motors for acceleration or hill climbing. The internal combustion engine in this case could be small, efficient and clean because it runs at one design speed. Alternative systems could rely exclusively on batteries for most trips, with the engine-generator for extended range only, or they could use both electric motors and a small internal combustion engine to drive the wheels, perhaps with the electric motors providing high power only when necessary.

Hybrid electric vehicles have three significant advantages over conventional vehicles: regeneration of energy during deceleration, automatic engine shutdown when the vehicle stops, and optimisation of engine drive to allow the electric motor to be used wherever possible. Their disadvantage is that they are heavier than conventional models because of the need to accommodate a relatively large battery pack, an electric motor and an inverter in addition to a conventional engine. This increases their manufacturing costs and reduces their potential efficiency in terms of emissions reduction. Nevertheless, fuel-economy ratings suggest fuel economy for hybrids as being 25% or better than for conventional vehicles.

Some efficiency-improving technologies, such as hybrid-electric propulsion systems, are still fairly expensive. Hybrid cars on the market today cost several thousand US dollars more than their conventional-engine counterparts[3], although costs are falling and there is some indication that companies such as Toyota are now at least breaking even on cost. In North America and Japan, consumers have shown enthusiasm for hybrids, although sales are low due to small production volumes and the availability of only a few models. In Europe, interest appears to be lower, perhaps because there are many diesel vehicles on the market that already fulfil the demand for high-efficiency vehicles to some extent.

The current high prices for petrol have triggered increased interest in hybrid vehicles. Toyota, the market leader has increased hybrid production and this could enable it to halve the price premium over conventional vehicles. Toyota aims to sell one million hybrid vehicles worldwide by 2010.

Honda has just launched a new hybrid version of its popular Civic in America and will put a hybrid engine into its luxury Acura. Producers in America, Europe and Korea have lagged behind Japan so far as hybrid technology is concerned. Ford has just announced it could increase its output of hybrid cars tenfold by 2010. Competitors, ranging from General Motors to BMW and DaimlerChrysler, are scrambling to roll out hybrids of their own.

Fuel Cells

A fuel-cell-powered vehicle is essentially an electric car with the fuel cell and storage tank (for a hydrogen-carrying substance) substituting for the battery. If the fuel is a hydrogen carrier (methanol or natural gas), an on-board reformer is required to release the hydrogen from the carrier fuel. Fuel cells work by taking hydrogen and oxygen and putting them through a chemical reaction to produce electricity and water. Excess electricity from the fuel cell can be shunted to battery storage. The vehicle can then use a high-power-density battery (or other storage devices such as an ultracapacitor or flywheel) to provide the necessary power boost for acceleration, so that the fuel cell does not have to be sized for the vehicle's maximum power needs.

[3] This cost differential varies in different markets. An important additional cost of around $US7000 arises with the need to replace the battery pack (usually after ten years). This, in turn, is tending to depress resale values for these cars.

Fuel cells are particularly efficient energy converters, they generate no harmful emissions and they can be refuelled quickly, so that range constraints are less of a problem than with battery electric vehicles once sufficient refuelling infrastructure is put into place. Three types of fuel cells may be suitable for light-duty vehicles: proton-exchange membrane (PEM) fuel cells, alkaline fuel cells, and solid-oxide fuel cells. Of the three, the PEM fuel cells are closest to commercialisation. Substantial reductions in the manufacturing cost of the fuel-cell engine are required for them to become commercially viable.

A fuel cell system using hydrogen produces no carbon dioxide emissions during vehicle use. However, the use of hydrogen fuel means the hydrogen has to be either stored on-board or produced from other fuels such as natural gas or methanol by means of a reformer. In this case, the gains in emissions savings are reduced by the impact of reforming the fossil fuel source.

With hydrogen fuel, the engine technology is simple and emissions and energy efficiency are optimised. However, current on-board hydrogen storage options are either expensive or carry significant weight and space penalties. Hydrogen has a low energy content density so that it requires a comparatively large storage area compared with other fuels. For this reason, hydrogen is often stored as a compressed gas in pressure vessels or as a liquid in cryogenic tanks. Present on-board gaseous storage is sufficient for buses, but the pressure is too low for passenger vehicles. On-board storage tanks are still too expensive and have short lifetimes, while the high energy needs for compression and liquefaction add considerably to the final cost of hydrogen. In the very long run solid storage has the potential to store hydrogen at a low volume of storage and low pressure and require fewer energy inputs. However, it is in the very early stages of development with more scientific research and a number of applied research problems needing to be solved.

In addition, the costs of developing a suitable fuel distribution network would be very large and there are difficulties associated with the potential for losses and leaks in the production process and during the filling of vehicle tanks. The ultimates cost is uncertain because only limited operational experience is available. Hydrogen refuelling stations have been built and deliver either gaseous hydrogen (90% of the stations built in 2004 and 2005) or liquid hydrogen. They either produce the hydrogen on-site from electrolysis or steam reforming, or receive it from centralised plants. There are significant potential economies of scale operating in hydrogen distribution.

The high cost of refuelling stations and the high initial cost of hydrogen for end-users due to the low level of demand and the low density of hydrogen infrastructure creates a problem. Little hydrogen supply infrastructure will be developed without significant hydrogen demand, but hydrogen demand depends on the existence of a large-scale hydrogen supply infrastructure that can deliver hydrogen at an attractive price. In order to achieve significant momentum in the transition phase, either a dedicated fleet of vehicles that operate in a small area (such as buses) or multi-fuel vehicles that can use hydrogen or gasoline will be required in order to encourage infrastructure growth.

Ballard Power Systems, the biggest maker of automotive fuel cells has formed a consortium with Daimler-Benz and Ford. A combined investment of US$1 billion is planned, and the new consortium hopes to produce an initial 10,000-50,000 cars a year powered by fuel cells. Ballard is seeking investment from China as it tries to increase sales in the world's third-largest vehicle market. Ballard has supplied the fuel cells for three DaimlerChrysler buses to for a pilot project in Beijing.

Ballard does not have the field to itself – about 30 companies are actively developing fuel cells for automotive applications, including Allied Signal and International Fuel Cells (part of the United Technologies Group) in the United States, De Nora in Italy, and Siemens in Germany. Among the vehicle manufacturers, General Motors, Honda and Toyota are also developing fuel cells.

Most fuel cell use today is limited to vehicles owned by government agencies and universities. Hydrogen-powered fuel cell buses using methanol as a primary fuel are being trialled in Europe and Australia and General Motors, Ford Toyota, Honda and DaimlerChrysler are within a few years of selling fuel cell family cars. Mercedes has developed its latest fuel cell-powered A Class, the result of a six-year research program, that uses the space between its double floor to house its fuel cell. However, the broad range of approaches being taken by vehicle producers suggests that there is no clear optimal strategy to get hydrogen and fuel cells to the market.

At present the cost of fuel cell vehicles is prohibitive with the IEA estimating it at US$167,000 currently, This breaks down into the cost of a conventional vehicle without engine (US$17,050), the cost of gaseous hydrogen storage (US$4,000), the fuel cell stock (US$144,000), and an electric engine (US$1,900). By 2010, the IEA expects the cost of the fuel cell stack could come down to US$40,000 and the overall vehicle to US$60,750. By 2030 the cost of such a vehicle might reduce to between US$22,000 (an optimistic projection) and US$27,000. The reduction in fuel stack costs to US$7,000 are achievable through mass-production and technology learning. To be competitive, the fuels stack costs need to be reduced below US$3,500, and that will require fundamental advances in materials, higher fuel cell power densities. Research is focusing on high-temperature membranes that are less prone to poisoning and enable on-board reforming. In addition to fuel cell stack cost reductions, hydrogen vehicles need improvements in their durability and reliability. Other components, such as the cost of the balance of plant, electric drive and hydrogen storage systems, need more attention.

A.4 Other Fuel-Saving Technologies

Major improvements in the energy efficiency of motor vehicles can be achieved through a radical shift in technology and design. The basic features of an advanced automobile incorporating radical new technologies are outlined below.

Materials Technology

The materials used in an average vehicle – glass, steel, aluminium and plastics – are highly energy-intensive. Moreover, traditional materials technology in vehicles is well short of optimal for recurrent vehicle energy consumption. Reconciling safety with environmental sustainability offers a considerable challenge to materials technology. Light composite structures can be even stronger than steel, although the assessment of the robustness of composites to accidental impacts is more difficult than for traditional metals. The manufacturing technology for strong, lightweight composite materials is still accomplished largely by hand and costs are prohibitive.

Much research needs to be done on the feasibility of automated manufacturing processes for new materials. Nevertheless, materials technology and its application to transportation in terms of motor body construction and for components is a key area for research in both the United States and Japan. The utilisation of new vehicle body materials, such as carbon-fibre or other composite materials, and also lighter metal alloys should increase energy efficiency by reducing mass, and at the same time have a lower energy-content in their production. The extensive use of aluminium and other light-weight materials (including high strength steels, magnesium, metal and polymer composites, titanium, and inter-metallic alloys) in suspension and other components (such as brake fittings, sway bars, and wheels) can also improve energy efficiency.

The IEA is sponsoring research on the development of revolutionary materials (structural ceramics and ceramic matrix composites) for operation at higher temperatures and pressure. Hard, wear-resistant, durable and insulating ceramic coatings are an expanding technology for improving the durability, reliability, and efficiency of diesel and turbine engines for automotive and industrial power. A key feature of the research is to assess methods of quantifying thin ceramic coating adherence in order to establish test standards for evaluating new technologies.

Research is also being conducted in the area of surface engineering in order to improve the resistance to wear and contact damage. Friction loss is inherent in most mechanical systems. This research explores the possibility that surface texture designs could reduce friction using thin films and coatings under a broad range of contact conditions.

Electronics

Integrated starter/alternator electrical systems allow engine shut down during idling or deceleration and instant restarting when needed. Regenerative braking is another energy saving technology. Improved engine efficiency operating under low-load conditions (e.g. shutting down cylinders) could increase engine energy efficiency by up to 25%. Improved drive-train efficiency and the introduction of more electric-drive-train components, such as 'drive-by-wire' (fully electric) steering can also improve energy efficiency.

Vehicle Maintenance

New technologies have an important role to play in enabling improvements in the maintenance of road vehicles. Better maintained vehicles will be able to operate close to their rated energy efficiency. On-board diagnostic systems monitor all the emission controls on a vehicle and warn the driver, through instrument panel displays, of any faults that may occur. These systems have become mandatory for new passenger motor vehicles in the United States. Even greater opportunities for detecting malfunctioning vehicles is provided by the use of transponders to allow roadside units to monitor the condition of vehicles as they drive by. Within 20 years, these systems could be installed in sufficient numbers to render inspection and maintenance programs unnecessary. The aerospace industry has been a leader in developing preventive maintenance strategies, and it continues to be an area of significant technological development. There are implications in all of this for the maintenance of rail and marine transport equipment.

Fuel Saving Technologies

Some examples of fuel-saving technologies are summarised below:

1. *Advanced transmissions* offer an improvement of several per cent in energy efficiency.
2. *Advanced aerodynamic styling.* Enhanced streamlining, using sophisticated body design and reduced frontal areas, aimed at reduce the vehicle's drag coefficient, can offer improvements in energy efficiency of about 2%.
3. The introduction of high-pressure, low-rolling resistance *tyres* can reduce fuel consumption by 1.5%.
4. More efficient *accessory equipment* (such as air conditioners) can increase energy efficiency.

In-use Vehicle Fuel Consumption

Light-duty vehicles (LDVs) on the roads in IEA countries typically use 20-25% more fuel per kilometre than indicated by their tested, rated fuel economy. Much of this gap is inevitable owing to traffic congestion. Integrated urban/transport planning and road traffic management therefore become important influences on fuel consumption (discussed in more detail in a later sub-section of this paper).

Other measures may help to reduce in-use vehicle fuel consumption. The IEA, in cooperation with the European Conference of Ministers of Transport (ECMT), recently completed a study of technologies and measures to improve 'in-use' or 'on-the-road' fuel economy of light-duty vehicles.

The IEA estimates that a 10% reduction in average fuel consumption per kilometre could be achieved for LDVs across IEA countries through a combination of the following measures:

- stronger inspection and maintenance programs that target fuel economy;
- on-board technologies that improve in-use fuel economy as well as driver awareness of efficiency, such as adaptive cruise control systems and fuel economy computers;
- better and more widespread driver training programs; and
- better enforcement and control of vehicle speeds.

Cost estimates for the CO_2 emissions reductions offered by in-use technologies and measures vary, but many technologies show low or negative cost per tonne of avoided emissions in some situations. The effects of technologies and measures on fuel consumption also vary, but a package can be developed that provides a 5-10% improvement in vehicle fuel economy on-the-road for a given tested fuel economy.

The self-driving car is undergoing developmental work. It can be the means of reducing in-fuel consumption through more efficient use of road space in urban areas. General Motors is trialling a car that uses updated technology combined with several existing innovations and could be in production soon. The GM car is based on the Opel Vectra, a mid-sized family vehicle and is undergoing evaluation at General Motors' subsidiary in Germany.

The advanced technologies incorporated in the self-driving car are:

- Automatic cruise control (already available in many expensive cars) incorporating a new laser technology for use at shorter distances and lower speeds.
- A system that corrects the car when it drifts out of its lane. Lane-departure warning systems have been introduced for a very few cars already, but the new technology uses cameras and laser beams linked to an electronic control unit attached to an electric power-steering unit.

The system is unlikely to have a smooth progression into production, however, despite achieving what General Motors says is a very high level of reliability during the development stage, and despite a modest estimated cost of US$1800 a vehicle. Several obstacles stand in the way. Self-steering cars are currently illegal in most European countries, and carmakers are concerned about issues of legal responsibility. In addition, most people would prefer to be active drivers solely in control of the vehicle. Moreover, the system is basically designed for heavy urban traffic or motorway conditions, and not the open road.

A.5 Trucks and Buses

Trucks

Heavy-duty vehicle efficiency can be improved by about 25% (in long-distance transport) to 50% (in short distance stop-and-go transport). Heavy duty vehicles operate in both long-distance and local transport, with the total fuel use being roughly equally split. After driver compensation, fuel costs are typically the second largest expenditure item for heavy-duty vehicle operators. As a result, virtually every large new truck and bus in the United States is already equipped with a turbo-charged, direct-injection diesel engine, the most energy efficient internal combustion engine available. State-of-the-art turbo-charged diesel engines achieve 46% to 47% peak thermal efficiency, versus only 25% for spark-ignited gasoline engines. Thus, there is less potential for improving fuel efficiency in heavy-duty than light-duty vehicles.

A variety of new diesel engines are becoming available to freight trucks. *Turbocompound* engines are technically ready but have not been commercialised although high fuel prices may provide an incentive for commercial developments. *Low-heat-rejection diesels* are compression-ignition engines that run at very high temperature and do not use energy-draining cooling systems. *Gas turbines* harness fuel energy by using the burning fuel's kinetic energy to spin a turbine rather than drive a piston. Both engines types require the development of mass-producible materials with higher heat resistance than currently available (structural ceramics or heat-insulating composites). Estimated fuel savings for low-heat-rejection diesels are as high as one-third over modern diesels.

Electronic engine control systems can monitor and adjust fuel consumption, engine speed, idle time, road speed, and other factors. They can also provide extensive feedback data to drivers on energy use. They were developed largely to meet new emissions requirements, but they have energy-efficiency benefits as well. They are currently available on some long-haul heavy trucks. Because they can recover braking energy and shut off the engine during idling, hybrid drive trains are a promising technology to heavy-duty vehicles that operate locally, in stop-go mode.

Electronic transmission controls measure vehicle and engine speed and other operating conditions, allowing the transmission to optimise gear selection and timing, thus keeping the engine closer to optimal conditions for either fuel economy or power than is possible with hydraulic controls. This technology offers about 4% improvement in fuel economy.

Better power/load rations can be obtained through the increased use of B-double and B-triple combinations. However, there are ultimate mass limits to the extent these designs can be taken, as well as impacts on road wear and tear to be taken into account. In addition, allowable truck size is controlled by regulations in both the United States and Europe, which are not fully uniform in either region. The use of lighter materials in truck and trailer bodies, engines and components can also improve power/load ratios, but there is sometimes a trade-off with safety to be considered in implementing such technologies.

It should be noted that currently available technology does not allow automakers to improve light-truck fuel economy through advanced aerodynamics to the same extent that they improve passenger vehicles. Load carrying requirements impose structural and power needs that are more of a function of the payload weight than the body weight of the truck, yielding fewer flow-through benefits from weight reductions. Open cargo beds for pickups and large ground clearance limit potential for aerodynamic improvements. Additional safety and emission requirements would create penalties for fuel economy.

Nevertheless, modifying the shape of the truck and trailer can yield significant reductions in energy use by reducing air resistance. The primary aerodynamic improvement used on heavy trucks today is the cab-mounted air deflector, which began to be installed in the 1970s. Since then, a number of improved aerodynamic devices have been used, including various devices to seal the space between the truck and the trailer, front air dams, and improved rooftop fairings. The simpler devices can often be retrofitted to existing trucks and, according to one analysis, offer rapid paybacks. Aerodynamic improvements to trailers include side skirts to minimise turbulence underneath the trailer and rear ‘boat-tails’ to smooth airflow behind the trailer. The energy savings of these devices are difficult to measure. Aerodynamic improvements to tractor-trailers are also limited by the need to connect quickly and simply to trailers of different designs and sizes, to tolerate road surface uncertainties, and to meet size regulations.

Radial tyres have largely replaced bias-ply tyres, except for special applications such as off-road use. This has resulted in reduced fuel use. A more recent tyre innovation is 'low-profile' radial tyres, which weigh less than standard radials and thereby save energy. Also now commercially available are 'low rolling resistance' tyres, which use new compounds and designs to reduce rolling resistance. Finally, fuel savings can be achieved by tailoring tyres to specific types of service, powertrains, and roads, including the use of smaller-diameter tyres for low-density cargo, and of very wide single tyres to replace dual tyres. However, truck tyres, unlike automobile tyres, are often recapped when worn: low-profile and low rolling resistance technologies, which cannot be incorporated into recapped tyres, will largely be limited to sales of new tyres.

Buses

The use of *dimethyl ether* (DME) provides a way to put natural gas into a convenient liquid form as a motor fuel. A commercially viable process for DME production has recently been developed. Interest in DME is generated, in part, because it can be produced from a wide range of feedstocks, including natural gas, biomass, agricultural and urban waste and coal. Like natural gas and methanol, DME is also a potential fuel for future fuel-cell technologies. It can utilise LPG infrastructure to a large degree. It is some way towards commercial application.

Biodiesel is an ester-based oxygenated diesel fuel made from vegetable oil or animal fats. It can be produced from oilseed plants such as soybeans and rapeseed, or from used vegetable oil. It has similar properties to petroleum-based diesel fuel and can be blended into petroleum-based diesel fuel at any ratio for use with conventional diesel engines. It significantly reduces greenhouse gas emissions. However, it is currently very expensive (an option is to produce it more cheaply for waste cooking oils, but supplies are limited) and there are concerns about its impact on NO_x emissions.

Several demonstrations for transit authorities of *hybrid-electric* vehicles have taken place. The total worldwide fleet could reach the thousands within a few years. Fuel economy has been tested in the range 55-60 litres per 100km, compared with 70-73 litres per 100km for standard diesels. The efficiency advantage for the hybrid buses occurred despite the fact that they were heavier than conventional diesel buses. Much, although not all, of the additional energy used for accelerating this weight can be recovered via regenerative braking in the hybrid-electric vehicle. Vehicle weight is a concern for hybrids from the stand point of passenger-carrying capacity.

A life-cycle cost analysis of hybrid-electric vehicle technology is complicated by the fact that the technology is quite young and therefore a large body of real-world operating data does not yet exist. It is thought likely that capital acquisition costs, despite reducing sharply, will always be higher than for conventional buses since they include several additional components. Battery replacement costs are a second factor, while maintenance costs are as yet unknown. Against these higher costs, fuel costs and emission costs are substantially lower. It is likely that these buses will require at least several more years of development, testing and cost reduction before they enjoy widespread commercial application.

While the understanding of the technology underlying *fuel-cell* stacks is approaching maturity, many surrounding vehicle and infrastructure issues remain in early development. In particular, costs, parallel development of electric-drive systems, on-board fuel storage and refuelling infrastructure challenges are likely to impede hydrogen fuel cells from becoming a competitive propulsion system in the near term and perhaps for another decade or more. Moreover, industry has no clear development path and seems to be moving in several different directions. Urban transit buses are serving as an important testing ground for fuel-cell buses.

When pure hydrogen is stored on board the vehicle and used directly, fuel-cell vehicles produce virtually no emissions except water. However, if emissions produced upstream, such as from the production of hydrogen, are included, the environmental impacts of fuel cells may be substantial, depending on the source of hydrogen and the method of reformulating hydrogen-rich fuels into hydrogen; production of hydrogen from natural gas produces a 30% savings, depending on the source of electricity. The long-term vision is to produce hydrogen by electrolysis using renewable energy sources, which would yield zero GHG emissions. On-board reforming of fuels shows that GHG emissions are only marginally lower than diesel buses.

One advantage to developing fuel cells for the transit bus sector is the central fuelling infrastructure. Since transit buses are typically centrally refuelled, new refuelling infrastructure would only be needed at bus depots. In addition, buses have more space than smaller vehicles to accommodate the fuel cell and the compressed-hydrogen tanks. However, scale economies for fuel cells will be largely driven by stationary applications, and the truck market will be of critical importance in developing transport-specific components of fuel-cell systems.

The IEA estimates that the cost of hydrogen fuel cell bus engine systems is around US$1,000,000, compared with US$500,000 for conventional diesel engines. The IEA calculates that fuel cell buses will become competitive if their additional cost is around US$100,000. Buses are potentially the easiest market in which to introduce fuel cells in the transport sector because refuelling is concentrated at fleet depots. However, other potentially leading markets for fuel cell vehicles are delivery vans (which have been operating in Germany since 2001), electric wheelchairs and carts, and forklifts.

A.6 Timelines for Changes in Technology

Changes in transport technologies that facilitate reductions in greenhouse gas (GHG) emissions can be considered with respect to three different time frames: near-term, medium-term, and long-term.

Technologies for the Near Term

Transport technologies for emissions-savings in the near-term are those that are currently commercially available, but whose diffusion is limited. The principal examples are:

- advanced internal combustion engines;
- hybrid electric road vehicles;
- the use of light-weight materials in road vehicles;
- improved aerodynamic styling in road vehicles;
- advanced fuel-saving transmissions;
- the use of high-pressure, low-rolling resistance tyres;
- more efficient accessory equipment in road vehicles;
- the use of ethanol derived from sugar as a fuel for road vehicles;
- on-board diagnostics to monitor vehicle emissions;
- the wider use of adaptive cruise control systems and fuel economy computers;
- advanced truck and bus designs for fuel economy;
- the increased use of electronic road pricing as a means of reducing traffic congestion;
- improvements in freight transport relating to trucking operation and system efficiency, reducing freight travel requirements, mode switching and advanced logistics and supply chain management; and
- the wider use of advanced information technologies to reduce transport requirements and facilitate virtual technologies.

The above list demonstrates that there are a huge range of newly available technologies that should provide individual incremental improvements in energy efficiency and, collectively, very substantial aggregate improvements. This would flow through to reduced GHG emissions on what would otherwise occur, given the constant emissions-intensity of energy consumed in transportation. In addition, the wider use of biofuels would reduce the emissions-intensity of transport energy. The key issue for the immediate future is accelerating the diffusion of such technologies. This implies overcoming the barriers to the wider diffusion of these technologies.

Technologies for the Medium Term

Transport technologies for the medium-term are technologies that may not be commercially available for some years but are likely to be in general use by 2030 and 2050 at the latest. Examples include:

- advanced two-stroke engines for two-wheeled vehicles;
- fuel-cell-powered road vehicles;
- ultra light-weight road vehicles;
- integrated starter/alternator electrical systems for road vehicles;
- the use of ethanol derived from cellulosic biomass as a fuel for road vehicles;
- advanced vehicle maintenance systems focussing on fuel economy;
- the introduction of self-driving cars; and
- further advances in truck and bus design.

This list contains many examples of technologies that would further increase the energy efficiency of transport. It also contains examples of technologies that would facilitate the move towards zero-emission transport (ZET) systems. These include advances in the efficiency of transit systems based on zero-emissions electricity and the commercialisation of fuel cell road vehicles based on ZET hydrogen. The latter would be accompanied by the initial development of a hydrogen fuel infrastructure to service road transport. The diffusion of ZET transport would most likely take a considerable amount of time.

Technologies for the Long Term

Transport technologies for the long term would not be commercially available before 2050.

Zero Emission Technologies for Transportation

The vision for the long term is to achieve a zero emissions technology (ZET) energy system. This ambitious goal is necessary if the world is to reduce anthropogenic GHG emissions to acceptable levels, given the difficulties in containing such emissions from the non-energy parts of the global economy. Two possible routes are available to achieving ZET transportation: electrification and hydrogen-fuelled transport.

Electrification provides a possible framework for a ZET transportation system. The essential requirement is that the electricity used in transportation is produced by zero emissions technology. In electrified transport systems, urban transport needs would be supplied by electrified rail, other electrified people-mover systems, and, possibly, novel urban freight systems. In order to provide the maximum scope for such urban transport systems, cities would need to evolve towards high density forms in which transport and urban planning were integrated. Advances in energy storage technologies could facilitate a major role for electrified cars, buses and delivery vehicles to cover the residual needs of urban transport. Inter-urban transport between heavily populated areas would be serviced by electrified rail. The transport gaps in an electrified system would be long-distance transportation in moderate to low population density areas, marine transport and air transport.

An alternative framework for a ZET transportation system would be based on hydrogen-fuelled vehicles. The key aspects of such a system would be hydrogen fuel derived by ZET and fuel cell-powered engines. Cars, trucks and buses would use fuel cell/hydrogen technology as would long-distance rail and marine engines. As such, the hydrogen-based transport would be capable of dealing with the transport problems of long-distance travel and freight needs as well as transport in low-density urban areas.

Appendix B

Review by Energy Research Centre of Policies for Reducing Carbon Emissions from Road Transport

In July 2009, the United Kingdom's Department for Transport released its "Low Carbon Transport: A Greener Future" setting out its carbon reduction strategy for transport to largely decarbonise transport in the UK by 2050. The strategy contains a brief review of alternative technologies for air, road and sea transport and sets out policies and programs that could be implemented to achieve this goal.

A number of detailed analyses and reviews of technologies and policies had been undertaken prior to the release of the strategy, concentrating on road transport and passenger vehicles in particular. The UK Energy Research Centre (ERC) has written a thorough review of over 500 reports and papers on policies for reducing carbon emissions from road transport. In their report (ERC 2009), they review the evidence for reducing carbon emissions and the cost-effectiveness of policies divided into two categories – (i) those that target car technology and consumer choice of cars and (ii) those that target wider travel choices. They found that the evidence for the first category of policies was better than for the second category. The review concentrates on transport policies but recognises that land use planning pays a significant role in effecting the demand for travel, choice of travel mode and the viability of public transport. As the review is based on evaluations of existing programs and policies it necessarily does not cover future programs, such as the provision of infrastructure in support of alternative fuels such as electricity and hydrogen. In addition it does not discuss programs supporting R&D or other innovation policies.

In presenting their findings, ERC divides the discussion of policies into three categories: (a) those that effect travel choices such as how and how far to travel, (b) vehicle purchase choices, and (c) fuel taxes and prices.

A. Travel choices

(i) Reducing the demand for travel

ERC found that fuel price increases reduce travel demand and encourage mode shifts and more efficient driving. Policies promoting tele-activity or working from home will also reduce demand.

(ii) Support for non-motorised modes

Policies to make cycling safer and more convenient through actions such as segregation and prioritisation encourage greater cycling activity and reduce other modes of transport. Congestion charges and other penalties for car use also lead to greater use of cycling.

(iii) Support for public transport

Although public transport creates less carbon per passenger km, the ability to switch from private to public transport is limited in the short to medium term by the need to add capacity to transport networks. This can be offset to some extent by improving utilisation at underutilised times and/or routes. Fare reductions and giving priority to public transport on roads can increase the demand for public transport. Land use planning is an important determinant of the attractiveness of public transport.

(iv) Car pooling

Car pooling reduces total car kilometres and leads to a greater uptake of non-motorised modes and public transport.

(v) Using vehicles more efficiently

This includes public awareness programs to promote more efficient driving skills, as well as measures to reduce and enforce speed limits.

(vi) Travel planning

Increased parking and other charges can encourage people to plan their travel more carefully by shifting to non-motorised modes and public transport car pooling.

(vii) Road pricing

Congestion charges for particular areas can reduce vehicle use and make vehicle use more efficient as congestion is reduced or eliminated.

(viii) Road space reallocation

Programs that reallocate road space from vehicles to pedestrians, cycling, and public transport must be carefully designed to avoid congestion for more carbon intensive transport.

B. Vehicle choice

(ix) Regulations and standards

Policies that set emission standards or fuel efficiency for vehicles need to be mandatory, ambitious, progressive and not amenable to circumvention.

(x) Vehicle taxes and subsidies

Vehicle purchase taxes can be used to make vehicles more expensive and hence reduce demand and can also designed to favour fuel efficient or low emission vehicles. Annual registration charges can be used in a similar way. Subsidies can be introduced to reduce both the purchase price and registration charges for low emission vehicles. Subsidies can also be used to encourage the greater uptake of new vehicles and accelerated scrappage of older vehicles improving average fleet efficiency.

(xi) Information labelling

Mandatory carbon vehicle labelling is rapidly becoming mandatory but can be improved by greater use in advertising.

C. Fuel prices and taxes

In the short term the demand for fuel is relatively inelastic with respect to fuel prices although more elastic in the long term as consumers buy more efficient cars and reduce the demand for travel. Large reductions in carbon emissions can only be achieved in the short term by relatively large increases in fuel prices and Governments are reluctant to impose taxes or charges to achieve these increases. If fuel taxes are continually raised to meet carbon targets that become increasingly stringent this only compounds the political problem.

Appendix C

Fuel Efficiency and Emission Standards in Various Countries

Fuel efficiency and/or GHG emission standards for new vehicles have been set by the European Union (EU), the USA, China, Japan, Australia and other countries. The stringency of these standards, as well as how they are defined and enforced varies considerably from country to country.

1. European Union

As part of its policy to reduce CO_2 emissions in the European Union by 20% by 2020, the European Commission has issued a regulation (No 443/2009) setting emission performance standards for new passenger cars registered in the EU. This was approved in April 2009 and sets the fleet average to be achieved by all cars as 130 grams per kilometre (g/km) compared to current levels of 160 g/km. The requirement will be phased in so that in 2012 65% of each manufacturer's new cars must comply, rising to 75% in 2013, 80% in 2014 and 100% from 2015 onwards.

A longer term target of 95 g/km has been specified for 2020 and measures to achieve this will be defined in a review in 2013.

For cars using petrol, fuel efficiency in litres per 100 kilometres (L/100 km) is equivalent to dividing emissions in g/km by 23.8. The new standard of 130 g/km is therefore equivalent to 5.5 L/100 km while 95 g/km is equivalent to 4.0 L/100 km.

From 2012 to 2018, manufacturers exceeding the CO_2 target will pay the following excess emissions premiums:

- 5 euro for the first gram of CO_2 exceeding the target;
- 15 euro for the second gram;
- 25 euro for the third gram; and
- 95 euro for each subsequent gram.

From 2019 manufacturers will pay 95 euro for each gram exceeding the target.

Manufacturers will be able to group together to form a pool to act jointly in meeting the target. Independent manufacturers selling less than 10,000 vehicles per year can apply for an individual target and special purpose vehicles such as those with wheelchair access are exempt.

The EU is currently assessing CO_2 emission targets for light commercial vehicles such as vans and minibuses. In a Communication from the European Commission in 2007 a target was proposed of improving fuel efficiency to reach 175 g/km CO_2 by 2012 and 160 g/km CO_2 by 2015 with a further goal of 120 g/km by 2020.

2. United States

The United States has regulated fuel efficiency through its Corporate Average Fuel Economy (CAFE) regulations since 1975. The standard applies to cars and light trucks defined as those with a gross vehicle weight rating of 8,500 pounds (3,900 kilograms) or less manufactured for sale in the United States. CAFE standards are administered and set by the National Highway Traffic Safety Administration (NHTSA) within the Department of Transport.

The CAFE standard for 2009 is 27.5 miles per gallon (mpg) for cars and 23.1 mpg for light trucks.

In 2007 the Bush administration announced a goal of 35 mpg by 2020.

In May 2009 the Obama administration increased the CAFE to 35.5 mpg and brought the introduction forward to 2016. This new standard was set to be equivalent to 250 gram/mile (172 g/km using the European test cycle or 156 g/km using the US test cycle). The Department of Transport will have responsibility for fuel efficiency while the Environmental Protection Agency will regulate GHG emissions.

If the average fuel economy of a manufacturer's annual fleet of car and/or truck production falls below the defined standard, the manufacturer must pay a penalty, currently $5.50 USD per 0.1 mpg under the standard, multiplied by the manufacturer's total production for the U.S. domestic market. However manufacturers can earn CAFE "credits" in any year they exceed CAFE requirements, which they may use to offset deficiencies in other years. CAFE credits can be applied to the three years before or after the year in which they are earned. Cars that can be run on alternative fuels such as ethanol blends receive are treated favourably in the calculation of a manufacturer’s average to encourage their use.

3. China

In September 2004, the Chinese Government through the Standardization Administration of China (SAC) issued Fuel Economy Standards (FES) for light-duty passenger vehicles (LDPV). The first phase took effect on 1 July 2005 with a second phase beginning on 1 January 2008. The China Automotive Technology and Research Center (CATARC) undertakes automobile testing, certification and automotive research, and was responsible for drafting the standards.

The FES limits fuel consumption by weight category and does not differentiate between petrol and diesel vehicles. The standards do not apply to alternative fuel vehicles or imported vehicles.

The standard differentiates “normal structure” vehicles with manual transmission and less than 3 rows of seats from “special structure” vehicles with automatic transmission of more than three rows of seats and for which the standard is 6% less stringent.

According to CATARC, the national average fuel consumption of passenger cars in China was 8.1 L/100 km in 2006 down from 9.1 L/100 km in 2002.

In Phase 1, standards for LDPVs under 3,500 kg and with no more than 9 seats were introduced in 16 weight steps for new models on 1 July 2005 and for continued models in 1 July 2006. Phase 2 tightened the standard by 10% and took effect for new models on 1 January 2008 and for continued models from 1 January 2009.

Unlike the standards in Europe or the USA, every model produced by a manufacturer must meet the Chinese FES standard for that weight category; otherwise the model cannot be produced.

According to an article in the New York Times in May 2009, the Chinese Government is currently in the process of planning further improvements in fuel efficiency of the order of 18% by 2015. China currently achieves a fuel efficiency standard of about 150 g/km (36.8 mpg) and aims to achieve a standard of about 130 g/km (42.2 mpg) by 2015.

4. Australia

Through the Federal Chamber of Automotive Industries (FCAI), the Australian motor vehicle industry has adopted a voluntary target of reducing average CO_2 emissions from new light vehicles to an average 222 grams of CO_2 per km by 2010 (or 176 g/km on the European Drive Cycle). FCAI estimates average emissions as 222.4 g/km in 2008.

In July 2009 the Council of Australian Governments (COAG) decided to “undertake a detailed assessment of possible vehicle efficiency measures, such as CO_2 emission standards, which international studies have indicated have the capacity to reduce fuel consumption by 30 per cent over the medium term, and significantly contribute to emissions reductions”.

5. Japan

Japan has regulated fuel efficiency for light-duty passenger and commercial vehicles since 1999. Initially targets were set for vehicles using petrol for 2010 and for diesel in 2005. The result was to be an average fleet fuel economy of 35.5 mpg in 2010.

The standards cover passenger vehicles with a capacity of 10 passengers or less and freight vehicles with a gross vehicle weight of 2.5 tons or less. They were followed by a series of fuel efficiency standards: standards for LPG vehicles were introduced in 2003, and in 2006 standards were introduced for heavy freight vehicles with a gross vehicle weight over 3.5 tons and passenger vehicles with a capacity of 11 or more passengers (with a gross vehicle weight over 3.5 tons).

The most recent revision of the standard was in December 2006. Fuel economy targets are set for each of 16 weight classes with a view to achieving fleet average fuel economy of new passenger vehicles of 16.8 km/L or 6.0 L/100 km by 2015. This is equivalent to 125 g/km of CO_2 emissions using the NEDC test.

Manufacturers are allowed to accumulate credits in one weight class to offset those in other classes subject to some limitations. Although they had realised the earlier target before 2010, there are only weak penalties if manufacturers do not comply with the standard.

The strongest aspect of the Japanese scheme is the so-called “Top Runner” method for continually improving standards. This method determines standard values based on vehicles presently on the market that have the highest fuel efficiency, while taking into consideration future prospects for technological development. This provides a built-in mechanism for regularly revising the standard.

Advantages

The main advantage of controlling GHG emissions from transport using emissions standards is that it leaves the choice of technology to achieve the standard up to the manufacturer and/or the consumer.

If emission standards are known in advance and a path for reducing emissions over the longer term is made clear, then manufacturers and other participants can plan model development and research and development programs to meet the standard.

Disadvantages

While setting an emission standard controls the amount of carbon per kilometre, it does not directly control the number of vehicles sold or the distance travelled in those vehicles. Increasingly stringent standards might be expected to increase the price of vehicles deterring some consumers from buying cars and substituting public transport for private transport especially in situations where this is convenient and affordable.

IDENTIFYING POLICIES AND IMPLEMENTATION STRATEGIES FOR IMPROVING ENERGY EFFICIENCY

CASE STUDY 2

Energy Efficient Air-Conditioners

May 2010

Centre for Strategic Economic Studies

Victoria University, Australia

With the assistance of the

Energy Research Institute,

National Development and Reform Commission

Beijing, P.R. China

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1. Introduction

Air conditioners are major consumers of peak energy demand posing potentially serious energy supply constraints in the near future. Yet the sector provides opportunities for simple, low cost improvements in energy efficiency. As a major global producer and consumer of air-conditioners, significant local and global benefits shall arise from the mass production of energy efficient air conditioners in China.

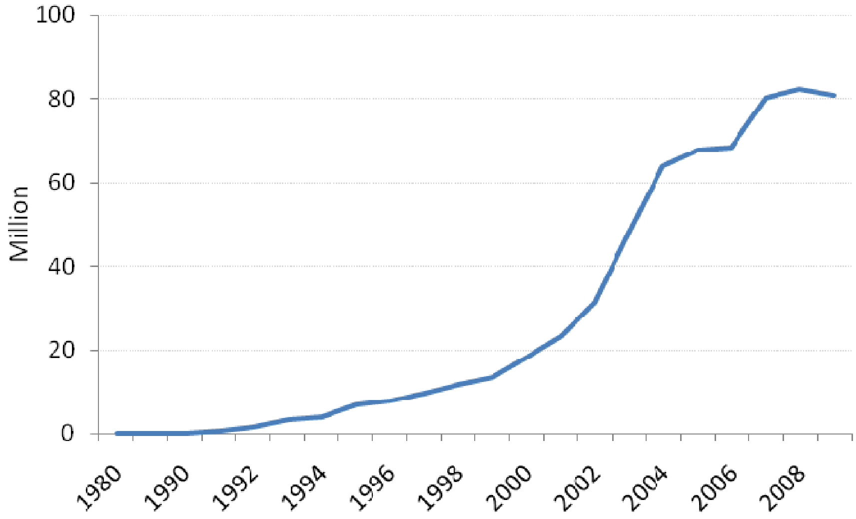
China's domestic and international air conditioner market settings are mature with strong investment in research and development for energy efficient air conditioners. The local market includes a diverse range of Chinese firms and many multinational companies. As the world's largest producer of and exporter of air conditioners, China has the capacity to produce 120 million air-conditioners, which would meet about 80% of global demand.[1] In 2008, the total revenue from air conditioner sales in China was US$31.9 billion[2] with export revenue totalling US$6.4 billion. The domestic consumer demand for air-conditioners in China is also very high, and is likely to remain so as incomes continue to rise.

Currently, China's household air-conditioner market is already three times larger than Japan's with annual sales of roughly 75 million units worth around US$25.5 billion.[3] The split room air conditioner (RAC) is the most popular air conditioner in China today with a cooling capacity smaller than 4500 Watts. The annual production of air conditioners has grown steadily during the past two decades from less than a million units produced in 1991 to nearly ten million by 1997 and reaching 80 million in 2007. Total manufacturing capacity is reportedly around 120 million units with a growing shift in production towards domestic sales in recent years. In 2009, China manufactured 80.8 million air conditioners, a decline of 2% on 2008 figures, despite the collapse of manufactured exports by 16% (Figure 1). Robust domestic sales boosted by the stimulus package were the key factor for the resilient figures.

In 2009, China has a reported 19 major air conditioner name brands with around 100 suppliers of air conditioners in China producing over 9,500 different product models.[4] The domestic air conditioner manufacturing market is dominated by four well-known brands, Hai'er, Hisense, Chonghong and Midea. Currently, about 60% of China's domestic sales of air conditioners come from four major manufacturers with the remaining 40% supplied by smaller domestic manufacturers.[5] The top four manufacturers are Gree Electric Appliances (Zhuhai), followed by Changhong Electric, Guangdong Chigo and Qingdao Haier. Many of China's top air conditioner brands and producers involve foreign investment, public shareholdings or overseas collaboration especially with Japanese and Korean companies.

[1] http://www.friedlnet.com/product_info.php?products_id=2330&cPath=26&osC
[2] http://www.ibisworld.com/industry/retail.aspx?indid=617&chid=1&rcid=86
[3] Nihon Keizai Shimbun (*Nikkei Weekly*) 25 May 2009.
[4] The number of domestic producers has been steadily declining since 2004 due to industrial restructuring and market mergers and consolidation activities.
[5] Ibid.

Figure 1. China's Annual Production Figures for Room Air Conditioner, 1978-2009



Source: NBSC, various years.

While electricity consumption by the residential sector in China remains low compared to other sectors, such as industry, it will increase dramatically over the coming decades. As China's emerging middle class seek improvements in their living standards, they will desire larger houses containing more energy hungry household appliances, all of which will simultaneously increase energy demand. Presently, electricity consumption in China's residential sector is about 10% of total electricity consumption. This is relatively low compared to the average figure of around 30% in developed countries. However, there are signs of a growing parity as the ownership of air conditioners by urban residents has increased dramatically from 8% in 1995 to 70% in 2004 and over 100% in 2009. Among energy intensive home appliances, air conditioners are expected to experience the most rapid growth in demand. According to Lin and Rosenquist (2008) over 30 million new room air conditioners were installed in 2004, requiring around 20GW in peak energy capacity, which is equal to the planned generating capacity of the Three Gorges Dam. It is therefore important to concentrate on improvements in energy efficiency of air conditioners in order to mitigate the expected growth in electricity consumption in China.

Lin (2006) argues that energy savings from potential efficiencies in three appliance areas – refrigerators, air-conditioners and gas water-heaters – would eliminate the need for US$60 billion in power station investment by 2030. In response to the dual challenges of rising energy demand and increasing greenhouse gas emissions, the Chinese government has established a comprehensive policy approach to achieving energy efficiency gains from air conditioners, encompassing plans, legislation, standards, pilot studies, building codes, labelling, fiscal incentives, targets, government procurement and institutions. Thus, while air-conditioners account for only a modest proportion of China's current residential and commercial energy use, they provide an important case study, bringing together domestic considerations of energy savings and issues and options arising from global market leadership.

While the Chinese government has introduced a wide range of energy efficiency measures to reduce electricity consumed by the growing residential sector, it appears that comprehensive measures to make this happen remain weak on the implementation side. For instance, there is room for accelerating the introduction of energy efficiency standards, as the 2005 Chinese standard for air-conditioners, for example, is well below that in Japan and Korea. Technologies and policy tools are available for achieving significant energy savings with high efficiency air conditioners, however key challenges remain in terms of: accessing new technologies and sharing intellectual property rights; and, the monitoring, testing and enforcement of compliance standards in the production, installation and maintenance of air conditioners. Presently, much of the enforcement of energy efficiency measures occurs at the local level, raising questions about local government priorities and incentives, but there are also issues about the establishment of national testing programs and of increased penalties for violations (Lin et al. 2006). There is also the question of whether efficiency programs apply only to new unit sales, or whether upgrade or replacement programs for the existing stock are possible. These implementation issues, involved in achieving much higher energy efficiency within China, will be the subject of a detailed examination in this case study report, to identify for air-conditioners (and implicitly for other appliances and for buildings generally) the most effective series of steps to much higher energy efficiency in the specific Chinese context.

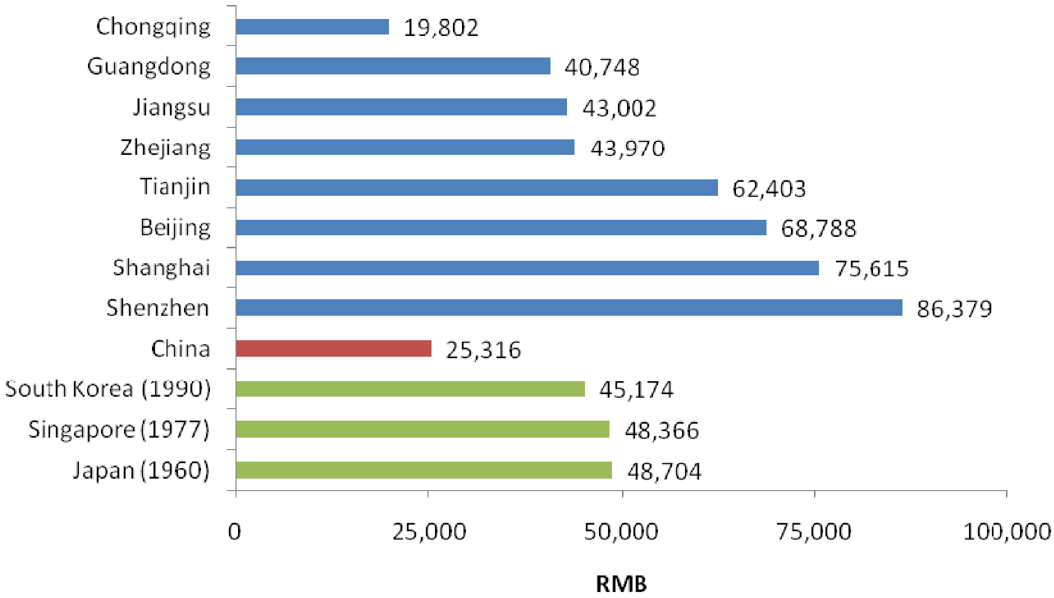
Furthermore, given China's position within the global market for air-conditioners, this case study report raises critical questions about the link between innovation and value added production: can China stimulate the technological level of domestic firms and help them to become innovative leaders by imposing and enforcing leading edge standards in the domestic market? Some years ago Michael Porter (1990) argued that stringent domestic market requirements provide a strong foundation for global competitiveness. This proposition will be examined in China for the case of air-conditioners, having regard to the increasing emphasis on energy efficiency in developed country markets.

This report tackles these issues as they relate to more energy efficient air conditioners through seven sections. After a discussion of the background relating to the air conditioner industry and the key drivers for their demand and use, the specific concern about energy efficiency and energy consumption in China is explored, including the role of labelling and fiscal incentive systems. In the third section, the economic opportunities and constraints facing the industry are discussed with reference to the role of research and development and the potential for expanding China's export markets. The fourth section looks at the factors affecting air conditioner energy consumption. The fifth section reviews the existing policy measures and offers several suggested policy options and instruments available for achieving greater energy efficiency in China. Before discussing the future direction of air conditioner usage in China, the economic implications of the expansion of high energy efficiency air conditioners is reviewed.

1.1 Rising Living Standards and Urbanisation

Typically growing energy consumption is associated with improving living standards. This linkage is due to several factors: the preference for larger houses; the use of additional air conditioning to improve comfort levels; and, the purchase of more energy consuming appliances associated with more affluent lifestyles. Air conditioners are 'luxury' goods and growing income levels in a country are likely to lead to a proportionately higher increase in consumption. There are indications that once the per capita income levels reach a critical level, the demand for consumer goods including air conditioners become the major force behind the increase in the demand for energy. This is being played out in China today as shown in Figures 2 and 3, that concomitant with the rising living standards and wealth is the demand for air conditioning use.

Figure 2. Comparative GDP Per Capita, 2009, RMB



Source: CEIC, 2010; NBSC, 2010; Rosen & Houser, 2007.

Income levels in China are highly variable between rural and urban areas and between coastal and hinterland cities. Figure 2 shows that while China's GDP per capita in 2009 was RMB25,316 it had already surpassed the 'critical' RMB30,000 level in several Chinese coastal cities, such as Beijing, Shanghai, Tianjin and Shenzhen, and is hovering around US$10,000 (Rosen & Houser, 2007).[6] The penetration rates are further correlated when compared with ownership levels according to income groups in Figure 3. While the average penetration rate in 2007 was 95.1 air conditioners per 100 households, this figure varied considerably according to incomes from under 18 per 100 households in the lowest income group to nearly 200 in the highest income households. The present per capita GDP of many Chinese coastal cities is currently around the same level as nations, such as Japan, Singapore and South Korea, when their air conditioner sales began to take off.

[6] In 2009, China's GDP per capita on a PPP basis is estimated at around US$8,300.

Figure 3. Urban and Rural Household Ownership Levels Air Conditioners According to Income Group, average per 100 households, China, 2007

Item	Average	Lowest income household	Low income household	Poverty household	Below medium income household	Middle income household	Above the median income household	High income household	Highest income households
Air conditioners	95.08	26.87	17.79	47.96	66.21	88.20	114.69	144.82	194.29

Source: NBSC, 2009.

The combination of rapid urbanisation and rising living standards provides a serious challenge for China to provide the necessary energy to power the cities of tomorrow. The process of urbanisation has been especially rapid during the past two decades jumping from 33% in 1990 to 50% in 2005. By 2030 there will be a further 350 million urban residents or an annual flow of 15 million rural residents to the cities searching for employment; all of which will require new buildings and power for everyday needs. Current commercial and residential floor space will increase by around 2 billion square metres annually or from 42 to 91 billion square meters between 2005 and 2030 respectively.[7] The resultant building boom will result in an additional 50,000 skyscrapers by 2025 increasing demand for energy further (McKinsey 2009, p. 16).

China's building sector currently accounts for 30% of China's total energy use with air conditioning the major source of energy consumption in buildings (Li & Yao 2009). In 2008, one of China's leading electronic appliance retailers estimated the local air conditioning market will reach 75 million units in 2008 of which 34 million will be from domestic companies.[8] The anticipated rapid increase in the installation of air conditioners will mean that the building sector in China is likely to consume a higher proportion of energy in the future.[9]

1.2 The Impact of Air Conditioning on the Peak Demand for Electricity

The energy consumption from air conditioning not only increases the demand for electricity; it is a major contributor to peak demand for electricity. The use of air conditioners is a major source of peak electricity demand in many countries. The contribution of air conditioning to peak power demand is also significant in China. According to Zhao Jiarong, director of the Environment and Resource Department under the NRDC, air conditioners consume around 20% of household electricity. During summer, this increases to 40% in major cities due to the higher penetration rates (Liu Jie, 2009).[10] Therefore, the management of peak demand is important to the stability of the electricity transmission and distribution system. An

[7] NBS (2007) Construction area of building industry, accessed June 2009 online http://www.stats.gov.cn/tjsj/ndsj/2007/html/01537.xls)

[8] See http://www.chinasourcingnews.com/2008/03/11/56172-suning-releases-chinese-air-conditioner-white-book/

[9] This is in the context of 10% annual economic growth; hence the increase in aggregate energy consumption will place enormous strain on China's energy resources, including electricity generation and distribution.

[10] See also http://www.reuters.com:80/article/latestCrisis/idUSPEK184037

unbridled increase in peak energy demand will put immense pressure on the capacity of the existing electricity system increasing the possibility of more frequent severe blackouts in cities.

The pressure on peak energy demand became particularly evident during the widespread power shortages in 2002 and the power rationing in 24 out of 31 provinces in 2004. Researchers from the Lawrence Berkeley National Laboratory (Lin & Rosequist, 2006) found that 'while most observers point to the strong economic growth in China as the primary cause for such shortages, incremental air-conditioning load is also a leading contributor.' During summer in many of China's large metropolises, such as Chongqing, Guangzhou and Shanghai, air-conditioner use consumes 40% of the peak load (Lin & Rosequist 2006, 1). In response to a 22% growth in energy consumption in Guangdong Province, government officials in the capital, Guangzhou, have been ordered to turn off air conditioners on so-called 'energy-shortfall days' to reduce energy consumption (Zhan Lisheng 2009). The key benefits of stricter energy efficiency standards for RAC units will be in reducing peak demand with estimated savings of around 4.5GW in 2010 and 20.4GW by 2020 (Lin & Rosenquist 2009, p. 1094). Based on expected sales of around 500 million RAC units between 2009 and 2020, energy savings to consumers would total US$32 billion due to higher standards.

The fact that air conditioning is already responsible for 40% of peak demand in major Chinese cities is of major concern. The expected rate of growth in the installation and use of air conditioners in China will place electricity transmission and distribution under great stress. While increasing the energy efficiency of air conditioners in the future will assist in alleviating the increase in peak power demand created by air conditioners this is unlikely to alleviate the need to resort to other measures to reduce peak demand. In the long term, if it is not possible to manage peak demand it will be necessary to add capacity to the electric generation, transmission and distribution system. This will inevitably impose significant additional costs on electricity consumers as the low power capacity utilization factor of peak generators will increase the marginal cost of peak power costs.

1.3 Energy Efficient Technologies

Achieving greater energy efficiency through new air conditioner technology will provide significant benefits to China. According to the IEA (2008), electricity consumption could be reduced by 38% (equivalent to 260TWh) in China's warmer southern provinces if new advanced technologies become available.

Presently, the most energy efficient room air conditioners appear to be concentrated in the Japanese market. The average EER for air conditioners sold in the Japanese market in 2005 was 5.27 and the expectation that the average EER for air conditioners will increase to 6.32 in 2010. This compares with average EER for air conditioners sold in China of 2.8. While the EER of air conditioners sold in China will increase in coming years, it is likely to remain significantly below the average EER of room air conditioners sold in Japan for the next five to ten years. The minimum energy performance standard (MEPS) for small air conditioners sold in China is set at 3.2 for 2009. As the average EER sold in 2010 is marginally above the MEPS, the average EER for split system air conditioners sold in China is likely to be in the order of 3.5.

In April 2010, the State Council announced the issuance of mandatory minimum energy efficiency standards for room air conditioners (RAC) to be enforced from 1 June, 2010 (Figure 4). The new standards were jointly developed by the NDRC in partnership with industry (Hai-er, Gree, Midea etc.), academia and the National Standards Institute so as to improve implementation. The new standard covers minimum energy efficiency performance, assigns values and grade for level of energy conservation, and stipulates testing methods and inspection requirements. The new standards are expected to realise a 23% improvement in overall energy efficiency for RAC units saving around 3.3 billion kWh annually.

Figure 4: National Room Air Conditioner Energy Efficiency Standards, 2010

New Energy Efficiency Standards for split RAC units (cooling capacity) to be enforced from 1 June 2010	
Power rating	Energy efficiency ratio (EER)
≤4500 W	3.2 EER
4500 W ≥7100 W	3.1 EER
7100 W ≥ 14000 W	3.0 EER

Source: China Energy Network, 2010

The new standards will be accompanied by a three-step grading or ranking program weighted to the size of the rooms. Grade 1 refers to the highest energy efficiency units. Grade 2 refers to units meeting the minimum standard value for energy efficiency performance. Grade 3 refers to the limited minimum energy efficiency value for products entering the market after the issuance of the new standards. The new standards will be implemented by the General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ). By late 2009, around 90% of air conditioner sales in China were reported to be high energy efficiency units.

There is great potential for increasing the average EER of air conditioners sold in the Chinese market in the future, especially considering the efficiency gap between Chinese and Japanese air conditioning units. There are also reports that some of the small split air conditioners retailing in Japan had an EER as high as 9. In Japan, nearly 100% of all residential air conditioners are fitted with inverters. The inverter compressor can reduce a units power consumption by around 30% compared with products not fitted with this technology. However, it was reported that in 2008 only 10-20% of Chinese air conditioners are fitted with inverters. It is expected that inverter-equipped air conditioner sales will triple to around 30 million units or 50% of total sales by 2012 following the subsidy program and tightening of minimum standards in 2010.[11] Therefore, the development and application of existing and new energy efficient technologies amongst Chinese manufacturers will play a

[11] Nihon Keizai Shimbun (*Nikkei Weekly*) 23-25 May 2009.

critical role in the speeding up industry acceptance of higher EERs as well as in bringing down costs.

1.4 Building Energy Efficiency

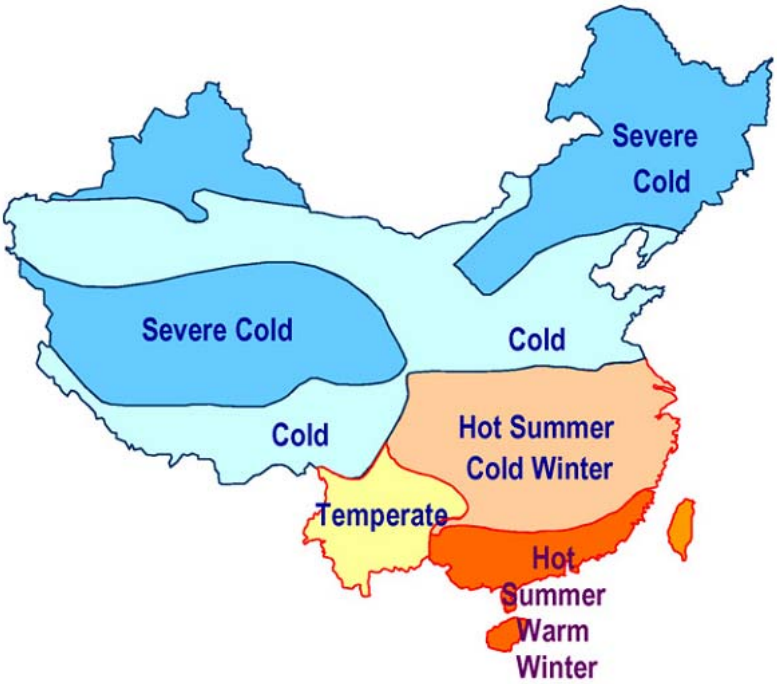
The consumption of energy by air conditioners and the buildings in which they operate are two sides of the one coin. Tackling appliance energy efficiency issues is difficult without considering the other equally important issues of building standards. According to McKinsey (2009), significant improvements in energy efficiency can be achieved in the buildings and appliances sectors, especially with improvements to managing the climate control systems of residential and commercial buildings. Moreover, according to the IPCC (2007, p. 59) AR4, the building sector can provide the largest and cheapest mitigation benefits across all the reviewed areas. Around 6.5 Gt of CO_2e can be saved annually across the planet by spending less than US$20 extra per tonne of CO_2e. Existing technologies and practices that could be adopted to achieve these targets include: efficient lighting and the use of natural lighting; the adoption of energy efficient appliances and heating and cooling devices; improved insulation; passive and active solar design for heating and cooling; alternative refrigeration fluids (CO_2); the recovery and recycling of fluorinated gases; the integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control at the household level; and, integrated solar PVs in buildings.

The IPCC recommends the adoption of a broad range of policies, measures and instruments: appliance standards and labelling; building codes and certification; demand-side management programmes; public sector leadership programmes, including procurement; and, incentives for energy service companies (ESCOs). China has already established such a broad array of policy measures including the use of standards and certification. For instance, China's current building energy efficient certification system adopts five levels and is compulsory for all large-scale buildings or buildings reliant upon public funds for their construction. Despite the great potential and low cost of achieving significant energy efficiency gains in the buildings and appliances sector, Jin and Rui (2008) argue that little progress in this sector has occurred until recently.

It is important to understand the significant regional variations in China when understanding the design and implementation of energy efficiency requirements due to the significant climatic differences across the nation. Existing policy measures, such as standards, demonstration projects and certification programs, will require significant adjustments to suit the climatic variation between the frigid north and the tropical south. Therefore, China's energy efficiency standards have adopted five climatic zones for the national standard (see Figure 5). To date, a major focus on China's building energy efficiency focuses on the energy hungry heating in northern China.[12]

[12] To date, the focus of most government policies, regulations and funding has been on the more energy intensive commercial buildings and residential buildings in northern China.

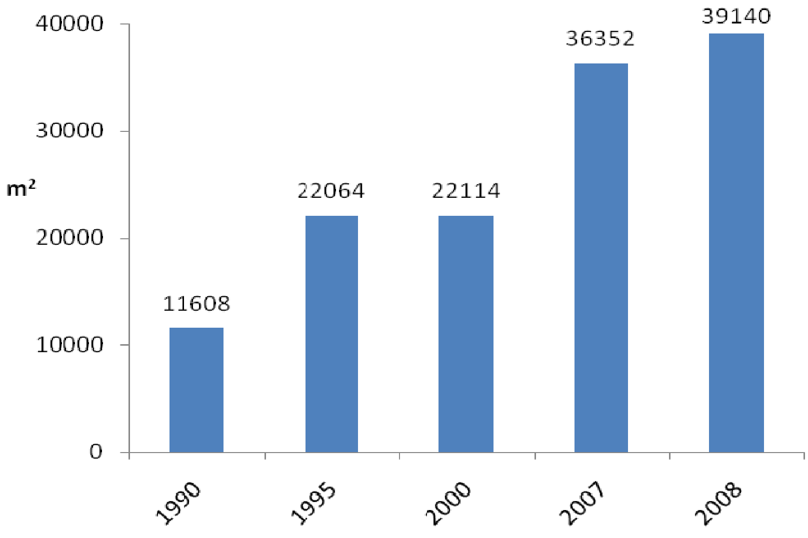
Figure 5. China's Climatic Zones According to the National Energy Efficiency Standard (GB 50176-93)



Source: Hong, 2009, 428.

The growth in building construction and the increase in the proportion of buildings installing air conditioners offers an insight into what is likely to happen in the future. Figure 6 illustrates the strong growth in completed new construction area in China's cities between 1990 and 2008. The figure highlights the rapid increase in the built area during the past two decades with capacity doubling every 5-6 years. In 2000, the area of annual construction was in the order of 22,000m^2 and by 2008 new building construction had almost doubled to nearly 40,000m^2. If these figures included smaller urban centres then the area of annual new construction was over 170,000m^2 in 2008 (Li & Yao, 2009). On the basis of this data the annual average increase in new building construction was around 15%.

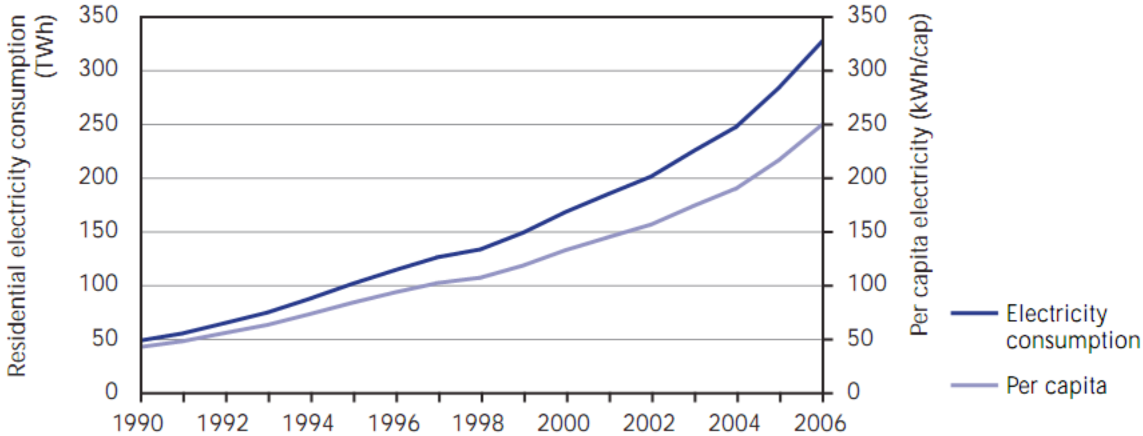
Figure 6. New Construction Area in China's Cities, 1990-2008, m^2



Source: NBSC, 2009.

The energy footprint of buildings in China is gradually increasing as a proportion of total energy use. At the beginning of the economic reforms in 1979, buildings consumed 10% of national primary energy. However, by 2006, this figure had risen to 25% and it is expected to increase to 35% by 2020. According to Hong (2009, 426) nearly all new buildings built in China can be classified as 'high energy consumption buildings'. Moreover, only 4% of existing buildings, covering 44 billion square meters (2006 figure), complied with existing national building energy standards.[13] This paints a grave situation for energy conservation in China.

Figure 7. Total Residential and Per Capita Electricity Consumption, 1990-2005



Source: IEA, 2009, 172.

The rising incomes, living standards and consumption patterns of these urban residents will fuel an appetite for larger residential and commercial buildings equipped with energy intensive consumer appliances, such as air conditioners and televisions. The outcome is already evident in Figure 7, which reveals the steady and increasing growth in residential electricity consumption vis-à-vis national per capita electricity consumption levels. Urban residential energy consumption, excluding heating, is estimated at around 200 billion kWh annually or between 10-30 kWh/m2 (Cai et al. 2009, p. 2055). Much of this increasing energy consumption is fuelled for instance by the annual sales growth of air conditioners, which has reached 20% nationally (Cai et al. 2009) The energy demand generated by the installation of new air conditioning systems every year is almost equal to the energy supply of a new power station (Li & Yao 2009; Cai et al. 2009). According to the Ministry of Construction, air conditioners are consuming an ever increasing proportion of total energy in large metropolises, such as Chongqing (23%) and Shanghai (31.1%) (cited in Li & Yao 2009). Estimates of growing energy demand show the building and appliances sector's contribution to total energy consumption rising from the present 17% to 25% by 2030 which would

[13] Similarly, while Cai et al. (2009) argue that there is a growing and positive alignment of new buildings with national energy efficient standards, they typically refer to the vague term of 'buildings built to match standards' as opposed to operating according to the standards. Nor is there much discussion of monitoring or measuring the actual energy intensity of the buildings to ensure they comply with the standards. While buildings may be built to comply with energy efficient standards, the installation, operation and maintenance of the buildings will play a key role in determining actual energy consumption levels.

require the construction of a further eighteen 1,000 MW coal-fired power stations. This increase would result in an annual increase of 80 million tons of GHG emissions so that the sector produces 3.2 Gt of CO_2e by 2030.

The government is not ignoring this issue, but is attempting to tackle the problem. For instance, the Ministry of Finance is trying to remedy this with the establishment of a RMB100 million[14] fund to set up an 'energy conservation scrutiny system' to inspect, measure, audit, certify and ration the energy intensity and conservation of buildings in 24 cities. Pilot projects have been operating in Beijing, Tianjin and Shenzhen.

In 2006, China's Ministry of Construction launched a green buildings campaign in six cities: Shanghai, Guangzhou, Chongqing, Xiamen, Fuzhou and Shenzhen for piloting stricter energy codes (GB/T 50378-2006: Evaluation Standard for Green Buildings). The campaign was launched following projections which indicated that buildings will be the primary consumer of energy worldwide as early as 2025.[15] The zero-energy buildings campaign targets energy efficiency improvements to reduce the impact of buildings on global energy consumption and greenhouse gas emissions.

While zero-energy buildings can utilize highly advanced building materials, many aspects of the program rely upon passive design improvements, which are either simple, rely upon existing technology and expertise, or are inexpensive. For instance, incorporating evaporative cooling, passive ventilation and 'daylighting' by strategically locating windows to maximize natural lighting. In addition, on-site co-generation heating and cooling systems can be installed together with renewable energy generation capacity using solar photovoltaics, solar hot water and wind energy.

An emerging and popular innovation in improving the energy efficiency of buildings is the use of deep-well geothermal heating and ground source heat pumps. The first utilises relatively constant temperature sub-surface water springs as a stabilising fluid for either keeping buildings warm in winter or for cooling during summer by piping the water around the buildings. The later system relies on stable soil temperatures to act as a supply of constant temperature that can be pumped up for either winter warmth or summer cooling. Both systems have been growing in popularity, especially in the Chinese capital Beijing. For example, by the end of 2007, around $10.5m^2$ million of building space was using ground source heat pumps. Furthermore, the government plans to increase this number to $35m^2$ million by 2010 (Romankiewicz 2009).

Air Conditioning Energy Use in Perspective

As discussed in the accompanying report *The Transition to a Low Carbon Economy: Implementation Issues and Constraints within China's Changing Economic Structure*, China's energy-intensive industrial sectors, such as steel and concrete, are the main consumers of

[14] The Chinese Yuan (RMB), otherwise known as renminbi (RMB), is mostly used in this report with an exchange rate of: RMB1 = US$0.146 or US$1 = RMB6.829.

[15] For example, buildings in the United States currently consume about one-third of the world's energy and account for 40 percent of primary energy use (NSTC 2008).

energy in China today. However, the major energy driver in the coming decades will be consumption-led energy demand, which is already significant in absolute terms. China's emerging energy profile highlights the growth in consumption, especially the use of air conditioning (Hanse & Houser 2007, p. 8).

Figure 8. Chinese Household Ownership of Air Conditioners, 2002-2008, per 100 household

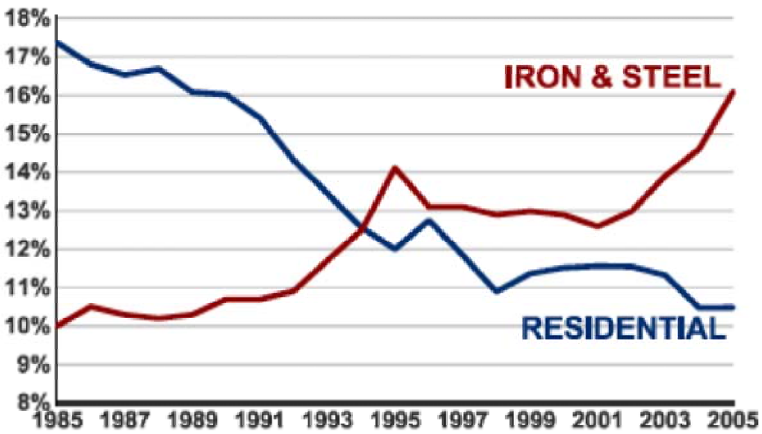
		2000	2002	2003	2004	2005	2006	2007	2008
Air conditioner units	Rural	1.32	2.3	3.5	4.7	6.4	7.3	8.5	9.8
	Urban	30.8	51.1	61.8	69.8	80.7	87.8	95.1	100.3

Source: NBS, various years; Berrah et al., 2007.

Figure 8 shows the rapid growth in the household penetration rate of air conditioners, which grew from 1.32 per 100 rural households and 30.8 in urban households in 2000 to 9.8 and 100.3 respectively in 2008. As a relatively energy intensive appliance, its rapid increase in use has exacerbated summer peak electricity loads, resulting in blackouts in southern China during the early 2000s.

While the energy consumption of air conditioners in China is significant it needs to be recognised that it is currently not the major cause of increases in electricity consumption. Instead, the rapid growth of electricity demand over the past decade was a result of the rapid expansion of energy intensive heavy industry, such as iron and steel (Figure 9). However, as Hansen and Houser (2007, 14) argue, the issues are not separate: 'If making the steel and glass to build office buildings and shopping malls is China's current energy challenge, lighting heating and cooling those malls and offices is China's future energy challenge'. The rapid growth in steel and iron production is supplying the residential and commercial buildings of tomorrow, which all involve embedded energy costs. Therefore, the annual growth in energy consumption in either the residential sector or in iron and steel production (see Figure 9) is probably indicative of short-term as well as mid- to long-term respective demand for energy, including the increased utilisation of air conditioners. Despite the significant reduction in the growth rate of energy consumption from the residential sector as shown in Figure 9 over the period 1985 to 2005, it still remains above 10%. Moreover, the expansion of steel and iron production point to a significant jump in residential and commercial building energy use in the future.

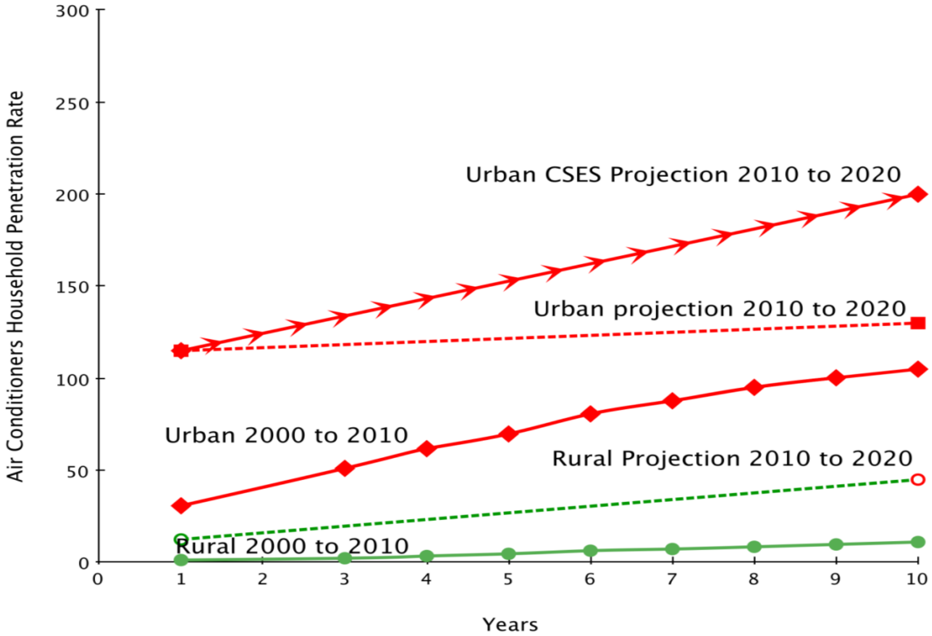
Figure 9. Relative Growth Rates of Residential Energy Consumption in China, 1985-2005



Source: CEIC; NBS, 2007; Hansen & Houser 2007, 8.

An indicator of the impact of domestic air conditioning on the demand for electricity in China in the future is illustrated in Figure 10. The chart in Figure 10 includes historical data and projections of air conditioning penetration rates in China for both rural and urban areas. The penetration rates are based upon the government's target of doubling household incomes between 2010 and 2020.

Figure 10. Past and Future Air Conditioner Penetration Rates, China, per 100 households



Source: NBSC, 2009; author estimates.

2. Energy Efficiency and Energy Consumption in China

Since 2001, the central government has introduced a broad range of policy measures aimed at improving the production of energy efficient household appliances, especially air conditioners. New energy efficient regulations, standards, codes, labelling systems, plans, pilot projects, incentive schemes, tax rebates, targets, and procurement policies have been introduced in an attempt to reduce the expected growth in energy consumption.

2.1 Energy Efficiency Improvements

As mentioned in the previous section, building designs are central to the efficiency and use of air conditioners. Since 2006, new building standards require new buildings to halve their energy intensity based upon current usage by 2010 and by up to 65% by 2020. Some cities, such as Beijing and shanghai have gone further calling for the 2020 target to be brought forward to 2010. In addition, a star-rating system has also been introduced on a voluntary basis with performance standards that encourage the incorporation of environmental considerations beyond the existing building codes. For public buildings, indoor air temperatures have been mandated to not go above 20°C in winter and not below 26°C in summer. In addition, retrofitting and passive design concepts have been promoted to showcase the advantages of sustainable building designs that generate power and provide natural lighting, cooling and heating.

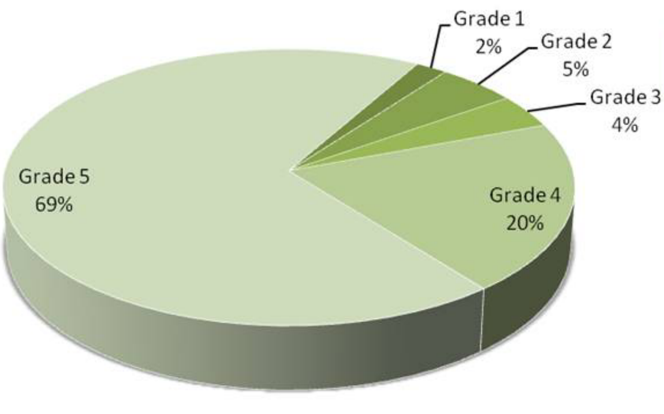
While policies targeting energy efficiency improvements in buildings tackles half of the problem, improving the energy efficiency of air conditioners has the potential to offset the increase in energy consumption arising from the anticipated rapid growth in the installation of air conditioners in China during the next decade. As early as 1989, China launched its first energy efficiency initiative when the former State Quality and Technical Supervision Bureau (QTSB) introduced the first energy efficiency standards for appliances including air conditioners. Since then, China has developed a comprehensive standards program covering a range of product categories aimed at promoting improvements in performance levels.

Following China's accession to the WTO, two overlapping institutions responsible for setting standards, the State Administration for Entry-Exit Inspection and Quarantine (CIQ) and the QTSB, were merged into the General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) under the responsibility of the National Development and Reform Commission (NDRC) (Zhao & Graham 2006). Then in 2001, the Standardisation Administration of China (SAC) was set up (under the AQSIQ) with responsibility for establishing and monitoring China's national standards. The SAC also manages the main standards research institute, the China National Institute of Standardisation (CNIS).

Standards and Labelling System

According to the IEA (2009), mandatory programs for labelling, standards and energy use in OECD countries have shown that energy efficiency gains of 10-60% have been achieved whilst simultaneously experiencing lower real prices of between 10-45%. In 2005, China introduced an energy efficiency ratios (EER) labelling program for classifying household appliances (see Figure 11). The energy efficiency label includes four components: product specification and type; energy efficiency grade; estimated product energy consumption; and, the relevant energy efficiency standard. According to the standard, energy efficiency levels of multi-connected products are divided into five levels or grades. The first grade is of highest energy efficiency, with an energy efficiency ratio of 3.4 and above. The second grade is the minimum figure needed for energy saving certification, with an EER of 3.2. The third and fourth grades are the average energy efficiency level of multi-connected products, with an EER of 3.0 and 2.8 respectively. Grade five is the minimum allowable value after the new standard was implemented, with an EER of 2.6.

Figure 11. Composition of Sales of Air Conditioners by Energy Efficiency, China, 2006



Grade	Energy Efficiency Ratio
1	3.40 ≤ EER
2	3.40 > EER ≥ 3.20
3	3.20 > EER ≥ 3.00
4	3.00 > EER ≥ 2.80
5	2.80 > EER ≥ 2.60

Source: IEA, 2008; He Bingguang, 2006.

The labelling program is aimed at providing consumers with more detailed information, saving energy, encouraging manufacturers to improve product energy efficiency and encourage distributers and retailers to select energy efficient products. In the first year of the program, the average EER amongst air conditioner sales are shown in Figure 11 together with respective energy efficiency requirements. In 2005, the existing energy efficiency standards (1990) for air conditioners were updated with the tightening of MEPS from 2.37 to 2.6 in terms of EER. It is clear that most air conditioners were located in the lowest of the 5 grades with an average EER of 2.8 in 2005 or just above the minimum requirement. By 2008, sales of high-efficiency energy-saving air conditioners only accounted for 5% of the market, according to NDRC vice chairman, Xie Zhenhua.[16] According to The Climate Group (2009), China's labelling system resulted in a 6% improvement in energy efficiency of air conditioners. The benefits are however, wider including raising public awareness as well as promoting the competitiveness of energy efficient appliances by including details about the product's environmental and economic benefits.

Testing to determine the grade of products can be either undertaken by the manufacturer, importer or by an approved testing institution (WRI, 2009). Labelling is mandatory for air conditioners and is the responsibility of manufacturers or importers to ensure labelling is accurate. It is the responsibility of the AQSIQ and the NDRC to ensure that they inspect such products to verify the information on labels.

In 2009, the government introduced a further tightening of labelling standards (see Figure 12) to raise the minimum allowable value to EER 3.0, so that products of fourth and fifth grades will be eliminated. When the new standard is implemented, the cost of manufacturing air conditioners is estimated to increase by around 15% and the price of air conditioners to increase by about 10% in 2010.

Figure 12. Minimum Energy Efficiency Ratios (EER) for Air Conditioners, 2009

Category	Rated cooling capacity (CC) (W)	EER (W/W)
Single package system		2.90
Split system	CC≤4500	3.20
	4500<CC≤7100	3.10
	7100<CC≤1400	3.00

Source: Lin and Rosenquist, 2008, 1091.

Prior to the issuance of the 2007 Energy Conservation Law (see the accompanying *The Transition to a Low Carbon Economy: Implementation Issues and Constraints within China's Changing Economic Structure* Report for details), sub-national jurisdictions were unable to introduce more stringent energy efficiency standards for air conditioners than those set at the national level. However, since its introduction some provinces and cities have introduced more stringent standards, such as Beijing's building design standards with energy efficiency targets around 65% higher than equivalent national requirements.

[16] *Xinhua New Agency*, 8 June 2009; *Shanghai Daily*, 1 June 2009.

Much of the detail in the new energy efficiency standards, laws and regulations points to penalties and strict compliance, yet there is very little detail about implementation and matching the requirements with the market or utilising market forces to improve energy savings. According to Hong (2009), implementation of the energy efficiency standards remains problematic at the local level, especially amongst small and medium sized cities. The key reasons for lack of enforcement are inadequate political will, poor human and financial resources and weak education or training. In response to the poor enforcement of building codes, the national government launched a building inspection program to monitor local implementation. Enforcement and compliance was threatened at the risk of loss of licence or certification for design forms, builders or developers since the levels of compliance have improved. Similarly, Hong (2009, 432) raises the problem of cross-referencing between different energy efficiency standards for meeting HVAC and lighting requirements, which makes enforcement, compliance and maintenance problematic.

Fiscal Incentives

In order to stimulate the domestic economy and increase the role of the market economy in improving energy efficiency, the Chinese government adopted a variety of fiscal incentives, tax rebates and subsidy programs to promote the commercialisation and sale of energy efficient air conditioners. In 2009, China has expanded funding for a variety of programs to speed up the sale of energy efficient appliances, including air conditioners, as part of its economic stimulus plan. This included a RMB2 billion grant from the Ministry of Finance to provide a 10% rebate, up to RMB850, on the purchase of new energy efficient air conditioners and other household appliances.[17]

In June 2009, over 1000 air conditioner models from 19 different manufacturers became eligible for the subsidy program. This was expanded to 4290 models produced by 27 companies by the end of 2009. Eligible models receive a subsidy ranging from RMB500-850 for units meeting Grade 1 standards and RMB300 – 650 for Grade 2 units. The aim of the subsidy program is to increase the market share of high energy efficient air conditioners from around 5% to 30% by 2012. Cities have also introduced their own programs to encourage the domestic consumption of energy efficient appliances. For example, in 2009 Hangzhou, Shanghai and Beijing commenced offering a RMB350 rebate or 10% of the retail price on old air conditioners when a new efficient one is purchased. The subsidy programs will reportedly result in savings of around 6 billion KWh of electricity and boost consumption by RMB60 billion.[18] The 2009 subsidy for high efficiency air conditioners will not cover air conditioners listed in the earlier rural household appliance subsidy scheme that started in 2008.

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[17] In addition, export rebates for air conditioners have been increased to 15-17% to assist local manufacturers and exporters during the global recession, which has witnessed a drop in air conditioner exports of between 40-60% in the first half of 2009. By October 2009, the program had cost RMB808 million to finance the subsidies.

[18] *Xinhua New Agency*, 8 June 2009; Shanghai Daily, 1 June 2009. The latter report mentioned figures of a RMB100 billion boost in sales of air conditioners and energy savings of 75 billion KWh and CO_2 abatement of 75 million tons.

Since the subsidy program was introduced in mid-2009, one of China's largest air conditioner manufacturers and exporters, Gree Electric, actually ceased the production of lower grade energy efficient air conditioners (Lu Jie, 2009). Other leading manufacturers also suggested they would phase out lower grade air conditioner manufacturing. Many of the major retail outlets have also stopped selling air conditioners below Grade 3.

In response to the subsidy program, two of China's largest air conditioner manufacturers, Changhong Electric and Hai'er have ceased production of some models that were below Grade 2 standards so that around 90% of the two companies range of products meet Grade 2 and above. Overseas air conditioner manufacturers, such as LG, Fujitsu and Daikin, responded to the energy efficiency challenge by increasing their exports to China and Chinese local production of high energy efficiency units.

Figure 13. China's Air Conditioner Exports, 2009

Year	Sales (10,000 sets)	Change YOY (%)	Cumulative Value (US$1,000,000)	Change y-o-y (%) Cumulative Quantity
January	1,910	-43.3	363.478	-35.3
February	4,580	-38.5	827.879	-33.3
March	8,540	-38.1	1,512.033	-34.7

Source: General Administration of Customs, 2009, 'China's export of air conditioner in March 2009', *Xinhua News Agency,* 1 June.

A combination of strong domestic demand (fuelled by the economic stimulus package) and healthy margins has resulted in growth and profit margins for most air conditioning companies remaining resilient despite the global economic crisis and over capacity due to the collapse of export markets (see Figure 13). The collapse in exports has affected most air conditioner producers across the country with drops in export revenue ranging from 18-60%.

2.2 Energy Performance of Installed Air Conditioners

It is important to recognise that the claimed EER of an air conditioner may not be achieved after the air conditioner is installed. This could be the result of fraudulent practices of the manufacturer, inadequate testing procedures, poor installation of air conditioners, service durability and under-performance of components. The loss in efficiency of the air conditioning units may lead to a substantial increase in energy consumption.

A report to the American Council for an Energy-Efficient Economy (ACEEE, 2008) found that 'residential air conditioners and heat pump systems as installed in the field generally do not achieve the efficiency implied by their SEER ratings'. A similar study (Falcioni, 2008) examined the difference between declared and test results for nine air conditioners measured according to the labelling requirements. The study revealed most of the nine products were labelled incorrectly with most of the top 'Grade A' labelled air conditioners being relegated to the lowest grade, 'Grade F' (EU standards). In contrast, a Chinese study found that compliance levels improved significantly between 2006 and 2007 from 11 out of 43 to 3 out of 73 respective models found to be non-compliant.[19]

A 2008 report noted that Shanghai authorities had tested 22 different types of air conditioners and only found that one unit, manufactured by LG (China), failed to comply with minimum energy efficiency standards. The unit in question had an EER rating of 2.48, which is below the minimum of 2.6 EER. Retailers were instructed to stop selling this model until it was able to meet the minimum standards.[20] Nevertheless, a thorough assessment of China's monitoring and verification framework found that it required 'a more robust system of enforcement and monitoring' (CLASP 2007).

There are several reasons for performance deficiencies. One cause is the inability of a national performance standard (SEER) to adequately predict performance in hot-dry or hot-humid climates. In addition, equipment over-sizing and installation errors such as improper refrigerant charge, substantially reduces efficiency. Finally, duct leakage easily increases energy use by 20% or more. Clearly, different problems require different solutions, and not all of these issues can be controlled by the equipment manufacturer.

The cumulative effect of such performance issues is huge. Neme, Proctor and Nadel (1999) argue that improved practices could save 24% of energy use in heating, ventilation, and air conditioning (HVAC) in buildings and 35% in new buildings: 'Customers are not getting the comfort and economy they contract to buy, dealers are getting too many call-backs, and manufacturers are blamed for inefficient and poorly operating systems, when they only control the equipment, which is one element of the system' Sachs et al. (2008).[21]

These findings are extremely important as they highlight that improvements in the EER of an air conditioner may not necessarily lead to corresponding reductions in the energy use of air conditioners. In order to ensure that improvements in the energy efficient standards are reflected in the performance in the field it is necessary to have complementary measures to ensure that manufacturers' products meet the labelled performance standards and that air conditioning units are installed correctly.

Figure 14. Air Conditioner EER and Energy Saving Relationship

Air conditioner EER	Electricity use	Heating requirement kWh	Energy saving
2.8	0.36	1	
4	0.25	1	25%
6	0.14	1	55%

Source: Author's own estimates.

[19] The study of air conditioners sold in Beijing found that there was 100% compliance (Zhou, 2008a).
[20] See online discussion for more details: http://www.chinacsr.com/en/2006/09/14/730-lg-air-conditioners-fail-to-reach-energy-saving-standard/
[21] A 2009 survey of Chinese consumers found that over 70% would not follow up on faulty electronic appliances largely due to a lack of technical understanding and a lack of confidence in having their complaint resolved (South China Morning Post, 14 June).

Given that air conditioners installed in China have an average EER of 2.8 there is great scope for reducing energy consumption from the use of air conditioners. There are a large number of air conditioners available on the world market with an EER in excess of 4. Further, recent developments in Japan and China have resulted in EER of around 6. A shift from an average EER of 2.8 to 4 on the basis of the same usage levels would reduce the energy consumption from air conditioners by 25% (Figure 14).[22] If the average EER for new air conditioners were increased to 6 the corresponding saving in energy consumption from air conditioners currently sold in the market would be in the order of 55%. These savings are based on the current EER performance of air conditioners in the market. With the expectation of further improvements in the EER of air conditioners, it is reasonable to expect a reduction of energy use per air conditioner unit of well above 60%.

3. Economic Opportunities and Restraints

China provides the world with a unique opportunity in terms of an 'economy of scale'. While the scale of China's economy is often associated with negative environmental aspects, the significant positive opportunities of China's massive domestic market and production need to be acknowledged in not just cost reductions, but also in bringing new innovative products and technologies to market through mass production. The scale of China's domestic market and access to international markets will ensue that if China can manufacture low-cost high energy efficient air conditioners, then they will not only capture the global market, but they will generate significant global energy savings and lower carbon emissions. In order for China to fulfil this opportunity, both domestic and international standards need to be tightened, the pricing system adjusted, and public and private research and development funding boosted to ensure that the skills and technologies are available for commercialisation.

According to the World Bank, the Chinese market provides enormous opportunities for mutual benefits.

Foreign technology developers would be able to demonstrate their products, probably on a scale not possible elsewhere, leading to local manufacturing of the products. Chinese experts and enterprises would be exposed to these technologies and could gain experience with them by partnering in joint ventures or even by leading development (Berrah et al. 2007, p. 167).

[22] An air conditioner with an EER of 2.8 would require .36 kWh of electricity to produce a 1 kWh of heat and an air conditioner with an EER of 4 would require .25 kWh of electricity to produce 1kWh of heat. A decline of .9 kWh per air conditioner and this translates to a 25% reduction in electricity use per air conditioner.

Box 1: A Changing Tide in Corporate Management

Zhang Yue is the chair and president of *Broad Air Conditioning*, a company he established back in 1988 to manufacture natural gas powered central air conditioning. These units claim to be '200% more energy efficient, while its CO_2 emissions are 4 times lower and investment is 1/3 less' than conventional electric powered air conditioners (The Climate Group, 2010). In order to remain competitive, Broad air conditioners have focussed on reducing their purchase price, energy use and maintenance requirements.

In a break with convention, Broad upholds eight corporate governance principles: no polluting the environment, no stealing technology, no misleading consumers, no unfair competition, no complex borrowing arrangements, no tax avoidance, no bribery and no immoral practices. Broad is a member of The Climate Group and has established aggressive carbon and energy reductions for both its manufacturing plants and its units. To further prove his unconventional role, Zhang Yue, has been a strong advocate for improving building energy efficiency programs, declaring that 'one of my major tasks now is to eliminate [air conditioning] – to eliminate my own business' (Huo Weiya, 2009). According to Zhang, ideally buildings should not require air conditioning at all, but instead be designed and built to maximise passive use of light, air circulation, heating and cooling.

3.1 Research and Development

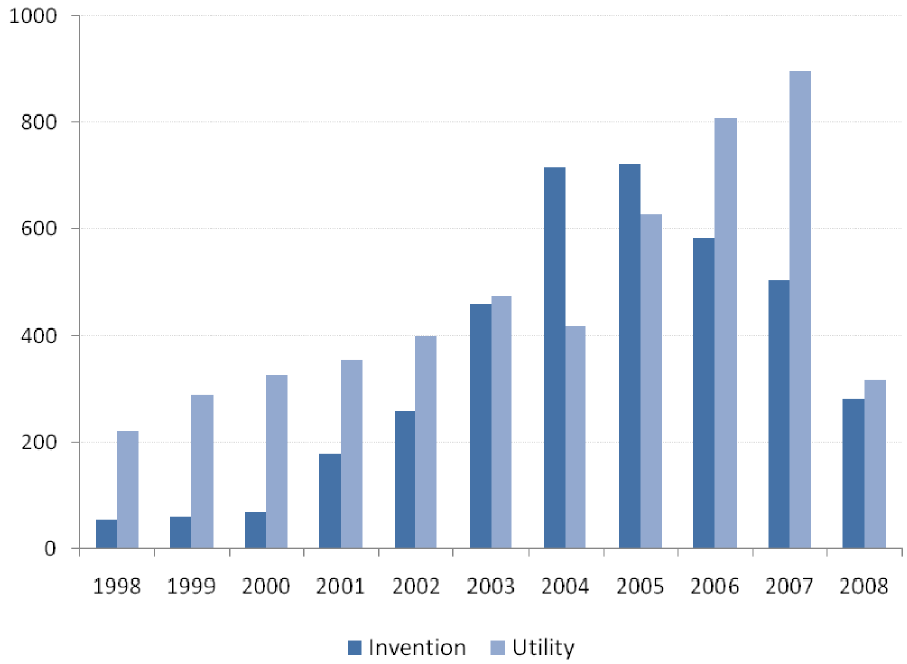
Chinese domestic manufacturers are reluctant to invest in research and development, since the resources of medium and small scale domestic manufacturers are low. Actually, the percentage of expenditure on research and development in China was 1.52% in 2008 (NBSC, 2009) or half of R&D expenditure in Japan (reaching 3.49% in 2004) (METI, 2009). Moreover, very little of China's R&D comes from the private sector, especially compared to Japan. The expenditure of small enterprises is likely to be far smaller than the average percentage of R&D expenditure for the whole industry. In developing countries, there are typically a higher proportion of small or medium sized manufacturers, compared to developed countries (METI, 2009). However, recent industrial consolidation is resulting in greater vertical integration in the air conditioner industry and the rise of domestic name brands as market leaders. These companies are increasing their cooperation with national-level research centres and universities as well as building up significant R&D teams within their companies. Figure 16 below highlights the strong growth of patent applications by both domestic brands and universities, many of which maintain strategic partnerships.

According to an insightful interview with Daikin's CEO Noriyuki Inoue (JARN, 2009), the company set up a strategic partnership with Gree in Zhuhai to produce more energy efficient air conditioners, because he argued that if Daikin didn't share technology and production knowledge, such as the invertors, then Chinese companies would gain these abilities anyway. They would either partner with another air conditioner company or develop the technologies themselves. The catalyst for the shift in approach to IP resulted from the tightening of China's COP standards, which would make it difficult to meet COP=3.0 without the use of inverters.

Technology sharing and the protection of intellectual property rights are both important aspects of developing and applying new technologies on a commercial scale. Progress to date on technology transfers under the auspices of a global climate change agreement seem unlikely in the present political environment, however, there remains significant domestic innovation as well as technology transfers through foreign investment (see Figure 15). Since China's accession to the WTO in 2001 and the introduction of China's National Intellectual Property Strategy Plan in 2008, the country has been strengthening the legal system in order to protect IPR owners, promote the market value of inventions and innovations and strengthen its international competitiveness. The IP plan proposes that the government, at various levels, should offer additional policy and financial support to assist firms strengthen investment in innovation. It would be beneficial to investigate the benefits of such IP protection and advancement within the air conditioning sector.

The registration of patent applications offers a useful insight into the levels of research and development as well as the level of concentration in industry innovation. Figures 15 and 16 provide the total number of Chinese origin 'air conditioning' patent applications as well as the representation of the top applicants.[23] 'Chinese origin' in this case refers to patent applications with Chinese priority, for instance China being the first country where patent protection was sort. The patent application counts have been split between invention and utility (or design) applications and cover the period 1998 to 2008. Utility applications relate to the ornamental design of a product whereas the invention applications relate to a process/method, object or composition of matter.

Figure 15. Chinese Origin 'Air Conditioning' Patent Applications, Invention versus Utility



Source: Chinese Patent Office, 2009.

[23] The search criteria for the patent set was a combination of IPC and key word search. The IPC classes were F24F (Air-conditioning; Air-humidification; Ventilation) and F25B (Refrigeration machines, plants, or systems). From these were chosen patent applications with the text string 'air condition' in either the title, abstract of claims. This was quite a strict criteria – meaning, it's likely that most of these applications are air conditioning related but that its' possible that some applications could have been left out.

Figure 16: Top Patent Assignees for 'Air Conditioning' Patent Applications, Chinese priority

Assignee	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total	Invention Applications	Utility (Design) Applications
LG Electronics				1	77	205	511	472	197	70		1533	96%	4%
Hai'er	9	14	13	32	58	45	28	54	57	31		341	40%	60%
Gree Electrical	1	7	16	15	4	15	8	36	64	107	26	299	27%	73%
Kelong Electrical	2	19	14	26	11	25	30	41	32	6		206	25%	75%
Midea Electrical	12	22	16	8	7	8	4	14	36	45	17	189	14%	86%
Lejin Electronics				43	38	61						142	97%	3%
Jiaotong University		2	1		6	21	15	4	8	11	8	76	95%	5%
Changhong Electrical							2		19	19	13	53	17%	83%
Tsinghua University					6	10	4	6	9	12	6	53	70%	30%
Samsung Electrical						1	2	11	15	22		51	16%	84%
Hisense Group					1			11	20	9		41	27%	73%
Xinfei Electrical						27	5	1				33	6%	94%
Yuejin Electrical				13	17							30	100%	0%
Liang Jialin (inventor)				4	10	1	11	2				28	100%	0%
Li Wanhao (inventor)					9	11		5				25	52%	48%
Matsushita Electrical								10	6	3	6	25	32%	68%
TCL Group			1			1	4	6	6	1	4	23	4%	96%
Hisense										17	5	22	18%	82%
Suzhou Qutu								5	5	9	3	22	41%	59%
Chigo								6	4	6	5	21	33%	67%
Hunlan Group					14	1	3	1	1			20	25%	75%
Xinfei Electrical						5	4	8		1	2	20	20%	80%
Grand Total	276	351	396	533	658	935	1136	1353	1392	1403	601	9034		

Source: Chinese Patent Office.

Figures 15 and 16 clearly illustrate how China's invention patent counts began to grow rapidly in 2001 after the country's accession to the WTO and even overtook utility applications in 2004. From 2005 a truncation lag is evident in the data, which appears to affect the invention applications approximately two years earlier than utility applications. The reason for this is unclear, but it may relate to the time delay in approving new patents. The majority of applications were lodged by LG Electronics Tianjin, followed by Hai'er, Gree, Kelong and Midea.

Figure 16 provides a list of the top assignees with only assignees with 20 or more applications included (for which there were about 20). The top 6 assignees account for approximately 30% of all patent applications. In total there were approximately 4000 different assignees listed (although it is likely there is some degree of overlap).

The dominant position of LG Electronics is obvious in Figure 16 with a total of 1533 patent applications between 1998 and 2008, far more than the second placed Haier Group with 341 and nearly as much as the next dozen assignees. It is interesting to note the company's heavy emphasis on invention applications (96%) compared to utility applications (only 4%). It is unclear what the rationale is behind these applications, other than the obvious concern with protecting intellectual property rights by lodging patents with Chinese origin to increase the protection from reverse engineering or other infringements to IPE.

3.2 The International Context of China's Air Conditioner Standards

The revised 2009 MEPS for air conditioners purchased in China will be comparable in energy efficiency performance to air conditioners sold in developed and advanced developing countries. Given that the Chinese market for room air conditioners in 2008 is estimated to be in the order of 76 million units. There are also expectations that the market for room air conditioners in China will grow by 20% per annum over the next decade. This means that if the market for Chinese room air conditioner is sustained, then there will be around 600-650 million units by 2020.

3.3 Price Restraints

Retail prices have been a significant impediment to the growth of energy efficient air conditioners, which make up a small segment of the market because they are often 50% more expensive than standard units. Typically, productions costs are RMB300-500 higher for units meeting the reach standards (Lin & Fridley, 2007). However, according to the Energy Research Institute a higher production cost of RMB320 will result in the retail price varying by as much as RMB2000. The low sales level of energy efficient units exacerbates the impact of the price variation. The level of public awareness of the cost savings in purchasing an energy efficient air conditioner is reportedly very low (Lin & Fridley 2007). The rising MEPS ratings and 2009 Ministry of Finance subsidy and export rebate programs will alleviate this discrepancy somewhat.

There are numerous hurdles to overcome in order to achieve greater penetration of energy efficient air conditioners into the market. Although the additional cost of the energy efficient air conditioner will be paid back over time, the extra upfront cost will dissuade consumers from purchasing a more expensive energy efficient unit. This is likely to be a more significant issue in China than elsewhere because of the low usage rates for air conditioners (Koizumi & IEA, 2007, p.7). This means that other things being equal it will take longer for an energy efficient air conditioner to pay back the household for the initial higher outlay.

The existence of mandatory MEPS does not provide an incentive to manufacturers to produce energy efficient air conditioners. Unlike Japan there is little or no institutionalised incentive in China to strive for increasing the efficiency performance of air conditioners. Moreover, it is unclear how long the existing subsidy program will be available to consumers.

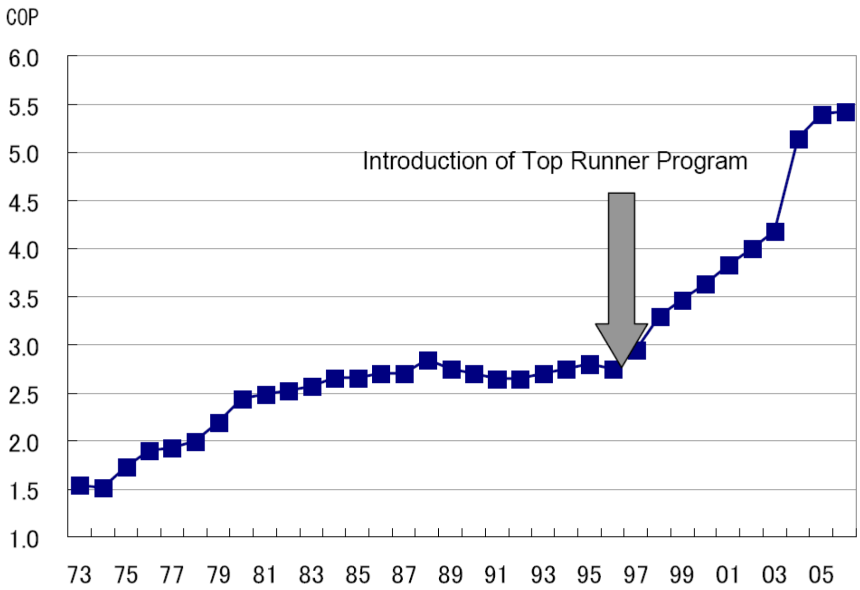
Given the very large size of the Chinese room air conditioning market there is great scope to encourage the development of highly efficient room air conditioners. If for example highly efficient air conditioners constituted 10% of the Chinese market for air conditioners in 2020, a large scale manufacturer would be needed to meet this demand. Careful consideration needs to be given to how the demand for high efficiency air conditioners can be stimulated in China. Japan's Top Runner provides an insight into how policies can be developed to stimulate the demand for high efficiency air conditioners.

A review of the Top Runner Program on The Energy Conservation Centre of Japan's website (METI, 2009) provides a succinct outline of the program:

> *The Top Runner Program uses, as a base value, the value of the product with the highest energy consumption efficiency on the market at the time of the standard establishment process and sets standard values by considering potential technological improvements added as efficiency improvements. Naturally, target standard values are extremely high. For achievement evaluation, manufacturers can achieve target values by exceeding target values by weighted average values using shipment volume, the same as the average standard value system. The implication of using weighted average values is the same as the average standard value system, that is, the system is meant to give manufacturers incentives for developing more energy-efficient equipment.*

Japan's Top Runner policy is designed to encourage the rapid uptake of the most energy efficient products on the market. Figure 17 illustrates the marked shift in energy efficiency performance following the introduction of the program.

Figure 17. The Impact of Japan's Top Runner Program on Air Conditioner COP



Source: Sugiyama, 2009, 14.

The efficacy of the Top Runner program is unquestioned as the EER of room air conditioners sold in Japan is above any other country in the world (see Figures 17 and 18). For example, according to the IEA (2009), the coefficient of performance (COP) of an air conditioners' heat-pump improved from about 4.3 in 1997 to around 6.6 in 2006, with some COPs reaching 9.0 (IEA, 2009). The program achieved an impressive 67.8% improvement in energy efficiency between its introduction in 1997 and 2004. Similar energy conservation targets were met for a range of household appliances, such as refrigerators, PCs, VCRs and TVs.

Figure 18. Japanese Room Air Conditioner Energy Usage Levels, 1995-2007, kWh

	1995	2000	2002	2004	2005	2006	2007
Cooling function	412	262	262	237	227	217	213
Heating function	1080	755	755	708	692	665	652

Source: Japanese Energy Efficiency Centre, 2007.
Note: data for a split system wall mounted 2.8kW energy efficient model.

The Top Runner Program needs to be closely examined and consideration given to including the elements of the Japanese program that have been central to creating a market for high efficiency air conditioners.

3.4 Penetrating Export Markets

China is currently the largest exporter of air conditioners in the world with sales revenue exceeding US$7 billion in 2008 compared to US$4.34 billion in 2005 (see Figure 19).

In developing export markets it is important that Chinese air conditioners are perceived as high quality and that the claimed performance standards of air conditioners reflects the actual standards. Misleading claims about the energy performance of air conditioners by one branded product can create negative perceptions of other brands exported from the same country. There was a reported incident in Australia of a small manufacturer from China supplying air conditioners that claimed a superior energy efficiency performance than its actual standard. This incident may have been the result of a misunderstanding of the efficiency standards of Australia. Regardless of the cause, it is important that the energy standards of the importing country are fully understood so that products sold into import markets are correctly labelled. The failure to do so is likely to slow the penetration rate of air conditioners into new export markets.

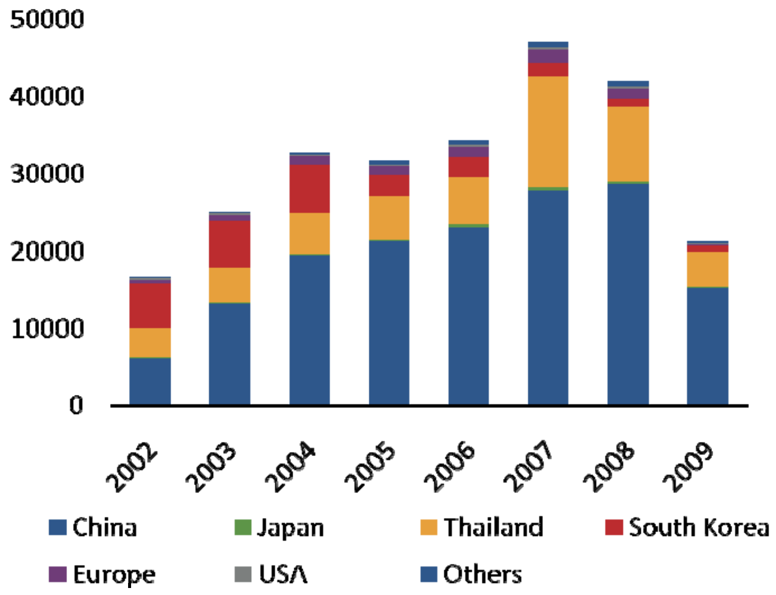
Figure 19. China's Air Conditioner Exports, 2005-2008

Year	Sales (10,000 sets)	Change YOY (%)	Cumulative Value (US$1,000,000)	Change y-o-y (%) Cumulative Quantity
2005	30,340	5	4,341.27	12.9
2006	33,720	11.2	4,770.98	9.9
2007	39,830	18.1	6,337.35	32.8
2008	38,720	-2.8	7,116.24	12.3

Source: General Administration of Customs (2009), 'China's export of air conditioner in March 2009', *Xinhua News Agency,* 1 June.

China has dominated the export of RACs during the past decade. As Figure 20 shows, RAC exports have increased strongly through to 2007 and there was a decline in the world export market for RAC in 2008 due to the global financial crisis. Despite the decline in the world export market of RACs in 2008, the value of Chinese exports continued to increase in 2008.

Figure 20. Composition of RAC Exports Selected Regions, 2002-2009



Note: 2009 figures only include data for the first six months.
Source: Trade Data, October 2009.

In the past there have been indications that Chinese air conditioners were not able to meet the energy efficiency standards of the importing country. For example the early introduction of tighter energy efficient standards for air-conditioning units in Australia was claimed to be adding to difficulties amongst smaller Chinese air conditioner manufacturers. Australia brought the introduction of new standards back to September 2009 from 2010 to satisfy the needs of small manufacturers. To facilitate increased penetration of export markets in the future, Chinese manufacturers of air conditioners need to be able to meet the current and anticipated energy efficiency standards of the importing country.

The ongoing tightening of standards and subsidy program is expected to result in a major global shift in the market share of production and sale of energy efficient air conditioners. This is an important point considering the scale of expected growth within the domestic Chinese market as well as in exports to other developing markets. One question remains, however, regarding the off-shoring of old Chinese plant and equipment to developing economies, such as Vietnam, Pakistan and Brazil amongst others.

4. Factors Affecting Air Conditioning Energy Consumption

4.1 Thermal Efficiency of Building

The thermal efficiency of buildings is a critical factor in determining the amount of electricity consumed by air conditioners. Policies to improve the thermal efficiency of buildings need to be implemented at the same time as the energy efficiency of air conditioners is improved. Improvements in the thermal efficiency of buildings in the future should be an important offset to increases in the number of installed air conditioners.

As well as considering the thermal efficiency of buildings, it is necessary to take into account the size of the buildings. This is a matter of particular concern in the domestic sector. For example, in recent years in Australia the improvement in the thermal efficiency of houses has coincided with an increase in the average size of dwellings. It is anticipated that China will experience a similar phenomenon as the average size of the home increases in accordance with rising incomes and living standards.

4.2 Penetration Rates, Behaviour and Usage

Given that more than a quarter of China's energy consumption and nearly a third of its CO_2 emissions occur due to individual consumers' choices and activities (CASS, 2007), understanding energy efficiency issues from the household level wields significant benefits. Moreover, as the number of air conditioners in China increases sharply over the next decade due to rising income levels, then tackling behavioural issues relating to the purchase and use of air conditioners is critical.

Conservative figures are included in Figure 21 and Figure 22 (CEACER, 2009), which provide a useful insight into the implications of an exponential increase in energy demands from air conditioners due to the combined effects of increasing penetration rates, more urban households, longer hours of use in larger areas. On the up side, is heating demand will decrease and building energy efficiency ratings will improve, but not sufficiently to ameliorate the growth in air conditioner demand.

Figure 21. Residential Housing Heating Air Conditioning Situation

	2005	2010	2020	2030
Area consuming energy for heating in town & village residential housing (kg/m^2)	23.4	20.8	18.9	16.8
Town & village household use of air conditioner (hours)	94	129	186	237
Days requiring heating (days)	115	118	122	129

Source: CEACER, 2009.

Figure 22. Urban Household Appliance Penetration Rate

	2020	2030	2050
Households (million)	288	336	380
Penetration rate of 50% heating energy savings in buildings (percent)	20	45	65
Air conditioner units per 100 households	130	180	260
Air conditioner power index (2000=1)	1.3	1.4	1.6
Air conditioner time utilisation rate (2000=1)	1.6	1.8	2.2

Source: CEACER, 2009.

The CEACER (2009) projections for the penetration rate of household air conditioners through to 2020 appear to under estimate current patterns of growth. This conclusion is based on an examination of recent data on the penetration rate of air conditioners in major cities in China in 2009. In wealthier provinces, such as Guangdong and Shanghai, the penetration rate of air conditioners has already reached nearly 200 per household. Given the rapid rise of per capita incomes in second tier cities, it is likely that most cities will reach similar penetration rates even before 2020. The CEAACER (2009) report estimates that most households will limit the usage of air conditioners to a single room in every house. However, already data on the penetration rates in wealthier cities reveals that most houses will own between two and three air conditioners on average.

Energy demand from air conditioners will rise even more considering urban temperatures are rising due to the combined effects of climate change and urban heat effect. If the penetration rate of air conditioning is greater than current expectations there is likely to be a rapid rise in peak demand for electricity from air conditioners in China around 2020. In these circumstances substantial improvements in air conditioning would assume even greater importance in restraining electricity demand than current expectations.

4.3 Technology and Power Considerations

The current focus of the air conditioner industry is on improving the energy efficiency of existing RAC units through the use of inverters and heat pumps so as to reduce power demands and thermal efficiency. Alternative more energy efficient units are generally restricted to evaporative coolers and water cooled units, which remain less popular and not as effective in some climates. The industry is also challenged by the growing consumer demands for the combination of functions in new air conditioners so that each unit can heat, cool, sterilise and purify the air. All of these functions require greater energy demands and components and raise the price of units.

Geothermal (or Ground Source) Heat Pumps (GHP) are emerging as a popular new cooling and heating technology with economic and technical advantages over existing systems. Natural gas powered are the most energy efficient power source for transfering heat to and from the earth through the GHP via a refrigeration process. The GHP acts as a stabilising temperature for buildings by absorbing heat energy from the ground via tubing or pumping either warm air or water to the heat pump and then into the building in the form of warm air or water during winter. The process is simply reversed during summer with warm air collected from the home and pumped down into the cooler earth and cycled back. Several cities offer subsidies for the installation of heat pump technology utilizing renewable energy, such as Chongqing. Problem is that GHP air conditioners are around 50% more expensive than conventional units, making residential use difficult unless incorporated in the apartment building. By the end of 2008, approximately $100m^2$ million of floor space was utilising basic geothermal energy in northern China for winter heating with enormous potential growth (The Climate Group, 2009).

Another emerging technology is the use of distributed natural gas tri-generation units that can produce electricity, cooling and heating at efficiency levels less than 25% of current electricity powered air conditioners (Malico, Carvalhinho, & Tenreiro, 2009). The innovative role of Broad was mentioned earlier in terms of producing a centralised cooling unit, but innovative, yet affordable high temperature ceramic fuel cells are at the research stage and may be available commercially in the next five years. In the next decade, fuel cell technologies may be able to utilise oxygen or hydrogen as the fuel source at an economically level.

4.4 Climatic Conditions

Climatic conditions have an important bearing on the volume of electricity consumed by air conditioning. An increase in average temperatures during summer is likely to lead to the increased use of air conditioners and therefore greater energy consumption during summer. The combined effects of the urban heat effect in large metropolises and rising temperatures and humidity levels caused by climate change will further exacerbate demand for air conditioners and their usage in a positive feedback loop. Another important factor to take into account is the regional location of increased demand for air conditioners.

4.5 Hours of Air Conditioning and Energy Prices

The hours that the air conditioners are in use significantly affects the volume of electricity consumed by air conditioners. The number of hours in which an air conditioner is operating will depend on a range of influences. These include the comfort requirements of inhabitants, the culture relating to energy use, government policies or regulations and climate conditions.

Other things being equal, the price of electricity will influence the amount of energy consumed by air conditioners. The absolute price level, income levels and energy costs as a percentage of business or household costs are important in determining the amount of electricity consumed by using air conditioners. A critical component in the success of policies to adjust energy prices and reduce hours of usage is the level of public awareness.

4.6 Availability of Energy

The availability of energy is an obvious necessary condition for the use of an air conditioner. If black-outs or brown-outs occur, then energy will not be available. As air conditioners throughout the world are an important source of peak demand for energy, black outs or brown outs are more likely to occur when air conditioners are operating.

5. Policy Instruments to Reduce Air-conditioning Energy Consumption

5.1 Building Design and Construction

The design and construction of a building is directly tied to the issue of energy efficiency and air conditioners. The adoption of simple, low-cost passive design and construction measures in new and retrofitted buildings regarding insulation, ventilation, orientation and shade are necessary. ERI estimate that efficient buildings are five to six times cheaper to heat, cool and light compared to than inefficient buildings. Therefore, such measures provide broader benefits beyond the energy efficiency improvements achieved through air conditioners alone. Moreover, new innovations are providing the technology to link together buildings and their appliances as single yet comprehensive systems that can efficiently integrate power, lighting, water, ventilation and waste systems with heating and cooling. The critical issue is the implementation of such systems in an efficient, effective and timely manner.

The improvement in the thermal performance of buildings can be driven by market incentives, regulations or a combination of both instruments. Experience in countries, such as Australia, suggests the specification of compulsory minimum standards by government is likely to be the most effective method of substantially improving the thermal performance of new buildings. All Australian states and territories build environmental considerations into the building standards.

Given that the price of energy does not include the full cost of carbon dioxide abatement, the market would not provide sufficient financial incentive to construct buildings with high levels of thermal efficiency. Further, even if the cost of carbon dioxide emissions were fully reflected in the cost of energy, there are likely to be other market failures that lead to the construction of highly inefficient buildings.

According to LBNL (2009), by 2008 nearly 100% of new city-based buildings are complying with the government's energy efficiency standards in the design phase and around 80% are compliant after being built. LBNL argue that "China has put into place a system that gives the proper incentives to the design institutes and builders which appears to be quite effective". The weakness in the existing building efficiency program is retrofitting existing buildings which is unlikely to meet the 2010 target of all new buildings achieving a 50% reduction in energy use. As such, this failure places more emphasis on tightening air conditioner standards and promoting energy efficient behaviour.

In a market system where households are free to decide on the size and nature of their house, the house owner is faced with a range of decisions from colour schemes to building materials, all of which are inherently time consuming. This implies that unless the owner has a special interest in the thermal efficiency of the home, energy considerations are likely to be towards the bottom of the decision making hierarchy. Home purchasers typically do not have the detailed knowledge of the thermal efficiency of various decisions. This lack of detailed knowledge on the thermal performance biases consumers away from energy efficient options. In societies where changes in home ownership occur relatively frequently (7 years or less) the short term cost of thermal efficiency improvements are unlikely to be recouped during the period of occupancy as many of the energy efficient choices have significantly longer payback periods than 7 years.

5.2 Building Standards

The high energy use figure for China's buildings has meant that the sector is a key focus of the national government's energy savings targets by 2020 with energy savings in building efficiency expected to contribute 40% of planned total energy savings. According to McKinsey (2009, 17), the building sector offers the best energy conservation savings and carbon abatement opportunity for the lowest cost across all sectors. For instance, the buildings and appliance sector offers the potential for reducing power demand by one-third and coal demand by 50%. McKinsey argue that 70% of the total carbon abatement from the building sector would provide a positive economic return from reduced energy consumption compared to the initial upfront investment. Timing offers a major caveat to the potential abatement savings, due to so-called 'lock in' effects if energy efficiency measures are not immediately adopted. The window of opportunity to introduce improved and compulsory building energy requirements and standards will not last forever. China's property boom has picked up speed after a brief slowdown in late 2008 and early 2009. Moreover, the next twenty years will see the most rapid expansion of China's building spaces and a rapid rise in energy consumption.

Specification of improved thermal efficiency standards for new buildings can ensure that new buildings use less energy compared with existing structures. It is critically important that the specifications are expressed in such a way that the thermal efficiency objectives are met. Poorly drafted building regulations can create unintended consequences and may result in buildings with poor thermal performance. While it is essential to correctly specify thermal efficiency building standards, it is necessary to ensure that these standards are enforced. Well designed building regulations that are not monitored by authorities will inevitably lead to inferior building construction and a failure to meet thermal efficiency objectives.

Well designed and implemented thermal efficiency building standards result in a guaranteed improvement of thermal efficiency of new buildings. However the preparation and adoption of building regulations is a relatively slow process and the latest regulations are unlikely to incorporate all of the latest technology available to improve the thermal efficiency of buildings. Governments need other policy instruments to encourage the use of more advanced energy efficient products. Building owners can be encouraged to go beyond minimum thermal efficiency standards by governments providing subsidies to install insulation, high efficiency windows and other products that improve the thermal efficiency of new buildings.

Providing financial support for the installation of products that improve the thermal efficiency of buildings will reduce the consumption of electricity from the use of air conditioners. Similarly, subsidy programs are important in increasing the penetration of super efficient air conditioners and reducing the growth in demand and usage of air conditioners.

5.3 Government Subsidies

The existing rebate and subsidy programs could be continued and targeted at the most energy efficient air conditioners. In designing a subsidy system to encourage the purchase of super efficient air conditioners the following issues need to be considered:

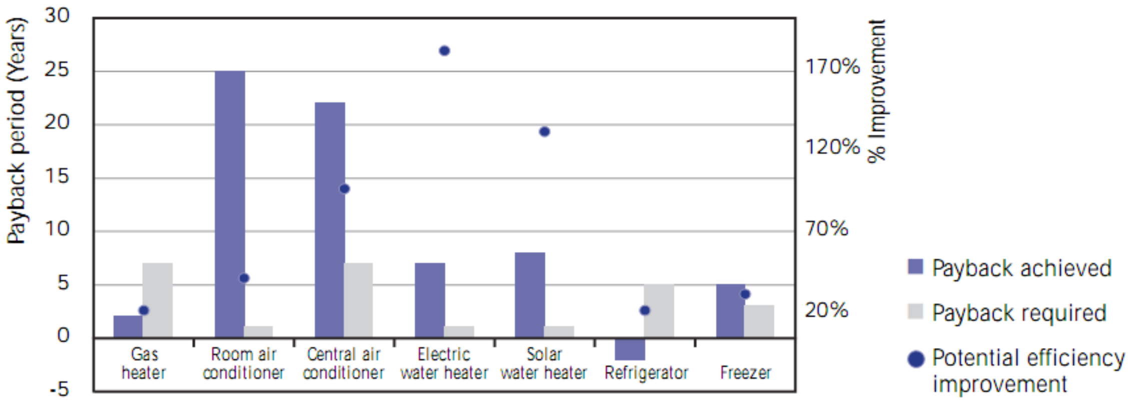
- small subsidies may not be sufficient to change behaviour;
- policy makers need to be aware of the impact of large/complete subsidies on level of purchase to avoid policy change because of significant budget costs;
- subsidy payment system can affect level of take up;
- subsidy financed from budget or electricity users; and

- consider extending and expanding the rebate program but only for super efficient air conditioners.

An effective subsidy scheme will encourage the purchase of high efficiency air conditioners and improve the average energy efficiency of air conditioners. While the policy is designed to boost demand for super efficient air conditioners on domestic market, an added benefit that manufacturers of super efficient air conditioners would achieve economies of scale and be able to export at highly competitive prices. In addition, the demand pull for super efficient air conditioners would encourage innovation by manufacturers. However, continuing a subsidy that covers the additional costs of a super efficient air conditioner may have a significant budget cost. And yet, partial subsidies may be ineffective in increasing demand. Additional barriers could be low consumer awareness of the benefits of the subsidy and retailers may have no incentive to sell the subsidised product.

China's NDRC and Ministry of Finance currently provides subsidies to companies whose products reach a defined energy efficiency level before the products are sold at the subsidized price to consumers. This scheme is in addition to the rebate program announced in the stimulus package for refunding 13% of the consumer price of selected household items, such as air conditioners. In addition, wealthier provinces and cities are encouraged to establish funding pools for promoting energy efficient products. The aim of the initial program is to assist energy efficient products gain market share. Air conditioners will apparently be one of the first home appliances to receive the subsidies, ranging from RMB300 to RMB850 for each unit.

Figure 23. Consumer Payback Requirements for Energy Efficiency Improvements Versus Achieved Payback Periods



Source: McKinsey cited in IEA, 2009.

The aim of the subsidy is to ensure the sales of energy-efficient home appliances will make up over 30% of market share by 2012. According to the Ministry of Finance, sales of Grade 1 and 2 air conditioners in 2009 tripled compared to 2008 and accounted for 50% of total sales for the year.[24] The decision to select air conditioners as a priority is in response to the

[24] Henan Commercial Daily (2010) Taking up the Offer of "Energy Saving Subisidies": Guangdong's Chigo Promotes the Popularisation of Energy-Efficient Air Conditioning, 5 February; 《河南商》借势"节能惠民"广东志高推进高能效空调普及 (in Chinese)

identification of these household appliances as offering the biggest energy efficiency gains with the lowest cost. Figure 23 illustrates how air conditioners compare to other household appliances in terms of energy efficiency improvements versus payback periods.

5.4 White Certificate Schemes

A number of countries have introduced 'white certificate schemes' to encourage the purchase of energy efficient consumer products. White certificate schemes are designed to encourage the sale of products that minimise the cost of increasing the energy efficiency of household appliances. Products included in the scheme have higher efficiency performance than products typically purchased in the market. The selected products are able to create certificates for every unit of energy saved from using the product. A government authority determines the estimates of energy saved. The certificates created from the energy efficiency products are sold in a regulated market and the price of certificates determines the value of the subsidy provided to the purchaser of the energy efficient product. Therefore, if the scheme is soundly structured, then it has the potential to encourage the purchase of super efficient air conditioners.

Introducing a mandatory requirement on electricity retailers to purchase white certificate schemes requires complex accreditation and arbitrary judgements on relative energy efficiency gains from purchasing accredited products. The experience in Australia of these schemes indicates there are difficulties in avoiding loopholes and there is a tendency to encourage the purchase of low cost items such as energy efficient light globes. In the case of light globes it is very difficult to determine that the purchase would not have taken place in the absence of the white certificate scheme. This means the energy efficiency level may not go beyond business as usual.

To the extent the policy boosts demand for super efficient air conditioners on domestic market, a spin off for export markets is that manufacturers of super efficient air conditioners would achieve economies of scale and be able to export at highly competitive costs, which could in turn boost further innovation.

The scheme needs to be implemented carefully as the super efficient air conditioners will compete with other energy efficient products for the creation of white certificates. There is a potential problem that the value of the certificates will not be sufficient to increase the sale of super efficient air conditioners or the price could affect alternative technologies that offer greater energy savings. Finally, international experience shows that the time and complexity of demonstrating proof of purchase and installation may not warrant consumers applying for the white certificates.

5.5 Monitoring and Testing

According to Lin and Fridley (2007), many of the technical staff assessing energy efficiency standards are trained in health and safety rather than monitoring and verifying appliance performances. The NDRC and the AQSIQ are responsible for undertaking inspections for energy efficiency labelling and compliance with energy efficiency standards. Typically, the agencies publically announce inspections prior to a campaign. The performance measures of local officials now include energy efficiency targets. More work is required in monitoring the success and progress of energy efficiency programs so that further adjustments can be made.

Governments commonly neglect the monitoring and enforcement of mandatory requirements. Yet this is a critical area of policy implementation. Unless the performance of air conditioners in the field is consistent with stated performance measures energy efficiency policies will fail. The matching of the claimed performance of an air conditioner with the actual performance is a necessary condition for an effective MEPS or any other performance standard. EU testing results revealed A/C units were substantially below reported standards. In addition, if there is a concern in international markets that the specified standard of an air conditioner does not reflect the actual performance of a product this will have an adverse effect on exports. Moreover, greater synchronisation towards global testing and labelling standards could streamline processing and bring down the cost of energy efficient air conditioner units. Risks remain with greater global standards on energy efficiency testing and standards because to achieve global agreement, a high-degree of trade-offs and consensus is involved, which ends up reducing the efficiency gains resulting in ineffective and unsubstantial agreements.
There is unlikely to be any resistance from companies that have high standards of quality control. Instead, resistance is likely to come from firms that are struggling to keep up with mandatory standards.

5.6 Labelling

By 2009, the NDRC has published a series of four energy efficiency product catalogues covering a variety of household products, including air conditioners. The China Standard Certification Center is responsible for China's national certification and labelling program. In March 2009, new labelling laws were implemented by the NDRC covering speed-controlled air conditioners and split module air-conditioning units. The new labelling requirement is mandatory for all new products, but will be phased in for those already in production prior to the end of December 2008 to be implemented by 1 March 2010. After this date, manufactures will be forbidden from selling or importing into China units failing to meet relevant energy efficiency standards. Fines will be given to firms not complying with the minimum standards or labelling laws.[25]

Presently, China's mandatory energy efficiency label for air conditioners is based on the EU energy label that includes 5 categories of energy performance. It is reported that manufacturers are able to self report on energy efficiency labels. Experience overseas suggests that self reporting may not be satisfactory. As long as the stated energy efficiency

[25] Source: http://www.chinacsr.com/en/2008/11/17/3635-energy-efficiency-labeling-of-home-appliances-to-be-mandatory-in-china/

label reflects the performance of the air conditioner, then labelling should encourage an increase in the energy performance of air conditioners sold on the Chinese market. To improve the effectiveness of the program and reduce bad publicity, domestic manufacturers should ensure that labelling meets the requirements of international markets. As energy conscious consumers would prefer to purchase advanced energy efficient air conditioners increased demand would encourage manufacturers to produce more efficient air conditioners.

6. Implementation Strategies: Top Runner, Smart Meters & Electricity Cycling

6.1 World's Best Practice: The Top Runner Program

A study prepared for the Australian Greenhouse Office in January 2005 provided a comparison of International MEPS for Room Air Conditioners (EnergyConsult, 2005). The products included in the study were single phase split systems and window air conditioners that were reverse cycle and cooling only. The study is helpful in identifying countries that are leading the way in setting MEPS for room air conditioners (RACs) and provides a brief summary of the policies used to increase the sales of more energy efficient air conditioners. The study found that for RAC cooling only units, the 'the most stringent MEPS levels currently in force are those of Korea (from 2004). In terms of an industry –wide policy, however, Japan's Top Runner program provides a clearer direction for the sector to achieve a rapid transition to higher efficiency air conditioners.

Key features of Japan's Top Runner program, such as the market leader policy, could be adopted in China. This approach is most likely to encourage rapid innovation of energy efficient RACs. Any adoption would need to be in line with local Chinese conditions. For example, a mix of voluntary and mandatory elements would require reviewing, as would the adopted method for the value system (minimum standard, average standard or maximum standard) for determining the energy consumption efficiency standards. The maximum standard has been utilised as part of the Top Runner program in Japan (see discussion earlier in the report). A summary of the impact of such a policy initiative is presented below.

The Top Runner program's mandates performance standards based on the weighted average of air conditioners sold reflecting the best performing air conditioner sold on the market when the new standards are determined. The standard would also allow for improved energy performance over time. By setting the energy efficiency standards at a high level and providing an incentive to manufacturers to increase the energy efficiency of air conditioners there is likely to be an increase of approximately 50% in the energy efficiency performance of air conditioners sold in the first seven years of the program.

A market leader policy would provide a strong incentive to manufacture super efficient air conditioners in China. Moreover, as manufacturers are likely to produce air conditioners with a range of energy performance levels they can target world markets with a wide range of product requirements. However, there may be some resistance from manufacturers because they will be required to provide data on the value of sales of different types of air conditioners sold on the domestic Chinese market.

China's new EER standards for RACs, effective from 2009, are at the forefront of energy efficiency standards for air conditioners. In fact, the new requirement for RAC units (split system 4500 Watts) is actually higher than the European Union's A label, and is just behind Japanese and South Korean requirements (Lin & Rosenquist, 2006). In terms of the window air conditioners, the 2009 Chinese standard is above other international comparisons with a minimum EER of 2.9, compared to 2.88 in South Korea, 2.87 in the US and 2.85 in Japan. (Lin & Rosenquist, 2006)

Figure 24: Proposed Extension of the EER Standards in China, 2011-2025

12th FYP, 2011-2015	5.5 EER
13th FYP, 2016-2020	7.0 EER
14th FYP, 2021-2025	8.0 EER

Source: Author's own proposal.

Consideration should be given to increasing the EER of air conditioners beyond the levels currently proposed. A substantial increase in the MEPS could be achieved over the next decade. A leading manufacturer in China Gree, has indicated that they are capable of manufacturing air conditioners with a substantially higher EER on a large scale. Figure 24 presents one possible scenario for a technologically realistic stretch of the EER standards that could be achieved in China over the next three five year plans (FYP).

The proposal in Figure 24 is an extension of China's current MEPS standard for RACs. The proposed EER represents a substantial increase on the existing EER. The listed EERs are considered realistic stretch targets based on the capability of major manufacturers in China. Technology is available to commercially produce air conditioners with an EER of >7.0 in 2009 in Japan. Also GREE have indicated that they have the capability of producing an air conditioner with an EER of 6.5. With expected technology improvements an EER of 8.0 is achievable by the end of the 14^{th} FYP.

The energy efficiency benefits will result in an incremental increase in the average EER of air conditioners sold on the domestic market. The impact on energy consumed by households will be affected by size of the replacement market and the extent to which the MEPS EER exceeds the lowest performing air conditioner on the market. Also it is important to consider whether improved energy efficiency is likely to increase the use of air conditioners because of lower running costs. Any consideration of the impact on exports will depend on importing countries EER standards and the price of air conditioners produced in competing countries.

It is unlikely to produce significant innovation as all manufacturers would be required to meet the MEPS which by definition is not a super efficient air conditioner. Innovation may arise, however, with alternative technologies due to the increasing demands on energy efficiency and expected price increase. Implementation considerations or barriers may include equity or pricing concerns as well as support for industry restructuring. Further analysis of the impact of the increased standards on the cost to consumers vis-à-vis purchase price and operation costs is necessary. Due to the size of the Chinese market, economies of scale may mean only small increases in the cost of production. However, imposing stretch targets on manufacturers may lead to rationalisation of the air conditioning industry in China and the closure of older or smaller manufacturers. This may lead to resistance to change and protectionism from some local governments.

6.2 Time of Use

As the use of air conditioners adds to peak demand for electricity, the time in which air conditioners are used can affect the ability of the electricity generation and transmission system to deliver electricity during peak demand periods. The short implications of air conditioners operating in peak demand times is that air conditioner use increases the risk of black-outs and brown-outs of electricity. In the longer term the use of air conditioners increases the need to augment the capacity of the electricity generation and transmission system. For these reasons it is sensible to consider policies that lead to a reduction in electricity consumption during peak periods.

There are a number of options available to governments to reduce the electricity demand from air conditioners in peak periods. These options include the use of time cycling of air conditioner units and the roll out of smart meters.

The time cycling of air conditioners involves the electricity distribution authority switching air conditioners on and off according to reduced peak demand of electricity. For instance the electricity distributor could switch off 50% of air conditioners every 15 minutes or so to reduce the peak demand for electricity emanating from air conditioners. For time cycling to be effective it would first be necessary to wield sufficient knowledge of air conditioning use, the ability to switch off 50% of non-essential air conditioners at any one time and broad acceptance by air conditioner users that an equitable system for time cycling of air conditioners was in place.

The time cycling of air conditioners in peak periods has been considered by a number of countries and may become a more important instrument in the future with the introduction of smart meters. Korea and Japan are undertaking trials of time cycling with smart meters and will probably lead the region in their roll out and manufacture. In the US, GE and Cisco are trialling the development of a municipal-level smart grid in Miami, Florida. Another interesting example is American Electric Power, which have commenced trialling time cycling with smart grids under two programs: *Smart Shift* and *Smart Cooling* in Michigan. Participants in the Smart Cooling program receive a $25 rebate of their electricity bill. The Smart Cooling service is only available to households that are located in a smart meter pilot project area. Customers are also supplied with real time information on energy use and peak and off-peak prices. In both sites, GE provides the smart meters and Cisco builds the network. According to Indiana Michigan power, a Programmable Communicating Thermostat (PCT) or 'smart thermostat' is used. The PCT is installed for free by the utility and during periods of peak load, the PCT 'receives a signal from the smart meter to raise the air conditioner setting by a few degrees or to shut it off for short periods of time.'[26] Trials for the use of smart meters is occurring elsewhere with Europe and the UK setting 2022 and 2020 as targets for the roll out of smart meters. It remains early days in the use of smart meters with much debate guaranteed due to concerns about privacy, equity, security, safety and access with insufficient details of the real energy savings. For instance, some Demand Load Control (DLC) programs in the USA have achieved 29% peak electricity load savings with minimal reduction in total energy consumed.

The existence of smart meters provides an opportunity to effectively reduce the consumption of electricity from air conditioners during peak periods. The control mechanisms of smart meters would significantly improve the effectiveness of air conditioner cycling or policies that centrally set lower temperature limits for summer cooling, but also in raising public awareness of the energy consumption of households and appliances. The success of Indiana Michigan Power's Smart Cooling service will be of interest to future developments in this area of policy. However as this program is based on voluntary participation, it is likely to be less effective than a policy initiative that has centralised control over the use of air conditioners.

The installation of smart meters can be used to control the use of air conditioners via market measures or administrative measures. Such meters provide valuable usage data for utilities, government and consumers, and thus raising awareness. The installation of smart meters in residential and commercial dwellings with the objective of controlling the use of air conditioning during peak electricity demand periods can be linked to market mechanisms to provide air conditioner users the option of allowing the central control of air conditioners in exchange for lower energy costs to charging consumers for the "true" cost of electricity and allowing 'consumer choice' on the use of air conditioner. In addition, air conditioners can be cycled on & off centrally as essential service measure to control the level of peak electricity demand.

It should be clear that smart meters and electricity cycling have no impact on energy efficiency. Instead, they should be seen an **energy conservation** measure that changes the behaviour of air conditioner users. The installation of smart meters in China would open up a range of opportunities for innovation. These include integration of smart meters with other energy using products to the collection of household data on energy use by various appliances. This data would be useful in evaluating the performance of electrical equipment and raising energy awareness. Moreover, if smart meters are installed on a large scale then China could become a major manufacturer of low cost smart meters globally. Smart meters are a relatively new device on the world market and there is limited experience of their effectiveness. Unless electricity prices reflect the "true" cost of electricity, **market measures** may be limited in their effectiveness.

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[26] For details of Smart Cooling in Michigan see
http://www.indianamichiganpower.com/news/southbendpilot/DLC.asp

7. The Future Direction of Air Conditioning Usage in China

7.1 Focusing on Energy Efficiency Performance Standards

The use of air conditioners is already a significant component of electricity consumption in China and is expected to grow sharply in the future. Most importantly air conditioners are generally used during peak demand periods. This means that air conditioners are a significant cause of greenhouse gas emissions and are an important factor in placing stress on the capacity of the electricity generation, transmission and distribution system. This is the context in which future policies relating to air conditioners should be considered. Policies will need to be developed that are not only designed to improve the energy efficiency of air conditioners but also to affect the usage of air conditioners during periods of peak electricity use.

The typical approach adopted by countries aimed at reducing energy consumption from air conditioners is to introduce mandatory minimum energy performance standards (MEPS). MEPS are designed to improve the efficiency of air conditioners by prohibiting the sale of air conditioners that do not reach a minimum standard. The effectiveness of MEPS in reducing energy consumption depends on the proportion of sub-MEPS air conditioners that would have been sold in the market in the absence of a MEP. If the market is ahead of the MEPS standard, the application of the MEPS will not have the effect of reducing electricity consumption from air conditioners. In these circumstances the MEPS will be following the market rather than leading the market.

The MEPS standard that came into force in China on 1 January 2009 sets the EER for a single-packaged room air conditioner (cooling) at 2.9 and a split system with watt capacity equal to or less than 4,500 watts at 3.2. The dominant product on the market is split air conditioners with a cooling capacity smaller than 4500 watts, which is higher than the EU standard, whereas the standard in USA and Canada only trails the requirements of Japan and South Korea (Lin & Rosenquist, 2006). The comparable standard in Japan ranged between 3.65 and 5.27 and in South Korea the standard was 3.37.

As the average EER of air conditioners sold in 2008 in China was 2.8 when the EER was 2.6 it is problematic whether the new Chinese MEPS will lead to a significant increase in the average value of EER for air conditioners sold in the market in 2009 and beyond. At this stage it has not been possible to obtain data on the proportion of small split air conditioners sold in China that were below 2.6 (EER applicable in 2008).

7.2 Determining the MEPS Requirement

The first consideration in determining the value of MEPS for air conditioners in the future is the extent to which policy makers in China want to lead the market or follow the market. If future MEPS standards are to have an impact in the future, then they need to be set at levels that stretch the capacity of manufacturers to reach the MEPS requirement. In principle the MEPS should be set at the highest level possible that is consistent with the technical and economic capacity of Chinese manufacturers to meet the MEPS for air conditioners, such as the approach utilised by the Top Runner program.

Instead of establishing a minimum standard approach to air conditioners allowed onto the market, Japan's Top Runner program sets an EER that is based on the highest EER value of an air conditioner on the market at the time the standard is established. The standard value is based on the most efficient air conditioner in the market plus potential technological energy efficient improvements. Manufacturers are required to have an average weighted EER value weighted by the volume of air conditioners shipped to buyers. The Japanese system is designed to provide incentives for developing more efficient air conditioners. In view of the success of the Top Runner policy serious consideration should be given to the practicality of introducing a similar policy in China.

7.3 The Importance of Energy Efficiency Labels

Most countries that have adopted MEPS for air conditioners have complemented this with a labelling system that encourages buyers of air conditioners to purchase air conditioners that exceed the MEPS. Countries such as the USA, Hong Kong and Australia have a mandatory star rating policy that assists buyers in assessing the relative efficiency of air conditioners on the market. China introduced an energy labelling program in 2005 and an IEA Information Paper issued in 2007 found 'that the energy efficiency requirements set by the labelling program have been effective in stimulating energy efficiency improvements in China' (Koizumi & IEA, 2007). Given the success of the labelling program additional efforts should be undertaken to increase the awareness and the significance of installing high efficiency air conditioners in households.

7.4 The Role of the Retailer

Complementary measures to enhance the effectiveness of energy efficiency labels should also be considered. The stock of air conditioners held by retailers and the manner in which these air conditioners are displayed have a significant impact on the sale of air conditioners. If highly energy efficient air conditioners were strongly promoted and displayed by retailers this would provide a further stimulus to the purchase of these air conditioners. Japan has recognised the importance of retailers in encouraging the purchase of highly efficient air conditioners. For example, Japan has introduced the 'Energy Efficient Product Retailer Assessment Program' (METI, 2008). China has similarly set up certification and award schemes for producers and retailers, but it is unclear how effective such measures actually are in promoting energy efficient air conditioners. Anecdotally, retailer awareness of air conditioner unit energy efficiency performance as well as product specifications was very high amongst larger retail appliance outlets in China.

Presently, most air conditioners sold in the Chinese market include the cost of installation and some service provisions. The benefits of this approach are significant in terms of integrating production with utilisation and ensuring potential energy efficiency savings are maximised. Many of the consumer complaints about air conditioner operation would also be reduced due to the manufacturer and retailer having full responsibility for the unit's operation.

7.5 Installation and Maintenance

In addition to developing sound and effective policies to promote the sale of energy efficient air conditioners, it is important that regulations are put in place to ensure that these units are correctly installed and maintained. Such regulations are necessary to ensure that installed air conditioners perform in accordance with the EER of the air conditioners. A recent study (Sachs et al., 2008) of the energy performance of air conditioners operating in the field in the USA covered the following areas:

- Refrigerant charge errors
- Refrigerant leakage over time
- Air handler impact on over-sizing (indirect)
- Ductwork and accessories external static pressure
- Cabinet air leakage
- Air filter rack and tight door
- Call for service (other)

All of these issues are important and require close attention, as it is the performance of air conditioners after they are installed that determine whether the purported energy savings are achieved or not. A study by Neme, Proctor and Nadel (Sachs et al., 2008) in the USA found that improved installation practices could reduce heating, ventilation and air conditioning (HVAC) energy use in existing buildings by 24% and 35% in new buildings. If the goal is to achieve optimal performance of installed air conditioners, it is essential that effective regulations are established, monitored and *enforced*.

7.6 Developing a Climate Friendly Air Conditioner

In the interest of wider climate change issues, developing an energy efficient air conditioner that sustains a high level of performance over time, is manufactured in a way which makes it easier to be recycled at the end of its life and uses low greenhouse gas refrigerants should be given a high priority.[27] An ecologically sustainable air conditioner could become a world market leader as a 'climate friendly' air conditioner and provide a new manufacturing opportunity for China.

More intelligent air conditioners need to better respond to the environment and climate in which they operate, especially in order to maximise energy efficiency. Such considerations need to be balanced with the increasing energy demands and costs of increasingly multifunctional air conditioner units. The growing popularity of co-generation heating, ventilation and air conditioning (HVAC) systems in buildings that incorporate distributed power generation, cooling and heating capacities will be important in bringing down the current high establishment costs. Existing technologies exist for centralised systems, but are

[27] Old air conditioners can fetch up to RMB400 due to the large amount of retrievable scrap metal and components.

also being trialled at the household level. For example, the development of the distributed tri-generation high temperature ceramic modular generators powered by natural gas will be worth watching.

7.7 Application of new Technologies

As the largest manufacturer of air conditioners in the world, China, will play a crucial role in determining the energy efficiency of units. Earlier comments about the relocation of second generation overseas plant and equipment in China are no longer relevant today with the presence of so many international companies in China as their base for manufacturing even top-end highly energy efficient air conditioners. In addition, to the example of Daikin, which has recently shifted production of high-end air conditioners to Gree's Zhuhai plant, an increasing number of international and domestic air conditioner manufacturers are increasing their in-house R&D investment as well as through strategic partnerships with universities and research centres. This is evident in the growth in Chinese origin invention patents by both manufacturers and research centres. The

7.8 The Role of Smart Meters

Another issue that warrants close consideration as far as the operation of air conditioners is concerned are options that are open to government to reduce the power used by air conditioners once they are installed. At present governments attempt to influence the use of air conditioners during peak electricity by moral suasion and the setting of temperature floors before air cooling conditioners can be switched on. These policies are likely to have some impact on air conditioner usage but are ad hoc and are not based on optimal design principles. Energy conservation improvements in a combination of HVAC systems are also an important component of achieving building energy efficiency, such as introducing smart or automated metering to manage building thermostats.

The introduction of smart electricity meters provides an interesting new opportunity to raise public awareness and centrally control the volume of electricity used by air conditioners in peak demand periods. Once buildings are installed with smart meters it is a relatively easy and effective task to centrally control the amount of electricity used by air conditioners. As major cities throughout the world experience electricity capacity constraints and unplanned black-outs there is likely to be an increased focus on controlling air conditioner usage during peak demand periods. The combination of smart meters and the central control of air conditioner usage is beginning to be considered by electric utilities. One example is Indiana Power Michigan which is planning a smart cooling program based on smart meters. While the Michigan scheme requires volunteer participants, the combination of smart meters and central control is likely to be far more effective in reducing energy consumption if it is mandatory to participate in a smart cooling program.

In order to evaluate the potential effectiveness of a centralised smart cooling program, China could select a city to participate in a pilot project. Smart meters could be rolled out to businesses and households and the electricity distributor for the city could set up a centralised smart meter system. The project could be used to evaluate the effectiveness of controlling air conditioners. Centralised decisions could be made to switch on air conditioners only if indoor temperatures reach a set level and/or allow the central controlling of the cycling (switching air conditioners on off on a systematic basis) of air conditioners in the participating city. Caution needs to remain in rolling out a smart meter system in terms of costs and its impact upon vulnerable members of the community, including low income earners, the elderly and sick.

7.8 Improving the Thermal Efficiency of Buildings

Although the focus of this report is the performance of installed air conditioners, it is essential that improving the energy efficiency of air conditioners be considered in conjunction with the thermal efficiency of buildings. Increasing the thermal efficiency of buildings maximises the benefits from improving the EER of air conditioners. Improving the comfort levels of buildings without cooling or heating will create less demand for air conditioning.

The setting of mandatory energy efficient standards for buildings needs to take into account the technical feasibility and cost of insulating buildings. There is a wide range of materials on the market that can dramatically improve the thermal performance of buildings but as a general rule use of these materials increases the cost of construction. It is also important that building standards go beyond the thermal efficiency of the building envelope. In particular, attention needs to be paid to essential items installed in a building as many electrical products can lead to excessive energy consumption in buildings, such as computer servers and lighting. The installation of halogen down lights, for example, use vast amounts of energy and generates significant heat, making air conditioners work harder during times of hot weather. The implementation and enforcement of energy efficiency standards are critical to the success of building standards. Considerable thought is required to design effective thermal efficient building standards and to address the manner in which these standards are going to be enforced and implemented so that energy efficiency is a core consideration through building design, construction and utilisation.

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IDENTIFYING POLICIES AND IMPLEMENTATION STRATEGIES FOR IMPROVING ENERGY EFFICIENCY

CASE STUDY 3

Increased Utilisation of Natural Gas in China

May 2010

Centre for Strategic Economic Studies

Victoria University, Australia

With the assistance of the

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1. Introduction

This report is the final in a series of case study reports on findings arising from the broader study into achieving increased energy efficiency in China. This report examines the potential for the increased utilisation of natural gas in China, including the opportunities and constraints facing the industry. Natural gas in China is entering a new and important phase as a transition fuel towards a low carbon economy. While domestic production of natural gas has expanded, it has been unable to meet the rapid growth in demand. Consequently, China has recently embarked on a policy of importing gas from overseas via pipeline and shipped LNG. To distribute the gas, an ambitious national pipeline network has been rolled out supported by the construction of tankers, ports, storage, gasification and liquefaction facilities. At the same time, the central government has been reforming the policy and regulatory framework governing the gas market to encourage its expansion.

The growth in annual consumption of natural gas in China exceeded both coal and oil between 2000 and 2008 when it rose 16.2% on average. This is nearly 10 percentage points higher than the annual growth rate of oil consumption and 6.6 percentage points higher than coal consumption's annual growth rate. Between 2000 and 2009 natural gas production grew by an average of 13.2%. In 2009, almost 83 bcm of natural gas was produced domestically. While most of China's natural gas comes from domestic production, imported gas supplies are making up an increasing proportion of consumption. China is rapidly expanding its investments in international gas supplies to ensure a diverse and secure supply especially while international gas prices remain depressed. Moreover, expectations within China of strong gas demand in the coming decade, both regionally and internationally, are resulting in many gas projects being brought forward, including several LNG ports and new field developments. China currently imports or has long-term supply contracts to import gas from Australia, Indonesia, Malaysia, Qatar and Turkmenistan. It also has initial agreements to buy gas from Russia, Papua New Guinea, Kazakhstan, Iran and Myanmar.

This report commences by setting the context around China's energy mix followed by a discussion of the role of natural gas in China, including the nation's gas resources, demand and market characteristics. China's national gas policy framework is then introduced before exploring the future of gas demand and the implications for supplies, infrastructure, unconventional gas resources and investment in the sector. The global and regional supply position for natural gas is then briefly discussed before presenting several policy options for increasing the utilisation of natural gas in China.

1.1. Background

Several factors shape China's current and future energy mix, including: China's national endowment of energy resources; its historical energy utilisation; energy security concerns; the cost of natural gas; the rate of economic growth and pattern of development; population growth; urbanisation; and, environmental considerations. Each of these factors encompasses many complicated issues and could be examined at length. Therefore, the issue of energy security, for instance, while probably the most important determinant of China's energy policy, is not the focus of this report. Instead, this report looks at the potential role of natural gas in improving the efficiency of China's energy mix with a particular focus on reducing carbon emissions. Before introducing the role of natural gas in China, it is necessary to briefly describe the two primary drivers for increasing energy demand in China: the structure of the economy and the nation's demographics.

In 2010, China became the second largest economy in the world and the world's largest trading nation. It has clearly led the global economic recovery following the effects of the financial crisis and is an engine of world economic growth. In the next two decades, it is predicted that China will surpass the United States to become the world's largest economy. It has maintained a sustained rate of rapid economic growth of nearly 10% over the past three decades and is predicted to continue to do so for a further two to three decades (CSES, 2010). In terms of demographics, China has the world's largest population of around 1.33 billion with almost half living in cities. It has the best record in reducing poverty and today boasts one of the world's fastest growing affluent populations. By 2030, one billion will be urban residents in one of the 233 cities with over one million people (McKinsey, 2009b). This will require a further five billion square metres of paved roads, the construction of a further 170 mass transit systems and 50,000 skyscrapers with 40 billion sq meters of floor space and an economy that is at least four times as large as today.

All this requires a lot of energy. As a result, China became the world's largest consumer of energy in 2010. In the next two decades, China will install more new electricity generating capacity than currently exists in the United States today (IEA, 2007). Most of this new capacity will burn coal with 105GW of thermal coal power brought online in 2006. A further 80GW of coal power generators were completed in 2008 (IEA 2009: Cleaner Coal in China; NBSC, 2010). This recent rapid spike in coal power is expected to moderate at around 50GW per year after 2010 according to ERI (CEACER, 2009). Due to the country's high dependence upon coal, China became the world's largest emitter of greenhouse gases (GHG) in 2006. The past three decades of rapid economic growth have had an enormous environmental impact with high levels of serious air, water and soil pollution. It is predicted, however, that China's path along the environmental Kuznets curve is expected to be rapid, relative to most developed and developing nations.

According to Figure 1, the IEA (2009a) estimates global primary energy demand to grow by 1.5% annually between 2007 and 2030, with most of the growth driven by China (2.9%) and India (3.4%). Electricity consumption in non-OECD countries is the main driver for rising energy demand. China will play a key role adding nearly 1400 GW of new power-generation capacity by 2030; representing nearly a third of the global total.

Fig. 1. Primary Energy Demand by Region in the IEA's Reference Scenario (Mtoe)

	1980	2000	2007	2015	2030	2007-2030*
OECD	4050	5249	5496	5458	5811	0.20%
European Union	n.a.	1684	1757	1711	1781	0.10%
North America	2092	2682	2793	2778	2974	0.30%
United States	1802	2280	2337	2291	2396	0.10%
Europe	1493	1735	1826	1788	1894	0.20%
Pacific	464	832	877	892	943	0.30%
Japan	345	518	514	489	488	-0.20%
Non-OECD	3003	4507	6187	7679	10529	2.30%
E. Europe/Eurasia	1242	1008	1114	1161	1354	0.90%
Russia	n.a.	611	665	700	812	0.90%
Asia	1068	2164	3346	4468	6456	2.90%
China	**603**	**1105**	**1970**	**2783**	**3827**	**2.90%**
India	207	457	595	764	1287	3.40%
Middle East	149	389	513	612	903	2.50%
Africa	128	378	546	702	1030	2.80%
Latin America	274	499	630	716	873	1.40%
Brazil	292	457	551	633	816	1.70%
World**	7228	10018	12013	13488	16790	1.50%

Notes: * Compound average annual growth rate. ** World includes international marine and aviation bunkers (not included in regional totals).

Source: IEA World Energy Outlook 2009

In terms of the energy mix, the IEA predict that coal, natural gas and renewables will take up some of declining supply of oil with coal remaining the core energy source and actually rising to 44% of the global total by 2030. The situation in China is expected to be little different, despite Chinese government policies promoting a low carbon economy, with coal continuing to play the dominant role for future energy demand. Coal provides energy security due to its low cost and relative abundance, primarily located in the northern and north eastern regions of the country. In contrast, China is largely reliant on imports for its oil requirements.

Fig. 2. Comparison of Air Pollutant Emissions from Various Energy Sources, kg

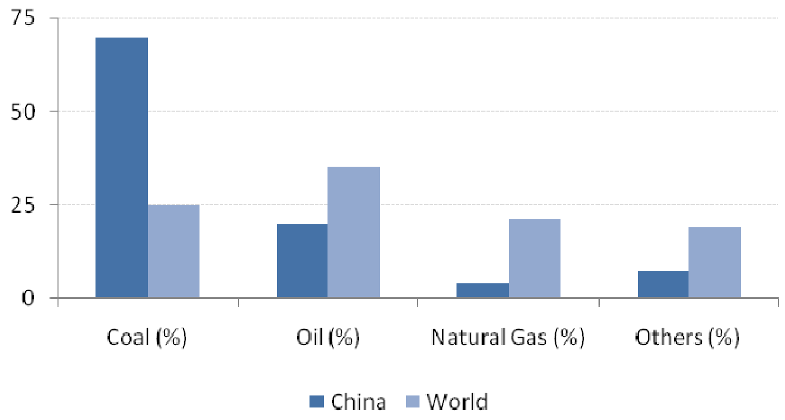
	Coal	Fuel oil	Natural gas
CO_2	6.2580	3.3320	2.1840
SO_2	0.0506	0.0420	0.0002
NO_X	0.0218	0.0069	0.0026

Source: Higashi, 2009

As shown in figures 3 and 4, China remains heavily dependent upon coal and oil for its energy needs with natural gas representing around 4% of the energy mix. This is around 6 times smaller than the rest of the world's average mix. Despite the initially low figure, the Higashi (2009) estimate China's primary natural gas demand will grow at around 5.3% annually between 2007 and 2030 from 73 bcm to 242 bcm. The stronger growth of natural gas is driven by the government's desire to diversify China's energy mix, improve energy efficiency, switch to lower carbon emitting energy sources and reduce air pollution. Figure 2 highlights the significant air pollutant emission benefits of natural gas vis-à-vis coal and fuel oil with around 35% reduced carbon, almost zero sulphur dioxide and less than 12% of nitrogen oxide emissions compared with coal. In addition gas emits virtually no particulates.

In addition to the reduced air pollutant emissions from natural gas, the energy efficiency of combined cycle gas turbines is 55% relative to the most efficient advanced super critical coal-fired power plants at below 40% (IEA, 2009b). As discussed in the CSES (2010) report, *The transition to a low carbon economy: implementation issues and constraints within China's changing economic structure*, the government has introduced a comprehensive range of policy measures for energy intensive industries with specific energy efficiency and pollution reduction targets. As a result of these measures, many of the higher value added industries are switching to natural gas as a fuel source.

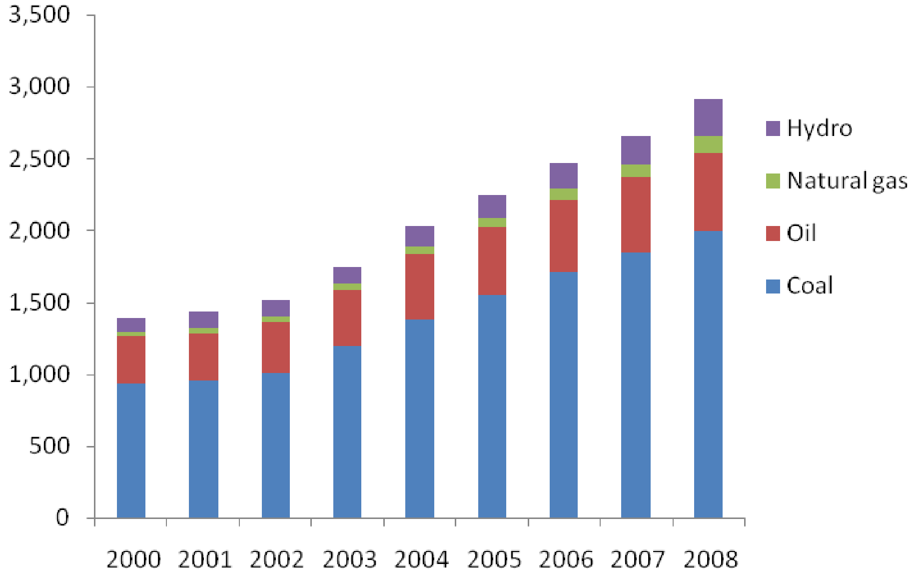
Fig. 3. Coal and Oil Dominate China's Energy Consumption



Source: Source: IEA, 2009a

Figure 4 illustrates the strong growth in the consumption of electricity in China, which doubled between 2002 and 2008. Each segment of the energy mix has generally maintained its share during the period 2000-2008 with increases in the proportion of coal (from 67.8% to 68.7%), natural gas (from 2.4% to 3.8%) and hydro (from 6.7% to 8.9%) whereas the share of oil has declined from 23.2% to 18.7%. In 2009, China consumed an estimated 3.1 billion tonnes of standard coal equivalent (btsce). In terms of future patterns of energy demand, the IEA (2009a) estimates China's primary energy demand will further rise to around 3,827 Mtce by 2030. This is based upon annual growth of 2.9% in their reference scenario. Due to the preeminent position of coal in China's energy mix, the IEA estimates that China will account for 65% of the global increase in coal demand between 2007 and 2030. Apart from hydro-power, other primary energy sources are relatively immature at this stage. The annual doubling of wind power capacity during the past four years and the strong growth of natural gas are notable, but the speed of economic growth and energy consumption continues to reinforce coal's dominant position.

Fig. 4. Energy Consumption by Source, million tons of standard coal equivalent (Mtce)



Source: CEIC Data (2010) from National Bureau of Statistics China

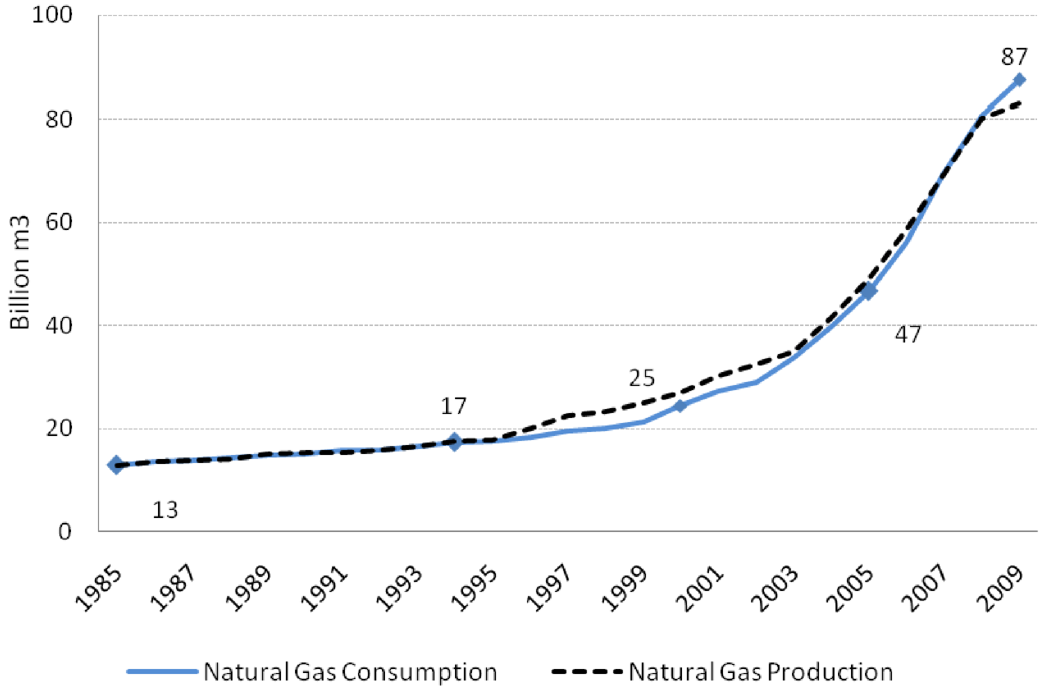
2. Natural Gas in China

This section reviews some of the background context surrounding China's current and future energy mix with a focus on the demand and use of natural gas. A key focus is on the future potential of natural gas to provide China with a clean and reliable transition fuel towards a low carbon economy.

The production of natural gas in China has grown steadily during the past decade from 27 bcm in 2000 to 86 bcm in 2009 largely due the construction of a high-pressure, west-east pipeline and spur lines. The west-east pipeline has had a dual effect of encouraging the development of gas resources in the western and central provinces to supply large cities along the eastern seaboard. By 2015, the Ministry of Land and Resources estimate domestic gas production to reach 160 bcm (Wang, 2009). Whereas the IEA (2009a) recently suggested Chinese gas production will only reach 100 bcm by 2015. A figure that is most likely to be exceeded by 2010. While the IEA is expected to revise this figure in 2010, they argued that such expansion in gas production may prove hard to maintain in the longer term due to the sector's modest growth until quite recently with very little infrastructure to bridge gas supply in the west with gas demand in the east of the country. However, this section explains how China has in fact invested heavily in the expansion of exploration, processing and distribution of gas resources whilst reforming the relevant policy and regulatory frameworks to ameliorate existing strain between demand and supply.

Figure 5 shows the steady growth in natural gas consumption and production since 2001. Until recently, nearly all of this gas demand has been met by domestic supplies. However, this relationship is entering a new phase. While domestic gas production is expected to grow with the development of new onshore and offshore fields as well as significant unconventional gas resources, domestic gas resources are expected to fall behind the strong domestic demand for natural gas. As a result, China's modest imports of gas are expected to grow rapidly shifting the country from self-sufficiency to a position of increasing dependence on gas imports. It is possible that half of China's gas needs will be met by imports by 2020. In order to facilitate this transition, China has invested heavily in both hard and soft gas infrastructure. In 2006, China's first LNG terminal at Dapeng in Guangdong received its first shipment of gas from Australia's North West Shelf. Then in 2009, pipelines connecting Central Asia to China were completed. Additional infrastructure investments have included the exploration and development of new fields, the construction of pipelines, LNG terminals, storage, liquefaction and gasification facilities. Commercial developments include overseas investments in gas companies, gas fields, and joint venture exploration and development projects.[1]

Fig. 5: Total Natural Gas Consumption and Production, 1985-2009



Source: NBSC, 2010

2.1. China's Natural Gas Resources

A CNPC 2005 gas survey estimated China's resources amounted to 56 trillion cubic metres (tcm). A more recent national survey (Figure 6) estimated total gas reserves of 45.58 tcm with 3 tcm of proven reserves, 17.4 tcm of verified resources and 1.65 of recoverable reserves. The IEA (2009a) estimated China has 2.7 tcm of proven reserves. China's gas reserves are mainly located in the north western and central regions of the country, whilst energy needs are concentrated in China's eastern cities. The largest gas fields are located in the Tarim and Junggar, Ordos and Sichuan basins. The largest fields include the 530 bcm Sulige and Changqing fields in the Ordos Basin with 2009 production at around 19 bcm and the 100-bcm Klameli field in the Junggar Basin. Offshore gas fields are found in the Bohai Sea, East China Sea and South China Sea. New coal bed methane resources are

[1] The 2010 Singapore-Chinese investment in Chesapeake Energy provides a good example of strategic partnerships that will accelerate the development of China's gas industry, particularly its unconventional gas reserves. Chesapeake is one the largest US companies in the shale gas sector.

being discovered with around 134 bcm in proven supplies and 76 bcm economically recoverable out of a total estimated reserve of 36.81 tcm.

Fig. 6. China's Distribution of Prospective Natural Gas Resources, 2007

Region	Total resources, trillion m^3 (tcm)	Utilised		Proven reserves		Verified reserves tcm	Recoverable reserves tcm
		Resource amount, tcm	Rate of conversion (%)	Capacity, tcm	Proven rate (%)		
National	45.58	20.51	45	3.107	15.15	17.4	1.651
On-shore	37.38	17.23	46	2.752	15.97	14.48	1.416
Eastern	5.04	2.77	55	0.978	35.25	1.8	0.407
Central	17.36	7.81	45	1.028	13.16	6.78	0.631
Western	13.06	5.88	45	0.742	12.62	5.14	0.376
Other	1.91	0.76	40	0.0047	0.62	0.76	0.003
Off-shore	8.2	-	40	0.359	10.95	2.92	0.237

Source: China Chemical Industries Yearbook (2008)

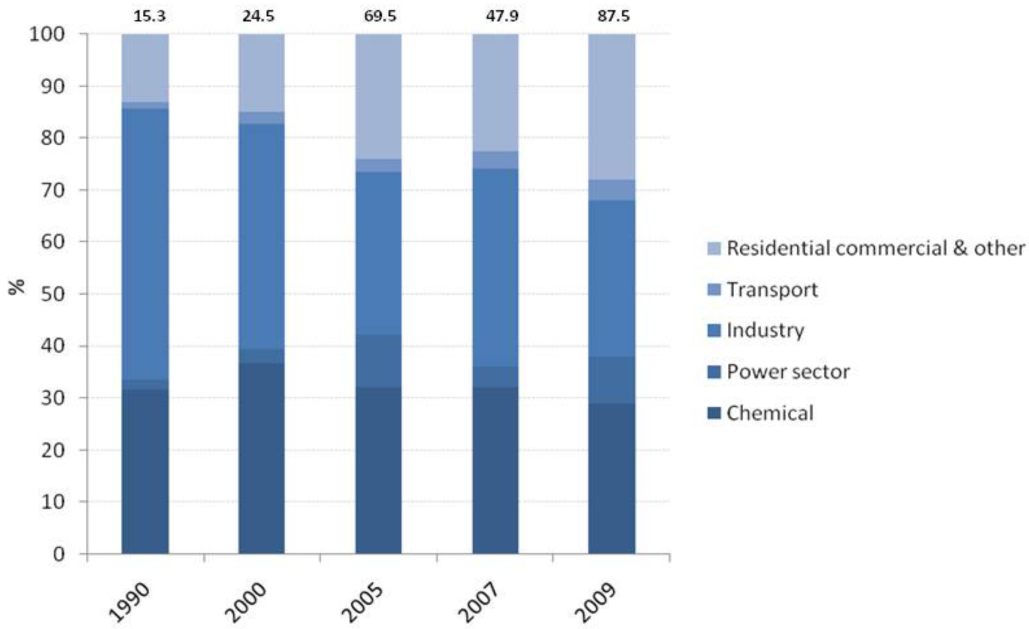
China has the world's third-largest estimated reserves of coal seam gas, at 36.81 trillion cubic metres (tcm) with 6.34 tcm in so-called verified workable natural gas reserves and 161 bcm of proven reserves.[2] Approximately 10 tcm or one third of China's CBM reserves are located in Shanxi Province, which recently announced plans to combine its gas reserves (coal-bed gas, natural gas, coke oven gas and substitute natural gas) into a single network (SinoCast Energy Beat, 2010). It would then connect to the West-East pipeline for the supply of up to 12bcm annually from 2015.Slow progress in exploiting CSM in recent years due to the industry fragmentation, pricing difficulties and technological impediments. Technical and geological difficulties will remain challenging for the CSM industry, but the key problem is a lack of willingness to invest due to uncertain pricing and market conditions. In addition, initial surveys of methane hydrate reserves estimate China has around 35 billion tonnes of oil equivalent located in frozen tundra and under the ocean floor (Zhang, 2009).

2.2. Domestic Natural Gas Consumption

In order to secure and diversify the country's energy mix, improve energy efficiency and reduce air pollution, the government has introduced policy measures supporting the development of a downstream gas industry. While gas remains only a small percentage of the total primary energy mix, domestic gas consumption has tripled over the past decade in China and is set to more than double by 2020 from the current 4% of total energy use to nearly 10%. This is set against a background of steady growth since the mid 1990s as shown in Figure 5 from 15.3 billion cubic meters in 1993 to 87.5 bcm in 2009.

[2] Sinopec claims that it holds 1.1 bcm of CBM reserve with 375 mcm identified as recoverable (Xinhua, 2010b).

Fig. 7: China's natural gas consumption and structure, 1990-2009, bcm



Source: CEACER, 2009, p.855; interview with ERI researchers

Figure 7 illustrates the breakdown of natural gas consumption between 1990 and 2009. In 2009, natural gas consumption (including methane) was equally distributed between industrial, chemical and residential users at around 30% with the remainder used for power generation and transport. Throughout the period, fertiliser production remains the most stable and single largest user of natural gas, supplying farmers with subsidised feedstock. In 2009, the nation's fertilizer industry consumed nearly 10 bcm of gas, accounting for around 20% of the nation's total gas consumption due to the low subsidised domestic gas prices (China Chemical Reporter, 2010). The structure of gas consumption is clearly quite variable from one year to the next, reflecting in some respects the immaturity of the market as well as the ability for users to switch fuels as a result of supply and price consideration. The clearest pattern emerging from Figure 7 is that the industrial sector's use is gradually declining with residential and commercial users expanding. ERI researchers expect residential demand to continue to experience strong growth together with the power sector.

In 2009, China produced 83 bcm of gas while consumption rose 11.5% for the year to 87.45 bcm, leaving a gradually increasing shortfall of around 4.5 bcm which was supplied by pipeline and shipped LNG. Despite a global drop in demand for gas following the global financial crisis (GFC), China experienced shortfalls in gas supply due to a combination of the colder 2009-2010 winter, chemical and petrochemical overproduction and rapidly growing urban demand. For instance, Beijing's daily natural gas consumption recently hit a high of 53 million cubic meters. As a result, industrial users were required to curtail use so as to free up supplies for household heating.[3]

[3] An investigation into the 2009/2010 winter gas shortages revealed that supplies were around 30 mcm short per day across China with specific shortages of: 300 000 cubic meters in Hangzhou; 600 000 cubic meters in

Industrial Use

Industrial use of natural gas is mainly used as a fuel and feedstock in several industries such as ammonia, methanol and chemical fertilizer production. Fertilizer producers, in particular, have been allocated cheap gas for feedstock because of the industrial and social policy for supporting farmers. Other major natural gas consumers in China's industrial sector include the energy sector, which uses gas mainly for the development of oil and gas fields, and the chemicals and petrochemicals industries for feedstock and fuel. Up until late 2007, an increasing number of chemicals and petrochemical industries were tapping in to domestic subsidised gas supplies to reduce their operating costs due to the rising price of oil. As a result, since 2008 the use of natural gas by industry, with the exception of fertiliser production, has been restricted by adjustments in policy.

Power Generation

Gas has been presented as the transition fuel for a carbon constrained energy market offering cleaner, lower cost and flexible power generation capacity that can substitute for base load and peaking coal-fired power as well as offering complementary and cost-effective base load power supplies when linked up with intermittent renewable sources, such as wind and solar. Gas powered turbines are effectively turn-key operations that can be switched on or off as renewable supplies ebb and flow.

Another possibility for increasing the competitiveness of gas vis-à-vis coal is through the Clean Development Mechanism (CDM). CBM provides a potential funding stream for the development of gas-fired cogeneration heat and power (CCGT) units as well as the development of new CBM fields due to the abatement potential of trapping the methane from coal mines. Utilising gas from coal fields improves mine safety and reduces the potential emissions from methane. So far, over half of global CDM funding has gone to China, mostly to renewable energy developments, such as promoting hydro, wind and solar, but it has also gone to coal seam methane projects.

New integrated combined cycle gas (ICCG) turbines generate around 30%-40% of the carbon emissions of coal power plants and cost around US$1 million per megawatt of capacity to build. The combination of a recent spike in gas prices and the construction of new super critical and ultra-super-critical coal-fired power generators in China, which are more efficient and less polluting than standard coal power plants, has reduced some of the demand for gas-fired power plants. According to the IEA et al. (2010) these new coal power plants cost around US$29.42 per MWh to generate electricity compared to gas at US$35.81 MWh (Figure 8). The investment costs and operation and management costs of both coal and gas-fired power plants are comparable. However, the higher fuel costs of gas are what differentiate the two fuels. The OECD price assumptions for the two fuels were US$86.34 per tonne of coal or US$2.95 per GJ compared with gas at US$4.78 per MMBtu (Million Metric British Thermal Units) or US$4.53 per GJ. In contrast, China's energy options ranged from the cheapest for hydro at US$11.49 MWh, coal (without CCS) at $29.42 MWh, nuclear at $29.82 MWh, gas at $35.81 MWh, wind at $50.95 MWh and solar at $122.86 MWh.[4] While gas currently remains a

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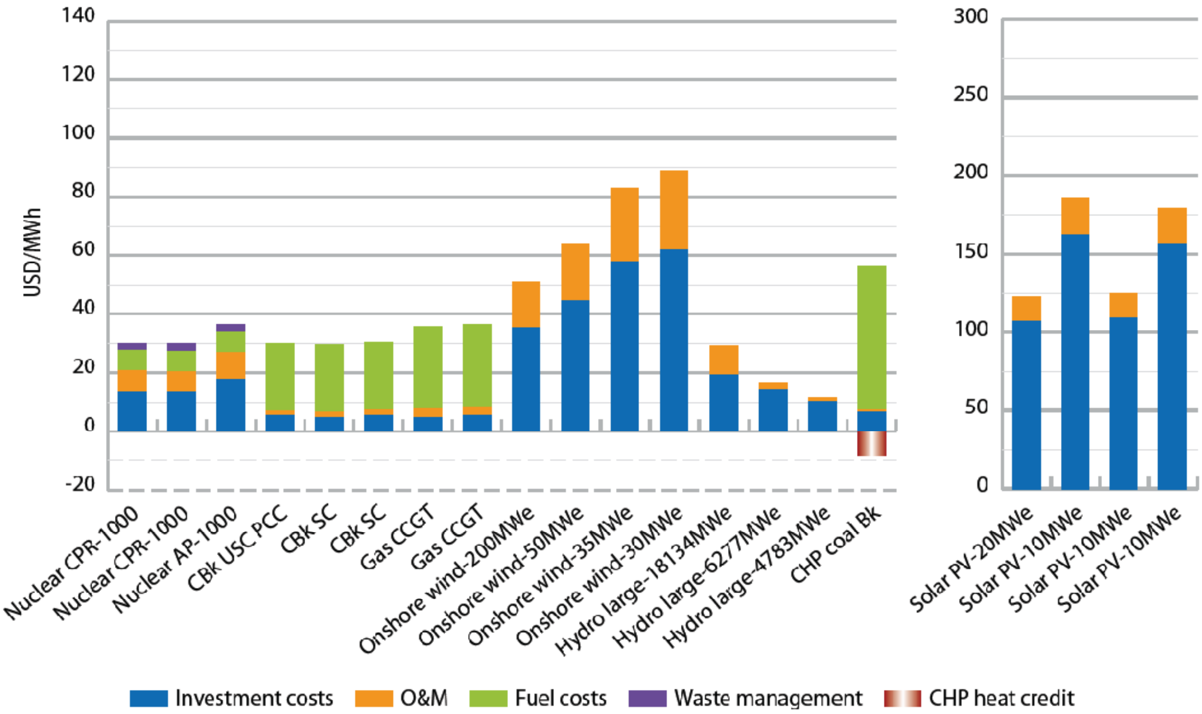
Xi'an; 700 000 cubic meters in Wuhan; and 8 million cubic meters in Sichuan and Chongqing (China Chemical Reporter, 2010).

[4] These figures are based upon 'lowest cost' of several options and include a 5% discount rate (IEA & NEA, 2010).

higher cost power generation fuel compared to coal (in the absence of a carbon tax), new highly efficient combined cycle gas turbine (CCGT) plants are a possible replacement for decommissioning older coal power plants.[5] It is also important to note that these prices do not incorporate any of the cost associated with the health and environmental implications of sourcing and burning either fuel.

Fig. 8. Electricity Generation Costs by Fuel and Type for China



Source: IEA et al., 2010, 83

To date, the use of gas for power generation has been somewhat subdued in China due to a combination of regulatory, pricing and supply constraints. Currently, gas-fired generators produced around 4GW of electricity in 2009 with an ambitious target of increasing that to 36 GW by 2011 and 50 GW[6] in 2020 (WEFN, 2009; CEACER 2050). Most of existing gas-power generation capacity is located in the Yangtze River Delta region with Guangdong and Fujian more recently committing to a further 10 GW of new gas-fired power generation. The construction of gas-fired power generation in both of these regions was supported to guarantee adequate demand for the West-East gas pipelines. However, due to surging industrial and residential demand for gas, many of these new power plants have been operating at reduced capacity due to shortage of supply. Following the arrival of new gas

[5] Several industry studies have reviewed the potential for gas to replace coal power generation in the UK, EU, US and Hong Kong. Estimates for Hong Kong showed that a 10% carbon abatement could be achieved by doubling the share of natural gas in the electricity mix, but retail costs could rise by 20% (Ng, 2009). A Bloomberg New Energy Finance (2010) report for the US, estimated the cost of a coal to gas fuel switch for the existing power sector to cost around US$90-95 per ton of abated CO2 equivalent. Instead, greater benefits and cost-effectiveness can be achieved through the gradual replacement of retiring the most inefficient coal power plants with gas plants and the use of gas as a complementary back-up for renewables.

[6] This is a reduction from the original 2007 government target of 70 GW by 2020.

supplies after 2011, it is expected that power generation will be the most important driver of gas demand through to 2030 (IEA, 2009a).[7]

Although natural gas consumption in the power sector is steadily increasing, it represented only an 11.6% share in total gas consumption in 2007, largely because the infrastructure is not on stream. In addition, the expansion of natural gas as a power generation fuel has been until recently limited due to government policies that restricted its expansion. The main reason for this policy was concern with protecting the coal industry and the high cost of natural gas. As a result, natural gas has struggled somewhat to keep up with the strong growth of coal and the renewable sector in China's energy mix. A 2005 target set by the NDRC called for the doubling of gas in China's energy mix from 2.5%-2.8% in 2005 to 5.6% by 2010. However, it is unlikely to be met due to the strong growth of the broader economy, especially the industrial sector, which remains heavily reliant on coal.

China's natural gas utilisation policy is already shifting away from limiting gas power generation to encouraging it as an alternative cleaner form of energy. A key component of this shift relates to the need to diversify the nation's energy mix, the recent drop in international gas prices, the abundant domestic supplies of coal bed methane, access to technology and methods for its economical extraction, the need to reduce air pollution and mitigate China's carbon emissions. Therefore, according to the government's long-term electricity development plan, gas-fired power capacity is expected to reach 70 GW by 2020 (a more recent plan shows capacity of 36 GW by 2010). However, the competitiveness of natural gas prices compared to coal has aroused uncertainties about the plan

Residential Use

Traditionally, most households burnt coal briquettes or coal gas for residential heating and cooking. But due to the health and environmental problems arising from coal use, many cities switched to LPG. However, today natural gas now leads both coal gas and LPG as the preferred option due to its health and safety benefits and lower price (Figure 2). The household price of natural gas in the southern cities of Shenzhen, Guangzhou, Dongguan and Foshan ranges from RMB3.45 to RMB3.8 per cubic metre. The number of urban residents with access to gas doubled from 32 million in 2001 to 71 million in 2005. By the end of 2008, 90% of the urban population had access to gas for heating and cooking due to the construction of gas pipeline networks and distributed supplies around domestic fields, as well as spur lines from the West-East pipeline or LNG import ports. In late 2007, the government introduced a new priority sector policy for natural gas, which categorised city residential use and combined systems for heat and power as the top priority. As a result, residential gas use has grown by an average of 25% during the past decade. Earlier IEA (2007) estimates predicted the number of Chinese cities with gas distribution to rise to 270 in 2010. The long-term target for residential gas is 65% urban penetration by 2050. In order to meet current demand and realise the long-term targets, many cities across the nation are being connected to ever-expanding national gas network of pipelines.

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[7] An earlier de-linking of oil-gas pricing and a shift to spot market pricing may expedite gas demand within the power sector.

Fig. 9. City Gas Prices, China, 2007

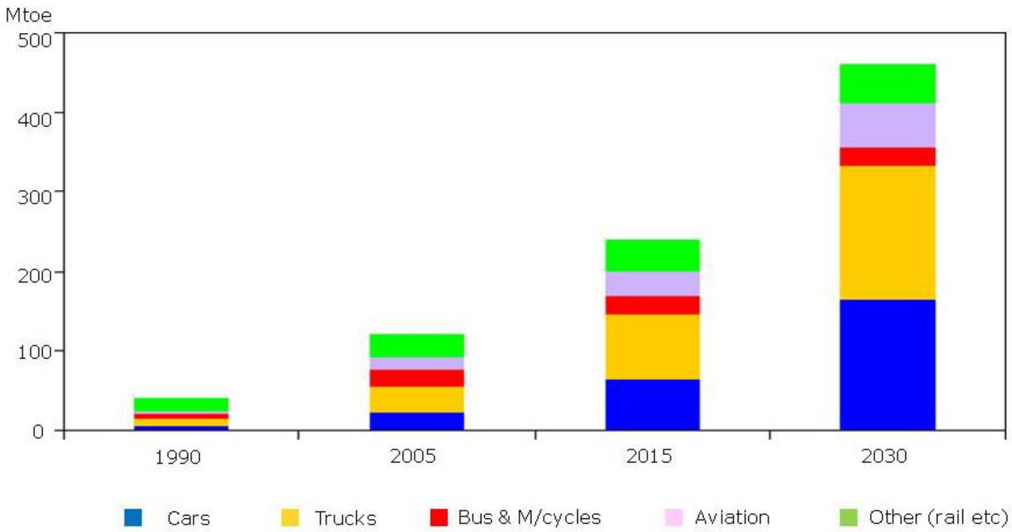
Fuel	Thermal value	Unit price	Calorimetrical value price
Natural gas	8 300 (kcal/m3)	2.19 (RMB/m^3)	0.264 (RMB/million cal)
LPG	12 000 (kcal/kg)	2.19 (RMB/kg)	0.490 (CNY/million cal)
Coal gas	3 600 (kcal/m3)	1.0 (RMB/m^3)	0.278 (RMB/million cal)

Source: Higashi, 2009

Transportation

Natural gas use in transportation is another sector being promoted by local governments concerned with the rising price of oil and the need to reduce air pollutants. In many cities, such as Chengdu, Harbin and Beijing, nearly all public buses and many taxis run on compressed natural gas (CNG) (McKinsey, 2009b). Figure 10 suggests that demand from the transportation sector is expected to almost double between 2005 and 2015 and again between 2015 and 2030.

Fig. 10. China's Transport Sector Gas Consumption Break-down



Source: IEA, 2007

2.3. Market Characteristics

China's wholesale and retail gas market is dominated by the three majority state-owned oil companies: China's National Petroleum Corporation (CNPC: 中石油), China's National Petroleum and Chemical Corporation (Sinopec: 中国石化) and China's National Overseas and Offshore Corporation (CNOOC: 中海油). CNPC is the largest of the three with around 75% control of domestic gas resources and an 80% holding of the pipeline network. In addition, CNPC is responsible for the Central Asia-China pipeline project. As its title suggests, CNOOC was set up to manage off-shore oil and gas resources and is the leading LNG company. In contrast, Sinopec has traditionally been an oil company with only a 10% share of gas production. In 2008, the company produced around 8.3 bcm of mainly from gas fields in Sichuan and Shandong. While the three companies are majority state-owned each control subsidiary companies that include private shareholdings and are consolidating their control of the natural gas sector through vertical integration.

In contrast, the residential gas sector is local government owned. Retailers at the city level purchase from big three. There is some private investment in terminals and residential market, including overseas investment.

While there does not appear to be much discussion about changing the current wholesale gas monopoly in China, already some shifts have occurred in terms of vertical integration and regional spread. Previously, the three leading gas companies operated regionally, but there are growing signs of increasing competition across regions but largely contained to the three gas majors. For example, CNOOC previously monopolised LNG but in recent years CNPC and Sinopec have started to invest in this area. Some industry analysts suggest that the three-majors monopoly is impeding the development of the natural gas sector; calling for the breaking up of their monopolies and greater competition (Dai, 2010). Market reforms are currently taking place that are reshaping the gas market in China and are discussed in the policy section of this report.

The coal seam methane market is less dominated by the big three with a growing number of smaller private outfits as well as some of the coal industry groups showing an interest. Currently, the Chinese government requires all foreign companies to work with the government's CUCBM. The CUCBM provides regulatory support with template contracts, assist companies in locating contractors and in gaining official clearance from various government departments. There are however, a large number of emerging private companies, including in the coal seam methane sector. Xinxing Natural Gas is one example of a company outside of the big three, which is involved in retail and wholesale gas supplies. Some commentators have noted the presence of tension between the gas and coal industry in the development of CBM. However, in recent years there have been several mergers between CNPC and coal companies for developing CBM. In the short-term these mergers have often been unsuccessful.

Pricing

The pricing of gas in China is currently in a period of reform as the government gradually moves towards a market based pricing system to facilitate the development of national and regional gas markets, increasing demand for gas across all sectors and the growing reliance upon imported LNG supplies. The current experience with gas price determination and outcomes in China can be described as follows:

- Historically China has adopted an accounting cost plus approach for gas based on extraction and distribution costs, and reflecting a controlled economy philosophy. However, this is slowly changing with increasing receptiveness to market principles.
- Natural gas prices have also been historically controlled due to fertilizer industry quotas and subsidised prices – used for both fuel and feedstock.
- General reforms have flown through more recently (getting prices closer to international levels), but control is still maintained, and city-gate prices vary by sector and location with industry paying the highest, followed by residential, the power generators and then fertilizer production.
- Average city-gate gas prices are:
  - fertilizer producers: US$2.70/MMBtu;

- industrial users vary from US$11.02/MMBtu in Shanghai to US$4.75 in Lanzhou; and
- residential users: US$5.85/MMBtu in Beijing and US$4.71 in Zhengzhou.

Currently, gas pricing schedules for chemical, commercial and residential sectors are set by the NDRC, whereas wholesale to retail schedule prices are set by local governments (Figure 11). In general, residential prices are lower than other users with the government providing a subsidy to retailers.

Prices vary considerably between source, regions, industry sector, wholesale and retail.[8] For example, a March 2010 report (China Business, 2010) found that prices varied from a low of RMB1.63 per cubic metre to a high of RMB3.85 per cubic metre. The cheapest gas came from the Zhongyuan Field and was supplied to Dapeng in Guangdong. In contrast, shipped LNG from Qatar is expected to cost around RMB3.5. Retail residential prices in the key southern industrial cities of Guangzhou, Foshan and Dongguan pay RMB3.45, RMB3.85 and RMB3.6 per cubic meter because of their proximity to low-priced LNG from Australia. The same report estimated the second west-east pipeline will result in wholesale gate prices in southern Chinese cities of around RMB3 per cubic meter, which is around double existing prices.

Relatively low natural gas prices at the beginning of the century resulted in many coastal cities embracing the fuel as a solution to its unsustainable reliance upon polluting coal. These coastal cities set in train energy policies with an increasing reliance on the cleaner gas. However, due to the rise in gas prices between 2004 and 2007 and central government limitations on its use (see later discussion), many of the cities needed to recalibrate their energy policies.[9] The combination of central government policies and high gas prices also resulted in slow progress in the approval of and commencement of construction of new LNG port terminals and a lull in new contracts to supply the terminals.[10]

The gradual pace of China's resource and energy price reforms in moving away from the existing capped well-head price to a market price aligned with global benchmarks is apparently slowing investment in CBM exploration and development (Chen Aizhu, 2010).[11] China's domestic natural gas well-head price ($3.5-$4.0/MMBtu) remains a third below China's imported LNG costs.

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[8] In the second quarter of 2010, reforms to the energy and resource pricing systems including further raising the cost of electricity, oil and gas, are expected (State Council, 2010). Upward pricing adjustments are more likely whilst inflation pressures remain low, due to sensitivity about negative social implications to the cost of living. In May 2010, natural gas pipeline transmission fees were increased slightly in the south west of China in an effort to curtail the large amount of fertiliser production occurring in the region, much of which is exported.

[9] The cost of imported gas doubled between 2004 and 2006 so that in some areas gas was four times the price of coal. However, in coastal cities the difference was much less with some even encountering parity.

[10] LNG port terminals in Fujian, Shanghai and Ningbo were all delayed due to disputes over the price of imported gas.

[11] For example, this report cited the case of Chevron relinquishing its interests in its three Chinese-based CBM production sharing contracts in 2009. While the reasons were not disclosed, analysts noted that a combination of institutional barriers, cost issues and the low price of gas would have contributed.

In 2010, the State Council proposed a new natural resources tax that will increase the amount of revenue raised by local government from natural resource extraction (Wang, 2010). Currently, all revenue from natural resources (with the exception of offshore resource taxes) goes to local governments. The new proposal includes a 5% levy on oil and gas prices, rather than volume and is estimated to increase taxes from oil revenues from the 2009 figure of RMB5.3 billion to RMB47.3 billion alone. The introduction of such a tax will increase downstream costs of domestic gas, but it may increase the incentives for local governments in developing coal seam methane reserves. Presently, local government revenues from coal mining are much higher than gas, which is seen as of little local benefit (Ng, 2009). The new tax may adjust the imbalances in incentives at the local level.

The ongoing discrepancy between the domestic and imported gas prices as well as between sectors was blamed for the shortage in gas supplies during the 2009-2010 winter apparently due to oil utilities trying to increase pressure on the central government to increase retail prices (Chen & Zhang, 2010).[12] The gas shortage was estimated at around 20 bcm in 2009 with predictions it could even rise to 90 bcm by 2020 (Zhai, 2009). Since late 2008, China has instituted a flexible domestic fuel price system reflecting the average of a basket (Brent, Dubai and Cinta) of crude oil prices over 22 days. If gas prices shift by more than 4% during this period then the domestic price is adjusted. For example, in November 2009, the NDRC increased the non-residential electricity tariff RMB0.028 cents per kilowatt hour and raised gasoline and diesel prices by 7%. The ten adjustments by the NDRC since the system commenced to April 2010 have included six rises and four declines with each shift balanced against any inflation risks. The latest move was in April 2010 when fuel and diesel prices rose 4% and 4.5% respectively with a less than 0.1% predicted impact upon monthly inflation (Caixin, 2010).

3. Current Natural Gas Policies in China

Natural gas is considered an important part of China's future energy mix in order to provide greater energy security through diversification, achieve energy efficiency gains in industry, reduce air pollution and decrease the nation's carbon intensity. Many of the government's key energy policies during the past five years have elevated the status of natural gas vis-à-vis coal and oil for industrial use, heating and power generation.[13] The strong economic growth of the past decade has stressed China's energy resources sector, including the supply of natural gas. In response, the government has promoted the extraction, development, distribution and utilisation of natural gas at a domestic level. In addition, the government has encouraged Chinese oil and gas companies to expand their investments in gas overseas. To balance the rising gas imports with expanding domestic demand, government reforms are reshaping the gas market, pricing, regulations, policies and the key players.

The Chinese government has been promoting natural gas use in order to improve energy diversification and energy efficiency, and as a solution to environmental problems. Under the 10th Five-Year Plan (2001-05), the government set the target of raising natural gas use to 10% of the

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[12] From November 2009 through to March 2010, many utilities and cities were forced to ration gas supplies to commercial and transport users so as to guarantee residential heating.

[13] The 2004 *National Energy policy and Strategy* supported the expansion of natural gas especially in the residential and power generation sectors.

energy mix in 2020, which was basically reiterated in the 11th Five-Year Plan (2006-10). As part of the national 11th Five-Year Plan (2006-2010), the government aims to cut energy use per unit of GDP by 20% and pollution by 10% by 2010.[14] Increasing the supply and consumption of natural gas was seen as playing an important role in contributing to these goals. However, the rising price of gas in 2007-2008 combined with strong local demand, resulted in the central government tempering its support for gas.

In order to resolve supply and demand issues, in 2007 the National Development Reform Commission introduced the 'Natural Gas Utilisation Policy'. The policy prioritised natural gas use for residential purposes, forbid natural gas development for methanol use or in areas with large-scale coal bases and maintained subsidised natural gas for fertiliser production. Current Government plans aim to double gas production to around 160 bcm by 2015 and 250 bcm by 2020 (equivalent to 10% of primary energy consumption). The global situation with natural gas is changing rapidly, in ways that might support a major, long-term expansion of natural gas use in China. For instance, there are large potential supplies of low-cost conventional natural gas and coal seam methane (CSM) resources available for development both domestically in China and globally. In the longer term (beyond 2013-14) gas prices are likely to fall relative to oil, reflecting the quite different supply positions of the two fuels.

In a further repositing of natural gas, the central government trialled a new electricity discharge or scheduling system which ranked natural gas below some coal-powered generation. Under the 2007 trial system, which was implemented nationally in 2009, power would need to be first purchased from low carbon sources of energy generation (wind, solar, hydro and nuclear) before coal and gas. Gas powered plants, including coal seam methane plants and coal-gasification are grouped together.[15] Higher efficiency gas and coal cogeneration plants are similarly grouped together, but importantly above coal fired generation. While the scheduling system does not promote gas-powered generation per se, it should strengthen investment in gas powered generation. Under the scheduling hierarchy gas is offered greater certainty with higher dispatch rates, which is an important criterion for plant profitability. Currently, dispatch rates amongst gas powered plants remain low, with most plants supplying peak loading power.

The National Development and Reform Commission (NDRC) is responsible for gas polices as well as wholesale price setting, while the provincial and municipal governments are responsible for local gas policies relating to supplies, distribution network and final price settings. This allows local governments to manage their own energy mix as is appropriate to local conditions. As a result, national policies try and avoid being too prescriptive to accommodate regional differences. The main driver for the expansion of natural gas from a policy perspective remains energy security. Yet, at the same time, environmental considerations are also a factor due to natural gas' lower carbon and pollutant emissions. See the separate CSES (2010) report "The transition to a low carbon economy:

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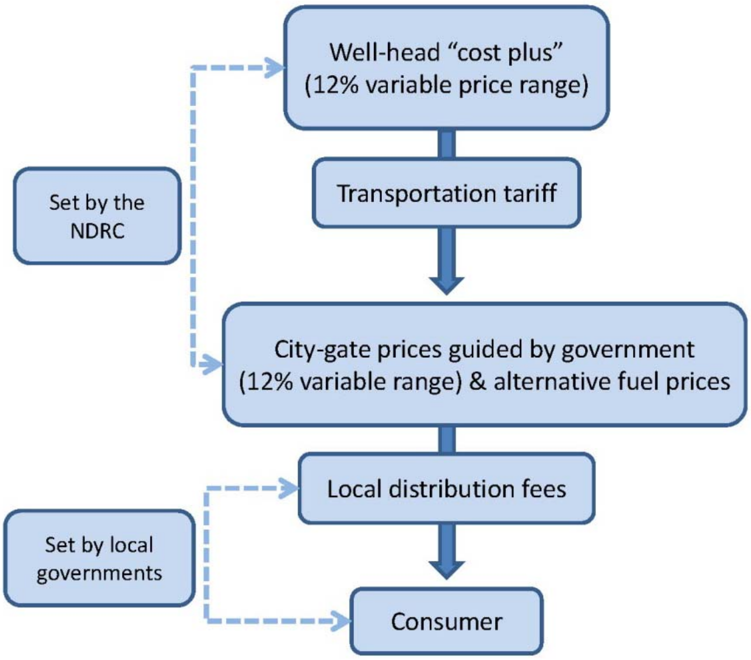
[14] This goal will most likely be adopted in the forthcoming 12th FYP (2011-2015).

[15] While natural gas are clustered together with CBM and CMM in the power scheduling hierarchy, the latter two receive value added tax rebates and state subsidies for the exploration and development of fields. Such government financial and taxation subsidies amounted to 33% of the sale price of CBM (Ng, 2009).

implementation issues and constraints within China's changing economic structure" for full policy details including discussion of China's 2007 National Action Plan on Climate Change.

There are a broad range of government policies that shape the demand and supply of natural gas in China. For instance, the recent growth in gas consumption has been caused by a combination of government-led market reforms in the coal industry; a significant expansion of natural gas infrastructure; environmental regulations demanding greater efficiency in the energy-mix; a partial closing of the price-gap between coal and gas; and, longer lead-times for alternative primary energy technologies.

Fig. 11. China Cost-Plus Natural Gas Pricing System



Source: Ni, 2007; IEA, 2009b

China's gas price-setting has been reviewed relatively recently, but is still based on a tiered system, where fertilizer makers receive a subsidised price, then the residential sector followed by commercial enterprises.[16] The existing price system has three components (Figure 11):

(A) Ex-Plant Price: determined principally on the production cost of natural gas (wellhead cost plus purification fee, including financing cost and tax) plus the appropriate margin for producers (IRR 12%).

(B) Transport Tariff: determined based on the pipeline cost (construction and operation) plus the appropriate margin (IRR 12%) with the variation of transport distance from each gas source to each city gate. The city gate price is (A) + (B); and,

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[16] A decade ago, the gas industry received the largest state subsidies for energy generation, however these have been reduced substantially from around US$23 billion in 1998 down to less than US$2 billion in 2005 (IEA 2007).

(C) Final price, as determined by the Provincial Governments by taking into account the distribution cost, alternative fuel prices and other market policy factors.

Limitations on the expansion of the natural gas sector

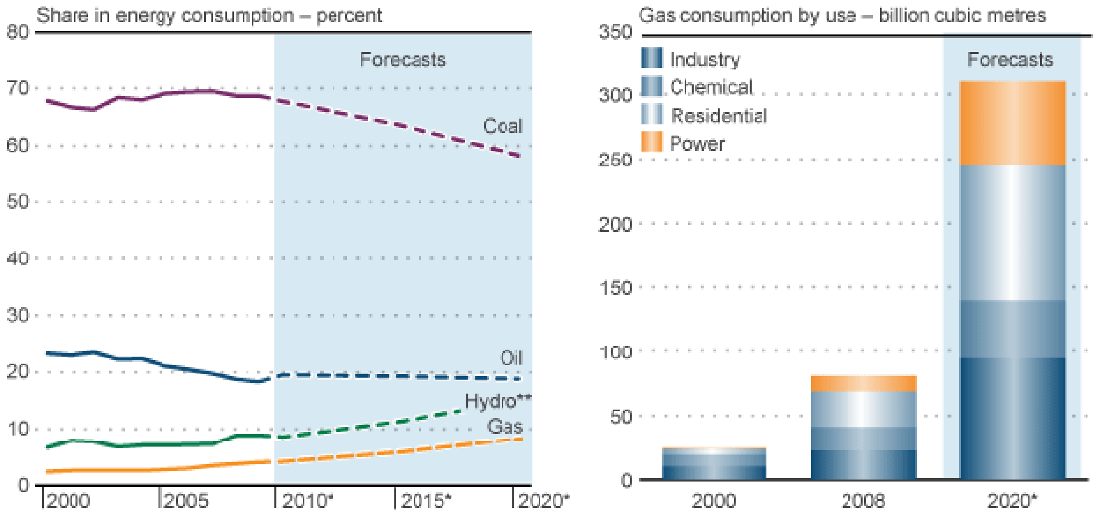
In 2006, the Energy Research Institute together with the Power Economic Research Center of the State Grid Corporation of China completed a major report on the role of the natural gas industry in China's economy and specifically about the role of gas-fired power generation in providing the impetus for the broader development of the industry (ERI 2006). The report concluded that, on both security of supply and environmental grounds, developing a substantial natural gas industry was very much in China's interests, and that a number of major gas-fired power projects would provide a critical boost for wider industry growth. But they concluded that many matters needed to be addressed if gas-fired electricity generation were to be competitive with coal, in the context of the developing competitive market for electricity and the high price of gas on world markets relative to the price for coal in China. The report made a wide range of recommendations, both for appropriate market-based arrangements for determining the on-grid tariff for gas-fired power plants and the gas price for power generation, together with methods for closing the gap between the net-back price from the on-grid tariff and the factory gate price. These methods include local authority subsidies and improved tax and tariff treatment for gas exploration, pipeline operation, LNG imports and gas-fired power generation.[17]

4. Projected Demand for Natural Gas

As discussed in earlier sections, China's demand for natural gas has risen steadily during the past decade and accelerated during the last few years. Moreover, gas consumption is spreading geographically from a traditional concentration around local gas fields towards coastal cities, especially the Yangtze River and Pearl River deltas due to increasing residential and power sector demand. The two diagrams in Figure 12 provide some context to this expansion by showing how the share of gas remains small in China's total energy mix, yet the expected growth in actual consumption is strong. By 2020, some industry analysts expect China's consumption of natural gas to exceed 300 bcm with consumption roughly divided between residential (34%), industrial (30%), power (21%) and chemical (15%) users (Figure 12).

[17] A further constraint on the development of natural gas is its exclusion from the eight core coal production areas. It is unclear how this policy affects the development of CBM opportunities, which is already impeded by 'overlapping mining rights between coal and gas miners' and uncertain government policy (Ng, 2009). While there has been a recent increase in the number of private and state companies exploiting CBM, the disappointing extracting rates belie initial optimistic government projections for its growth.

Fig. 12. China's Energy Mix, 2000-2020

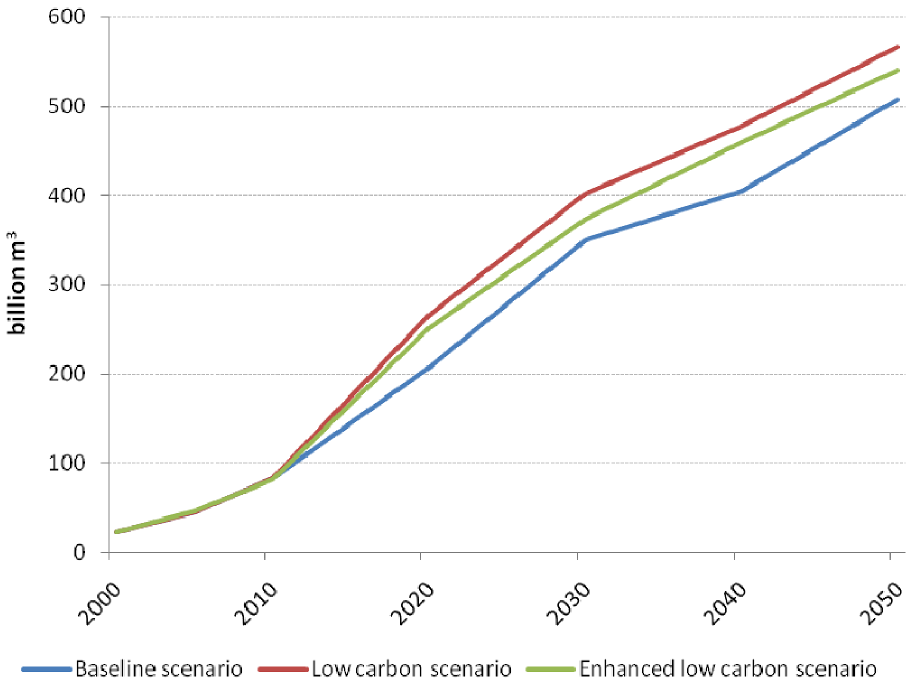


Note: * forecasts, ** hydro and renewables.
Source: NBSC, Bernstein Research and CNPC data in Reuters (2010) China's Energy Mix – the Rising Share of Gas, 17 March, online: http://graphics.thomsonreuters.com/310/CN_GS0310.gif

The future for natural gas in China is mixed. On the one hand increasing carbon constraints and taxes will increase its price. On the other hand, technological and pricing shifts will open up significant new domestic resources of gas, especially from coal seam methane in the short-term and coal gasification and methane hydrates in the medium to long term. According to estimates by the IEA's *2009 World Energy Outlook* and the EIA's *World Energy Projections 2009* reference case, natural gas consumption rises rapidly in China by more than five percent per year on average from 2007 to 2030.[18] The EIA and IEA estimates would lift gas demand to around 242 bcm respectively. This is a very conservative estimate. McKinsey (2009a) expect China's gas consumption to increase eight times between 2007 and 2030 to reach 420 bcm while Royal Dutch Shell (2010) expects gas demand to be between 200-300 bcm by 2020. A similar estimate is provided by CNPC (2009) of around 255.5 bcm by 2020 with domestic production exceeding 200 bcm and unconventional gas supplying 30% of total production. Either way, the expansion of gas demand in China will be a two-sided experience with rising demand driven by steady population growth, urbanisation, rising living standards and industrialisation as well as strong growth in the development of domestic reserves of gas, including so-called 'unconventional' supplies of CBM.

[18] The IEA (2008) estimated natural gas consumption in China would reach 108 bcm in 2015, surpassing Japan as the top gas user in the Asia Pacific. However, the rapid growth of gas consumption in China and the recent decline in the Japanese economy should see China eclipse Japan in 2011. In 2009, Japan consumed 94.68 bcm of mostly imported LNG.

Fig. 13. Primary Energy Demand Using Natural Gas, IPAC-AIM Technology Model

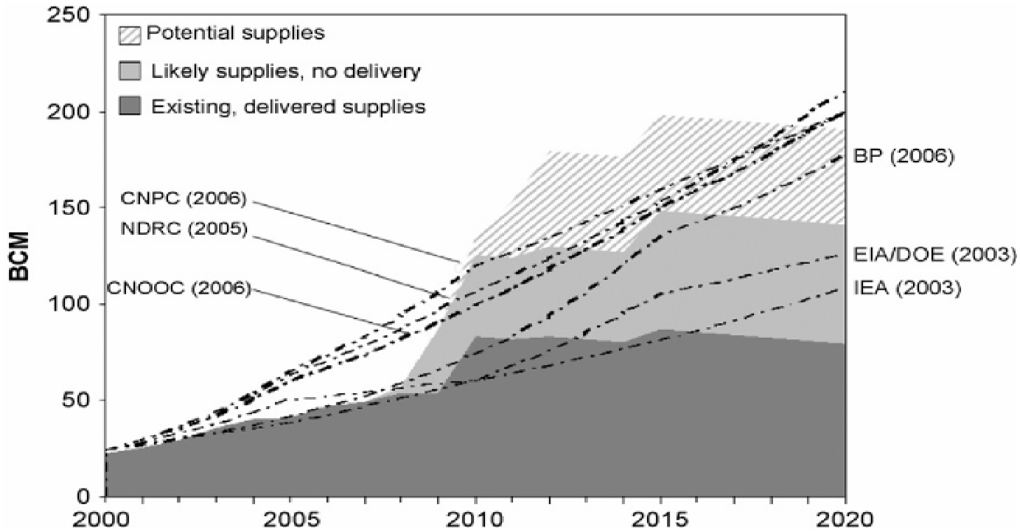


Note: Conversion estimate based upon 1 million metric tonnes of standard coal = 0.761 bcm (NRC et al., 2000)
Source: CEACER, 2009

According to ERI analysis (CEACER, 2009), future natural gas demand will vary depending upon the policy setting. A baseline policy scenario will lift gas demand from the current 83 bcm in 2010 to 206 bcm by 2020, 350 bcm in 2030 and 508 bcm in 2050 (Figure 13). In contrast, if China was to adopt policies commensurate with a low carbon economy then these figures would increase to 266, 403 and 567 bcm respectively in 2020, 2030 and 2050. Under an enhanced low carbon scenario the demand for natural gas would be somewhat slower due to higher energy efficiency gains and a greater presence of renewable, nuclear and CCS. While the ERI figures remain conservative, they do show that regardless of the national policy setting, the forecast for natural gas through to 2050 will be similar.

Due to China's limited conventional reserves of natural gas (Figure 14), China is accelerating the expansion of CBM reserve development, building more LNG terminals and continuing to enlargen the national network of pipelines to tap into local and international gas deposits for industrial purposes, to power newly built cogeneration natural gas power stations, for domestic and commercial building heating and to power local bus and taxi fleets.

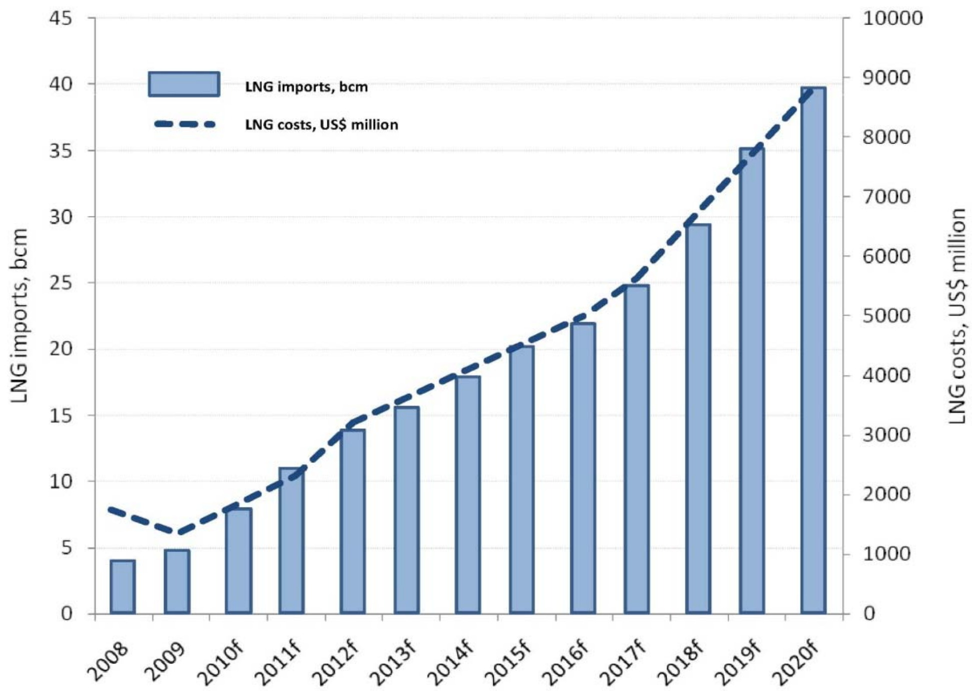
Fig. 14. Potential Natural Gas Supplies and National Demand Projections, China



Source: PESD estimates 2007, CNPC/Sinopec/CNOOC company reports 2007, ERI, IEA 2004, Chinese agencies: NDRC, China Energy Development Report 2003, CNPC, CNOOC Western sources: BP, EIA/DOE 2003, AIE/WEO 2002 cited in Jiang et al., 2008

Figure 14 highlights the gap between domestic supplies and demand for natural gas between 2000 and 2010, but also the need for greater investment in new supplies after 2020. Domestic gas production will increasingly yield market share to imports with at least 24 bcm of LNG and up to 40 bcm of Central Asian pipeline gas annually from 2011 (Higashi, 2009; Lin et al., *in press*).

Fig. 15. Estimated LNG imports and costs for China

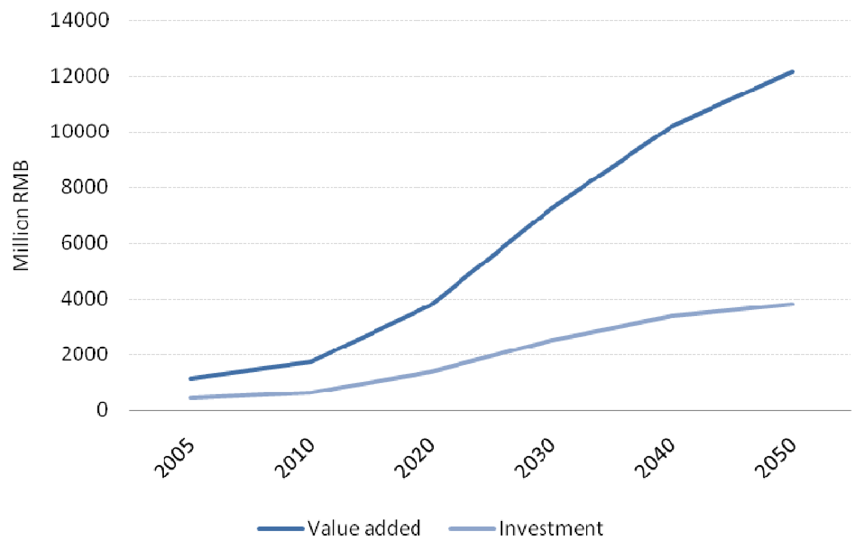


Note: *f* BMI estimates only.
Source: BMI, 2009

In terms of imports, Business Monitor International (BMI) estimates Chinese LNG imports will increase from 4.4 bcm in 2008 to 16 bcm by 2013 and around 40 bcm by 2020 (Figure 15). In 2009, China imported around 5 bcm of LNG, which was equivalent to around 6% of total natural gas consumption. So far, China has already signed agreements for the supply of up to 33 bcm from 2011. A figure that is likely to double by 2020. BMI estimate LNG costs to remain relatively stable through to 2020 with a slight drop in costs relative to volume of around 20% from around US$2 billion in 2010 to nearly $9 billion annually by 2020.

According to ERI's (CEACER, 2009) modelling, the economic benefits of an expansion in natural gas will steadily increase as it shifts away from low value added fertiliser and industrial use and is instead supplied into higher value added production. The results from a business as usual scenario of value added and investment in the natural gas development, extraction and processing industry shows that investment will reach RMB2 billion annually by 2025 and double by 2050 (Figure 16). The benefits of investment in the gas sector will multiply with a growing divide between investment and value added, especially after 2020.

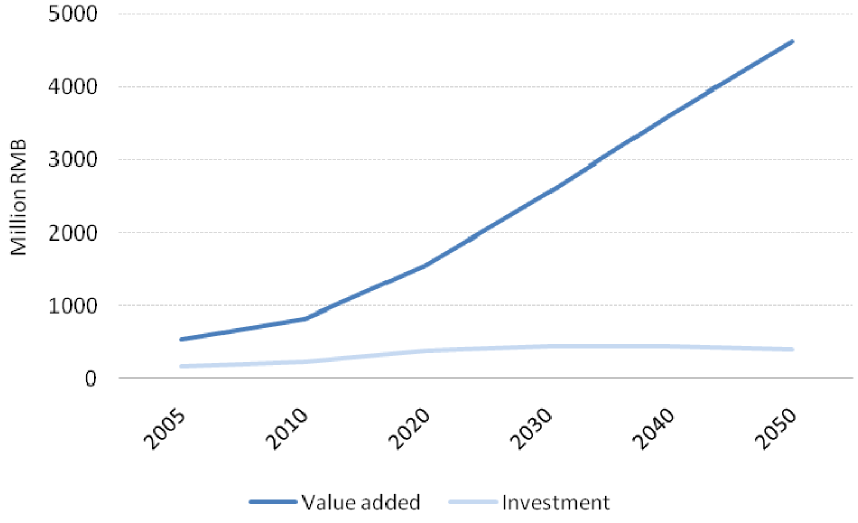
Fig. 16. Value Added and Investment in the Natural Gas Development, Extraction and Processing Industry under Business as Usual Scenario



Source: CEACER, 2009

As discussed earlier in this report, investment and value added in the CBM sector has been relatively slow. CNPC forecast CBM and shale gas could supply about 15% of China's 2020 target of 200 bcm natural gas usage (Chen Aizhu, 2010). ERI (CEACER, 2009) analysis suggest that while investment levels will remain low through to 2050, the economic benefits of coal gas will grow almost ten times between 2005 and 2050 when they exceed RMB4.6 billion (Figure 17).

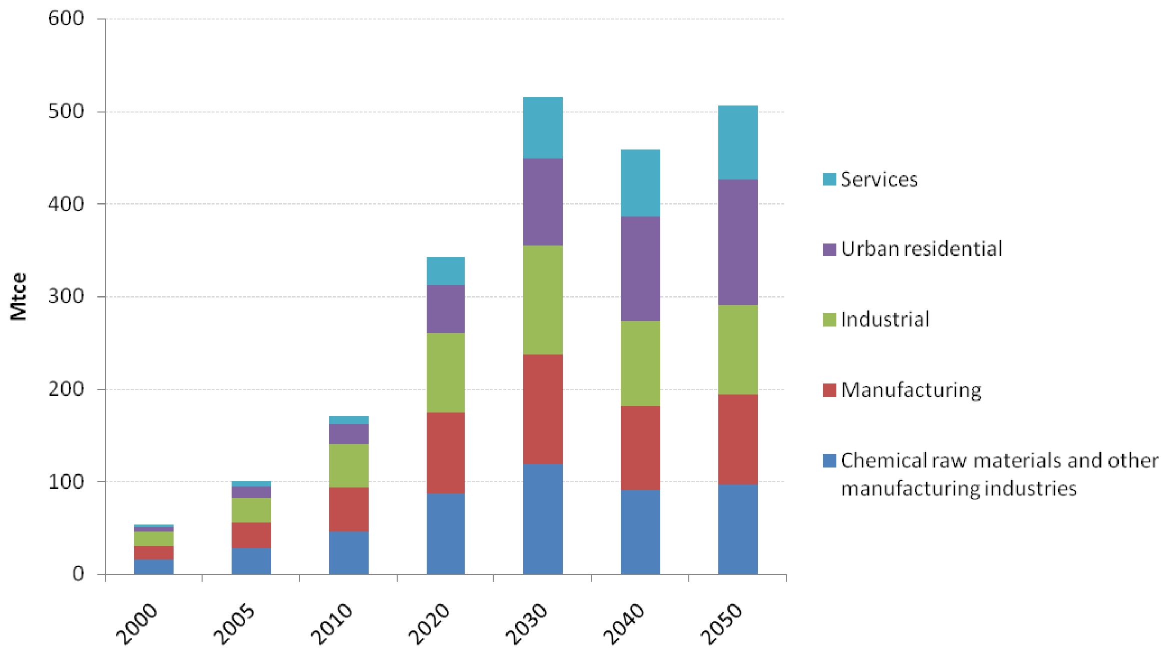
Fig. 17. Value Added and Investment in the Coal Gas Supply and Production under Business as Usual Scenario



Source: CEACER, 2009

ERI analysis of the key sector demands for natural gas under the baseline scenario reveal a surge in overall gas demand between 2010 and 2020 with all sectors experiencing a doubling of demand (Figure 18). The gas market will continue to be dominated by industrial, manufacturing and chemical sector demand. However, demand from these sectors will then peak and decline by around 20% by 2040 and then begin to slowly expand through to 2050. As a result, urban residential demand for gas will surpass each of these sectors by 2035 to exceed 100 bcm by 2050. Service sector demand for gas is estimated to steadily rise from 7 bcm in 2010 to 60 bcm in 2050.

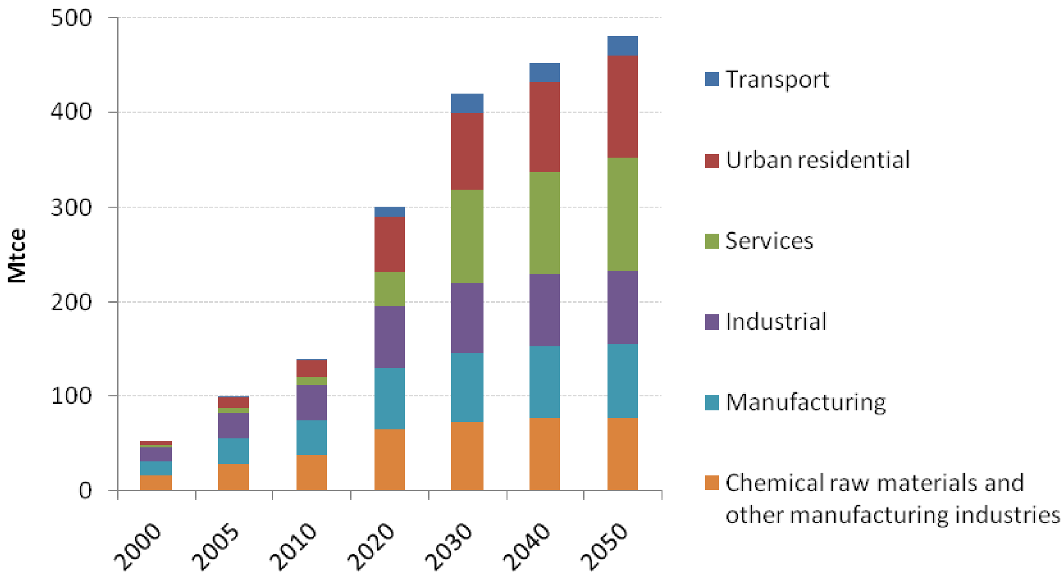
Fig. 18. Terminal Natural Gas Energy Demand by Sector (Mtce) Baseline Scenario (IPAC-AIM Technology Model)



Source: CEACER, 2009

Under a low carbon scenario (Figure 19), gas demand is expected to experience equally strong growth, especially between 2010 and 2030. However, in contrast to the baseline scenario, the services and urban residential sectors will be the main drivers for future gas demand, surpassing demand in the industrial, manufacturing and chemical industries, which will experience slower growth after 2020 and then reach a plateau in 2030. Overall gas demand growth will be slower to 2030, but is expected to reach comparable levels with the baseline scenario by 2050. The transport sector makes an appearance under the low carbon scenario between 2020 and 2030 due to the higher penetration and usage rates of gas-powered public transport.

Fig. 19. Terminal Natural Gas Energy Demand by Sector (Mtce) Low Carbon Scenario (IPAC-AIM Technology Model)



Source: CEACER, 2009

Regardless of the policy outcome China follows in the next decade and thereafter, natural gas is likely to play an increasing role in the nation's energy mix. However, as this section has discussed the dominant position of domestic gas production vis-a-vis imported gas is shifting quite quickly. Therefore, in order to satisfy expanding demand, China has adopted a gas diversification policy to expand local production whilst exploring overseas supplies.

5. Diversifying Gas Supplies

5.1. Introduction

China is entering a period of significant growth in gas demand. In response, dozens of major gas projects are either underway or will be completed by 2015, including, construction of gas infrastructure, the exploration and development of new fields and signing of international supply contracts. China currently imports LNG from Australia, Indonesia, Malaysia, Qatar and Iran with piped natural gas sourced from Turkmenistan with future supplies coming from Kazakhstan, Uzbekistan, Myanmar, Mongolia and Russia.

Fig. 20. Imports of Natural Gas, 2009

	Imports		Rate of changed compared with 2008, %	
	bcm	US$ million	Volume	Value
Natural gas & synthetic gas	5.53	1 279.5	65.8	35.5

Source: Customs Statistics, 2009

In 2009, imported natural gas increased to 5.53 bcm of gas costing nearly US$1.3 billion, which equates to growth of 65.8% by volume and 35.5% by value compared with 2008 figures (Figure 20). It is predicted that by 2015, gas imports shall exceed 40 bcm with the west to east pipeline bringing in 30 bcm and coastal LNG facilities handling more than 10 bcm. The Myanmar pipeline should also be operational with a capacity of up to 12 bcm of gas annually. At the same time, new domestic gas pipelines connecting the Sichuan basin with Shanghai, the Ordos basin with Beijing and the second West-East line will double existing pipeline capacity. Large storage facilities are being built in eastern coast cities and also at strategic points along the west-east trunk lines.

On the domestic front, PetroChina and rival Sinopec Corp are developing new, big fields such as Dina and Tazhong in northwest Xinjiang; Sulige in Inner Mongolia; Longgang and Puguang in southwest Sichuan, while fast-tracking explorations by adding 200 bcm of incremental recoverable reserve each year. Locally-based natural gas utilisation will grow significantly in China over the next decade as local governments and industry seek out diversified cleaner, low cost energy sources.[19]

Internationally, the start of long-term gas deliveries from Qatar, Indonesia and Malaysia will double imports of liquefied natural gas by 2011. These will surge even further in coming years, after firms such as Qatargas, Shell, BP and Exxon Mobil recently sealed supply pacts with Chinese firms worth over $100 billion. In May 2010, China and Qatari officials were negotiating the supply of a further 10 million tonnes of LNG on top of the existing 5 million tonnes (England, 2010). Several new LNG terminals, in addition to the existing three, will be supplied by new long-term supply contracts with Malaysia, Indonesia and Qatar. A further 5 bcm per annum will come from Australia's east coast CBM fields, 4.4 bcm from the North West Shelf (Browse) and rising a further 6.2 bcm and 2.7-4 bcm respectively once the Gorgon and Woodside Browse projects commence. By 2015, piped gas from Turkmenistan and Myanmar will together amount to 20 percent of China's demand, or 40 bcm. Russian gas may then follow with a further 70 bcm annually, but a high degree of uncertainty remains about a starting date.

5.2. Gas Infrastructure

For the past decade China has embarked upon an ambitious program of transforming its natural gas industry from a provider of small-scale fertiliser feedstock based upon local supplies to an important

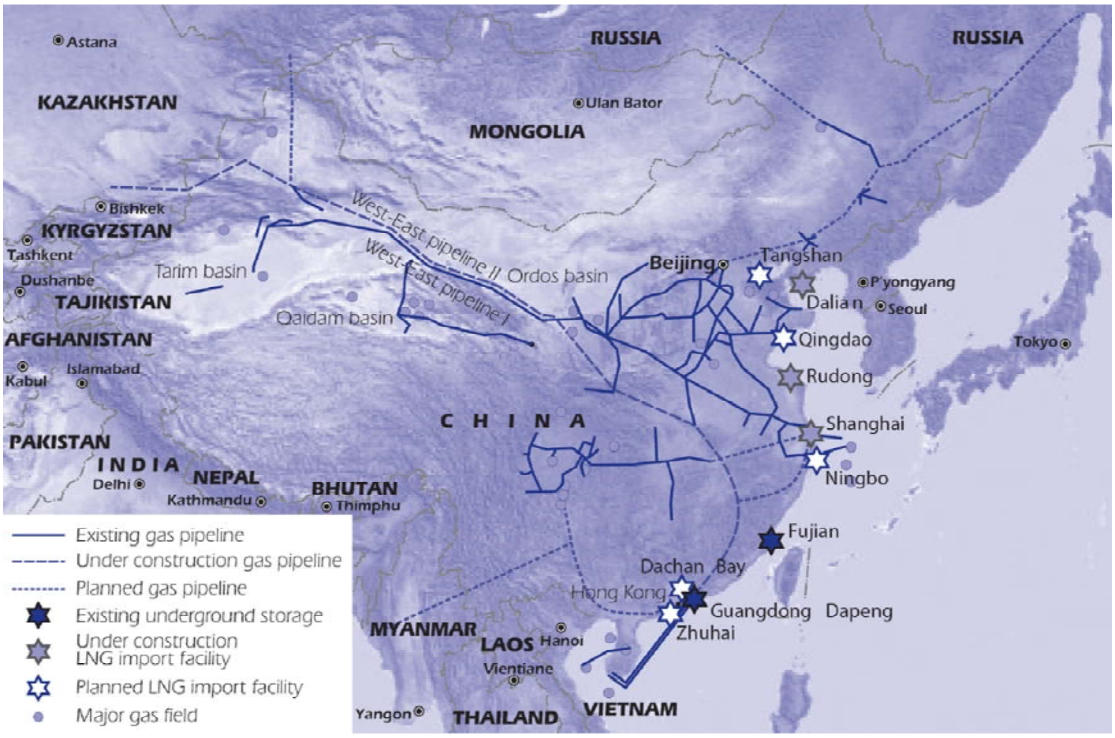
[19] Against a backdrop of an expanding national gas pipeline network, several cities are exploiting local gas deposits. For example, the city of Da'an, in Jilin province has access to natural gas deposits of around 2 billion cubic meters and will build a 100 MW cogeneration power-heat plant in the city.

international gas market player. To facilitate this transition, China is building up both domestic and international gas infrastructure, including new and expanded pipelines across the country and into neighbouring countries, new LNG terminals are along the east coast alongside liquefaction and regasification plants and the sinking of thousands of new gas wells tapping into CBM supplies. The scale and speed of natural gas developments in China are of an unprecedented magnitude. In order to facilitate this investment in gas energy supply infrastructure the IEA (2009a) estimates US$233 billion will need to be spent annually between 2008 and 2030. This is equivalent to around 5.5% of current total energy supply spending.[20]

Transboundary and Domestic Pipelines

Figure 21 illustrates the growing network of pipelines connecting up China's dispersed gas fields and LNG ports and new transboundary supplies. In 2004, China completed its first 3,900 km West-East domestic gas pipeline connecting fields in western China to coastal cities. This pipeline marked the

Fig. 21. Natural Gas Infrastructure, China



Source: IEA, 2009b, 127

country's transition from local gas supplies to a national natural gas market. Three earlier pipelines included the 868km Ordos to Beijing connection and the two ocean pipelines connecting the off-shore fields of Yacheng and Pinghu with Hong Kong and Shanghai respectively. By the end of 2008, a total of 31,000 km of pipes had been laid across China.

[20] The IEA estimate includes new gas energy capacity covering production, transportation and transformation as well as unit capital costs for gas throughout the supply chain.

Between 2009 to 2015, the state plans to double its gas pipeline infrastructure with a further 48,000 km of pipelines, including 24,000 km of trunk lines. For example, a third West-East gas pipeline will stretch from Xinjiang to Guangdong and run through Gansu, Ningxia, Shaanxi, Henan, Hubei, Hunan. The pipeline is estimated to commence operations in 2014 with a capacity of 30 bcm annually, which will bring total west to east pipeline capacity to 60 bcm.[21] Additional distribution capacity includes a 1,660 km long gas pipeline from the Sichuan gas fields to Shanghai, Jiangsu and Zhejiang provinces and a 1,000 km pipeline connecting Shandong's gas fields with the wealthy coastal ports of Qingdao and Weihai. Since 2009, China has commenced the next stage of gas development: from domestic supplies to an increasing dependence upon imported gas. This includes pipeline gas from Central Asia (notably Turkmenistan and Kazakhstan), Myanmar, Russia and Mongolia and LNG shipped from Qatar, Malaysia, Indonesia, Iran, Papua New Guinea and Australia.

In January 2010, the western section of the second West-East pipeline was completed facilitating the transmission of gas from Turkmenistan through central Uzbekistan and southern Kazakhstan to Xinjiang province. Gas from Turkmenistan is expected to provided 6 bcm of natural gas in 2010 gradually rising to 40 bcm annually by 2040 (Asia Pulse, 2010). The pipeline is the first to facilitate trans-boundary gas flows into China, which then connect to the domestic West-East pipeline, which traverses 8,653 km through 14 provinces before reaching Guangdong in the south. A further 4,843 km second-stage through to Guangdong with a capacity of 30 bcm per annum will be completed in 2012 (China Business, 2009). Both stages will collectively serve a large number of provinces with both domestic and imported gas. PetroChina is currently in negotiations with Turkmenistan, Kazakhstan and Uzbekistan for the construction of a further two Central Asian feed-lines to supply China's three West-East lines (China Business, 2009).

A further international transboundary pipeline is under construction between Myanmar and China. The 870-km long pipeline built by CNPC will transport gas from Myanmar's off-shore fields, which are being developed by a Korean-led consortium of Chinese, Indian and Myanmar interests. An oil pipeline is being laid next to the gas pipeline to transfer oil shipped from Africa and the Middle East to Myanmar so as to avoid the Malacca Straits. Both pipelines will connect to domestic pipelines feeding Yunnan Province from 2014 and the southern cities of Chongqing and Nanning.

LNG Port Facilities

China's ascendancy as a major LNG buyer has been rapid with the signing of several long-term supply and purchase agreements (SPAs) as well as initial agreements in the past five years (Figures 22 and 23). China's current share of the LNG market is around 2% but is expected to grow to 13% by 2020 (Morikawa, 2008). Although CNOOC dominates the LNG import market in China, CNPC and Sinopec are diversifying their interests and regional coverage by entering the LNG market. China currently has three LNG terminals in operation in Shenzhen, Fujian and Shanghai with a total capacity of 9.3 bcm annually. According to Figures 22 and 23, China is expected have a total 30 mBtu of LNG import capacity by 2015. In addition to coastal LNG facilities, approval was granted in 2010 for the construction of several new LNG stations in inland cities, for example in the Yangtze River cities of Wuhan, Yichang, Xiangfan and Huangshi. The gas would be used to meet growing demand from residential, industrial and transport users in the cities.

[21] However, to date only half of the supplies have been agreed upon leaving a possible 30 bcm shortfall.

Fig. 22. LNG Receiving Terminals including Sale and Purchase Agreements, capacity in million tonnes per year

LNG TERMINAL	STAGE	CAPACITY	STAGES	STAKEHOLDERS	AGREEMENT DETAILS
Shenzhen	Operation	3.7	Phase I 2006	CNOOC 33,% BP 30%	(i.) North West Shelf LNG Australia (Browse)25-year US$13.75 billion at US$3.16 per mBtu with price reports as low as US$2.50-US$2.70 per mBtu; (ii) Qatargas Operating Co. Qatar (Qatargas 2) 25-year MOU negotiated at market value; (iii) Total Gas & Power sourced from Total's global LNG portfolio 15-year; (iv) ExxonMobil Australia (Gorgon) US$41.1 billion 20-year agreement at US$10 per mBtu
	Construction	6.6	Phase II2011	CNOOC	
Fujian	Operation	2.6	Phase I2009	CNOOC 56%	(i) BP Migas Indonesia (Tangguh) 25-year US$2.40 per mBtu under old contract signed in 2002 and revised to US$3.80 per mBtu, then US$4.54 per mBtu under SPA in 2006, and finally US$5.93 per mBtu in 2008.
	Construction	5	Phase II2012	CNOOC	
Shanghai	Operation	3	Phase I2009	CNOOC 45%, Shenergy 55%	(i) Malaysia LNG Tiga25-year US$25 billion deal at $5-US$7 per mBtu; (ii) BG Group Australia (QCLNG) 20-year US$40-80 billion Project Development Agreement reportedly priced at a 10% discount to traditional LNG from natural gas.
	Construction	10	Phase II N/A	CNOOC	
Dalian	Construction	3	Phase I2011	CNPC 75%	(i) Qatargas Operating Co. Qatar (Qatargas 4) 25-year agreement
	Approved	6	Phase II N/A		
Rudong, Jiangsu	Construction	3.5	Phase I2011	CNPC 55%, Pacific Oil&Gas 35%	(i) Shell Eastern LNG Australia (Gorgon) 20-year US$27 billion agreement at US$10 per mBtu; (ii) Woodside Energy Australia (Browse) 15-20 year US$37 billion terms agreement at US$7-US$9 per mBtu. In early 2010 the deal expired.
	Approved	3	Phase II N/A	CNPC	
Tangshan, Hebei	Approval*	6	Phase I2011	CNPC:	(i) Pars LNG Iran (South Pars phase 11) 25-year MOU agreement Indexed to average oil price
	Approval*	10	Phase II N/A	CNPC	
Qingdao	Approval*	3	Phase I2013	Sinopec	Esso Highlands Papua New Guinea (PNG LNG) 20 year preliminary agreement at US$9-US$10 per mBtu
	Approval*	5-6	Phase II2014	Sinopec	

* These plants have received initial but not final approval from Beijing.

Source: Reuters, 2010; various media reports, Priestley, 2010

Fig. 23. Additional LNG Receiving Terminals, capacity in million tonnes per year

LNG TERMINAL	STAGE	CAPACITY	STAGES	STAKEHOLDERS
Ningbo	Construction	3	Phase I2012	CNOOC: 51% Zhejiang Energy: 29%
	Approved	9	Phase II N/A	CNOOC
Zhuhai	Approved	3	Phase I2011	CNOOC: 25% Guangdong Electric:35%
	Proposed	4	Phase II N/A	CNOOC
Hainan	Proposed	2	Phase I2010	CNOOC
	Proposed	1	Phase II2015	CNOOC
Shenzhen	Proposed	-	Phase I2012	CNPC (51%), CLP (24.5%)
Qinzhou	Planned	N/A	Phase I N/A	CNPC
Zhuhai	Approved	3.5	Phase I 2013	Sinopec
		3	Phase II N/A	Sinopec
Wenzhou	Approval*	3	N/A	Xinao Gas
Rizhao	Planned	0.5	N/A	Daesung
Shantou	Construction	1.2	Phase I2012	Sinogas

* These plants have received initial but not final approval from Beijing.
Source: Reuters, 2010; various media reports, Priestley, 2010

Storage

The gas shortages experienced during the winter of 2009/2010 have increased pressure to expand the storage capacity of gas across China. China's first major gas storage site was built in 2001 providing supply security for Beijing and Tianjin. By 2009, China had around 9.3 million tonnes of storage capacity across its gas terminals. New storage facilities are planned for LNG terminals and strategic locations along the West-East pipelines. In 2010, CNPC announced plans to build 10 natural gas storage facilities between 2011 and 2015 to stockpile 22.4 bcm of gas close to their fields in Inner Mongolia, Xinjiang and Shaanxi, including a 12 bcm underground storage facility next to their Changqing field (Ordos Basin) in Shaanxi. This will increase the company's stockpile capacity from the present 3% to around 8-10%.

It is expected that the significant investment in gas infrastructure across the nation will resolve the existing tensions between supply and demand up to 2020 (IEA, 2007). However, the growing complementarities between gas-powered generation and renewable energy, such as wind and solar, combined with the rapid growth of CBM into the system will require further investment in plants, pipeline and storage capacity beyond the existing grid.

5.3. The Rise of Unconventional Gas

Unconventional gas refers to gas resources that are complex and uneconomical to exploit, such as shale gas, deep gas, tight gas, deep geo-pressurised gas, coal bed (seam) methane (CBM) and methane hydrates locked in permafrost and the deep sea. The availability of horizontal drilling and fracturing technologies combined with scales of production are opening up significant unconventional gas resources. As a result of the recent growth of shale gas or CBM, some energy commentators are referring to unconventional reserves as an industry “game changer” and even as a “conventional” gas.

China has considerable potential in their domestic resources of unconventional gas and has been working to both prove up these assets and where appropriate develop such gas reserves economically, as Stern (2008) notes:

> *To encourage CSM projects, the Government has put in place several favourable policies for the industry, including a reduced 5% VAT rate for CSM projects with foreign partners, exemption from import and other duties on materials and equipment for CSM exploration and development, exemption from royalties for CSM projects producing less than 1bcm per year; and free market pricing of gas, with no State controls …*

Despite the abundance of resources and favourable development policies, CBM development in China has proceeded more slowly than similar schemes in the US, Canada or Australia. CBM production to 2007 was a mere 200 million cubic metres; compared to a target of 10 bcm by 2010 and 20 bcm by 2015. CBM output grew to 0.5 bcm in 2008, but continued to remain well short of projections of a revised 5 bcm target for 2010, which was further revised down to 2 bcm in 2009. In contrast, coal mine methane (CMM) production reached 5.2 bcm in 2008, exceeding the 2010 target of 5 bcm. In order for China to reach its target of 50 bcm annual production of CBM by 2020, the central government estimates that a further RMB1 trillion of investment is necessary (Ng, 2009). Most of the RMB1 trillion would need to go into the construction of infrastructure to get the gas to market, but also support exploration and resource development.

While the development of CBM commenced in the 1990s in China, it has received increasing interest during the past five years. A lack of domestic technology and expertise in CBM extraction saw the establishment of China United Coalbed Methane (CUCBM) to attract international investment in the sector. Government policies including a deregulated pricing mechanisms, tax concessions and soft loans for CBM development have been only modestly successful to date. Some argue that pricing and institutional impediments within the sector are the main obstacle to its expansion, particularly the ongoing low price of domestic gas and the divide in authorisation between provincial and central governments on access to coal fields (Higashi, 2009).

CBM production is one of the key 16 projects listed in China’s 11th FYP with an initial target of 10 bcm of CBM development by 2010. However, due to the slow evolution of the industry this target was later halved to just 5 bcm by 2010. In a situation reminiscent of the NDRC’s failed goal for gas production, in late 2009 the NDRC reduced its 2010 CBM production target from 5 bcm to 2 bcm and set a 2015 target of 3.5 bcm. The 2020 target however remains in place with expectations CBM production will reach 50 bcm. By 2008, 1.6 bcm of CBM was utilised, rising slightly in 2009. This is despite the venting of an estimated 5.7 bcm of CBM annually from China’s coal mines (IEA, 2008). Investment in CBM development has remained low with estimates that a further RMB670-1000 billion is necessary by 2020 for the exploration, development and production of CBM if it is to meet the 50 bcm target (Winn, 2009).

By mid-2009, China had around 3,500 CBM wells operated by Jincheng Anthracite Coal Mining, CUCBM and PetroChina (Winn, 2009). China Electric Power noted that between 2007 and 2009, 484 MW of CBD powered generation capacity had been built with nearly 2 billion kWh of electricity generated in 2009. To date, development of the sector in China remains modest with little supporting infrastructure such as storage, pipelines and liquefaction capacity. Commercial scale CBM has already taken place, most notably in the US. However, the costs are generally higher due to the drilling requirements, the higher number of wells and the slow extraction speed.

The benefits of both CBM and CMM include safety enhancements, reduced greenhouse gas emissions and a useful transition fuel and economic resource for communities in making the shift away from a heavy dependence upon coal.[22] The potential of CMM in China is strong due to the large scale of coal mines. CMM has traditionally been released from coal mines to reduce the risks of an explosion, but new developments in drilling technology (such as horizontal drilling and rock fracturing techniques), higher gas prices prior to the GFC and higher demand for gas have witnessed a growing commercial interest in CMM and CBM.

China is the leading emitter of CMM producing around 40% of the world total or over 135 million tonnes of CO_2 equivalent in 2006 (IEA, 2009d). These figures will have increased rapidly in recent years in line with the expansion of coal mining. Tapping into CMM offers China not only the benefits of improved mine safety, but also reduced reliance upon imported gas from overseas, such as shipped LNG and piped gas. CMM development has been quite successful in the coal heartland of Shanxi[23], but is slow to pick up elsewhere in China.

In recent years, China has discovered significant deposits of natural gas hydrates or “combustible ice” on the Qinghai Tibetan Plateau and in the South China Sea. The Qinghai find is estimated to wield estimated reserves equal to 35 billion tonnes of oil. Extracting gas from the hydrates remains technically and economically unfeasible with estimates of a 15 year delay in commercialisation. Another potential source of unconventional gas is coal-to-gas. Currently, China has around 15 coal-to-gas projects under construction or in the pipeline (Xinhua, 2010c). Three plants have so far been approved by the NDRC, including the Huineng Group’s 1.6 bcm project in Erdos, Inner Mongolia and two Datang Power International projects in Chifeng, Inner Mongolia and in Fuxin, Liaoning. Both of which expect to produce 4 bcm annually.

While the benefits of unconventional gas are significant, social, economic and environmental concerns relating to the extraction of unconventional gas remain, including from coal seam methane and natural gas hydrates. Such concerns arise due to the costs, method of extraction and end-use. For example, critics of CBM in the US claim the fracturing fluids, which are typically a brine, sand and chemical mixture, wield potential environmental and health impacts. According to the *Coal Mine Safety Regulation* (2006), it is forbidden to utilise coal mine methane when concentration levels are below 30% due to safety considerations.[24] The low methane concentrations also make commercial exploitation difficult resulting in the venting of the gas. Today, the government priority remains

[22] It is important to note that CMM differs from CBM because it is directly associated with coal mining activities. Trapping CMM has significant potential for greenhouse gas abatement. In contrast, CBM is a natural gas resource that requires directed mining activities for extraction.

[23] This is location of the world’s largest CMM operation which uses the trapped methane to power a 120 MW electrical generator.

[24] China Coal Mine Safety Regulation (29 September 2006, effective 1 January 2007), Chapter 2. Ventilation, Article 148.

focussed on safety whilst increasing the utilisation of coal methane due to the significant environmental and economic benefits of trapping methane in coal mines.

5.4. Investment and Technology

Natural gas is one of several resources that have been allocated 'critical' status for China's future economic growth. As such, investment approval is typically 'fast-tracked' for domestic and overseas investments that secure access to gas with financing forthcoming from China's Development Bank and other state-owned lenders. In recent years, there have been several important partnerships between China's big three oil and gas companies and many experienced oil and gas players, such as BP, Shell, Total, ExxonMobil, Chevron, Korea Gas and GAIL. Domestic joint venture investments have included the extraction and distribution of gas as well as the construction of pipelines and terminal and storage facilities. International partnerships have mostly related to oil and gas extraction and securing supplies, but also included the construction of pipelines, terminals, processing facilities and LNG ships. More recently, Chinese companies have targeted overseas firms due in part to their technological expertise and experience, for instance the joint bid from Shell and PetroChina for Arrow Energy in Australia. The increasing number of international commercial partnerships and cooperation could result in benefits, including:

- speeding up the adoption of both soft and hard technologies, especially in emerging areas of energy development, such as unconventional gas and carbon capture and storage; and
- the sharing of best practice in the industry, including environmental, occupational health and safety conditions so as to reduce the risks of accidents[25] and improve efficiency.

Technology and investment will continue to be critical to the future of CBM. In 2007, China opened up to foreign investment in CBM in order to speed up the development of the sector. While new technologies have made the extraction of CBM and CMM cost effective, it remains a limited market due to the challenge of the resource. This is due to the opposite relationship between gas content and access. For example, the gas content typically increases on a linear scale with depth, yet permeability decreases on an exponential scale with depth. With new technologies, the optimum range for accessing a combination of acceptable, economical gas content and economic permeability will expand. The greenhouse gas abatement benefits of trapping CMM have availed a growing number of opportunities for funding support through the Clean Development Mechanism (CDM) of the United Nations Framework Convention on Climate Change (UNFCCC). However, the failure to incorporate CMM recovery and utilisation from the commencement of coal mine operations has reduced the opportunities for receiving CDM support (IEA, 2009d).

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[25] Mine related deaths have been coming down in recent years in China, but gas explosions, flooding and collapses remain too common. In 2009, there were 2,631 official coal mine related deaths but many more go unreported. In 2003, an explosion killed 243 workers on a CNPC gas field in Chongqing and poisoned a further 4,000 others. In early 2010, twenty workers were killed in a natural gas explosion at an industrial furnace in Hebei. At the same time gas related accidents still occur overseas. For example, an explosion at a US gas power plant killed six and injured 26 workers. In 1998, an explosion at an Australian gas storage facility killed two workers. In addition to the human costs, gas accidents typically disrupt supplies.

6. Global and Regional Supply Position for Gas

Gas is the third largest global energy source after coal and oil. While the GFC led to a significant drop in global natural gas demand as well as excess capacity in 2008 and 2009[26], gas continued to account for around 20% of primary energy consumption. During the past decade, global gas consumption has increased annually by nearly 3% with China contributing to the largest growth of around 25% of total global demand. The IEA (2009a) predicts a slower expansion of global gas demand at 1.5% annually to 2030 in its reference case. This expansion in global demand will increasingly be met by imports, including LNG from countries such as Australia. Global LNG trade is projected by the IEA to rise by 3.7 per cent per year to reach 17 104 PJ (314 Mt, 15 tcf) in 2030. (GeoScience et al., 2010).

The world supply position for gas has developed significantly in the last decade (BP 2009, Stern 2008; IEA, 2009b). Compared to 30 years ago when gas was the poor cousin of oil, the situation has changed with the discovery of enormous and high quality gas resources and new technologies for commercialisation. In 2009, global reserves of proven gas reserves were estimated at around 185 tcm with around 918 tcm of global unconventional gas resources (GeoScience et al., 2010). The key official data shows the dominant share of reserves for world natural gas are located in the Middle East and Russia/Eastern Europe, with the Asia Pacific having a little less than 15%. As a result, the industry has matured somewhat with a convergence of prices and increasing global exchange of gas between regions. For example, global LNG trade expanded at an average annual rate of 6% per year over the past decade, accounting for around 7% of global gas consumption (GeoScience et al., 2010). Despite this supply side growth, there have been few material real price reductions for customers reflecting the market dominance to date of certain leading producers – especially the Qataris with their oil parity pricing approach, as well as GazProm of Russia.

There are emerging signs that current price rigidity will break down over time to the benefit of gas consumers, through:

- proactive policies aimed at diversifying European gas supplies and anti-trust action in Western Europe;
- local supply side growth in gas reserves from Qatar, West Africa, Papua New Guinea, Australia and Russia;
- the enormous expansion of LNG capacity in PNG and Australia, some of which has been deferred during the global financial crisis, and under which excess supply can be expected to influence longer term prices from 2015; and
- the discovery of new processes, and advances in technology to develop CSM deposits, that are demonstrating their potential in both China, the United States and Australia.

So it can be concluded that the prospects are positive for China not only to take infrastructure investment decisions in favour of developing its use of natural gas, but also to establish a more proactive gas policy context that facilitates a lower carbon and cleaner environment as a result.

[26] Global natural gas demand grew by 2.5% in 2008, but then declined by 2.5% in 2009.

During the past decade gas has experienced a revival with a sharp increase in the identification of diverse and abundant new gas fields on top of traditional suppliers, such as Qatar, Russia, Nigeria and Algeria. Five years ago, the EU and US were concerned about securing adequate domestic gas supplies. However, due to a combination of growing concerns about climate change and the emergence of CBM, countries across Europe and in the US are opening up previously depleted and uneconomical coal and shale deposits. New drilling technologies have opened up new supplies of gas that were initially deemed low quality or too expensive to tap into.

Since 2000, the natural gas market has grown considerably and strengthened its potential as a major natural resource in its own right. A combination of factors have merged to place gas in a competitive position alongside coal, oil, nuclear and renewables as fuel source for industry, power generation, transport and residential use. Firstly, the strong energy demands from the rapidly developing and emerging economies, such as China, India, Brazil and Indonesia, pushed the price of oil away from its historically low price to above US$100 a barrel prior to the global financial crisis and it still remains at around US$70-$80. Secondly, global recognition of carbon constraints and risks arising from anthropogenic climate change have increased the demand for low carbon alternatives and a shift away from coal as a source of energy. Thirdly, technological breakthroughs, industry consolidation and economies of scale in the gas industry have opened up significant new deposits of so-called unconventional gas. As a result, in 2007 gas overtook nuclear as the second largest source of power amongst OECD countries. In fact, gas-fired power generation made up four-fifths on incremental power amongst OECD members between 2000 and 2008 (IEA, 2009b). These developments have opened up new supply opportunities for the gas industry, which have been made even more attractive since 2009 as the price has remained below US$5 per million Btu (British thermal units), which is seen as below the benchmark of economic viability for investment in the gas industry.[27]

The future of gas supplies will continue to be linked to the fate of oil somewhat but probably more significant is the ongoing search for diverse and low carbon energy supplies in a carbon constrained environment. After an ongoing close correlation between benchmark natural gas and oil prices for the past two decades, the two diverged to their highest levels in late 2009 and again in early 2010. Typically, the price ratio between natural gas and oil varies between 1:6 and 1:12. However, the price ratio in recent months jumped to 1:21.8. While analysts argue that the two commodities will eventually realign to their historical relationship, it is clear that in the short-term this is unlikely.

Some risks arise due to a low gas price, especially for future investment in the sector. Demand will grow, but if the price is too low then investment in the development of new fields, trains, pipelines and storage will be delayed. In early 2010, the US benchmark (Henry Hub) price of gas was below US$4 per million Btu. While demand-side pressure increases when the price is low, investment in new gas fields and gas infrastructure is driven by higher prices. According to the IEA (2009b), when the price drops below US$5, companies have little incentive to invest. For example, an internationally high price for natural gas remains an important factor in Australia to the many proposed natural gas (and LNG) developments. Without a higher price, natural gas projects remain less economically

[27] According to the US EIA (2010), the Nymex April Henry Hub price was US$4.44 per million Btus (MMBtu) and the spot price averaged $4.29 MMBtu in March, $1.03 below the average spot price in February and $0.64 lower than 2009 EIA forecasts.

attractive for companies to develop. In the mid-term this could place upward pressure on natural gas prices. The key determinant will be the speed of economic growth following the global financial crisis (GFC) and the global demand for gas.

A further consideration for the delinking of gas and oil prices relates to the shift in future growth for each resource. According to the IEA (2009a), oil demand from OECD nations is likely to continue its current decline brought about by the GFC through to 2030. The IEA predict declining average annual oil demand in the US of 0.7%, 0.4% in Europe and 1.8% in Japan. In contrast, China's insatiable demand for oil is estimated to increase at an annual average rate of 3.3% through to 2030.[28] At the same time, demand for natural gas is expected to rise in Europe, North America and Japan as these countries attempt to curtail carbon emissions from coal power generation. According to the IEA (2009a) World Energy Outlook there is a close relationship between future demand for gas and climate change. In the IEA's Reference Scenario, demand for gas rises 41% between 2007 and 2030 from 3.0 tcm to 4.3 tcm respectively. This is equivalent to an annual increase of 1.5%. Even under the 450 Scenario gas demand grows but more slowly and is 17% lower in 2030 than in the Reference Scenario. The slower growth is due to slower demand, energy efficiency gains, lower electricity demand and increased switching to non-fossil energy sources.

The supply side of the natural gas sector has experienced a divide in recent years between OPEC and non-OPEC countries. While OPEC natural gas liquids production has steadily grown from an average 4.47 million barrels per day in 2007, to 4.55 million b/d in 2008 and 4.67 million b/d in 2009, average non-OPEC gas production has declined from 3.65 million b/d to 3.79 million b/d and then 3.34 million b/d respectively. Much of this is part of the long term decline in pressure from fields, but also a result of declining demand following the GFC. Natural gas prices in the Asia Pacific market also declined following the GFC.

It is expected that gas production is set to expand due to the exploitation of CBM sources in China, Europe, North America and Australia. Estimating unconventional gas supplies is difficult as most remains unmapped, but conservative IEA (2009a) estimates are 921 tcm, which is more than five times proven conventional gas reserves. In addition to the aforementioned CBM projects in China and Australia, the US, Europe, Canada and Indonesia are all exploring the future potential of CBM to contribute to the fuel mix.[29] The development of CBM will most likely place downward pressure on prices and could risk future investment in gas infrastructure. In 2008, Russia was the biggest natural gas producer. However, in recent years the US has increased shale gas production (including CBM and tight gas) to levels satisfying half of its domestic gas demand. The rapid expansion of shale gas in the US to over 600 bcm saw it surpass Russian gas production in 2009. The strong global interest in CBM has led some analysts to predict a glut of gas on international markets, which will in turn bring prices down.

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[28] The IEA (2009b) tempers these projected rises due to the increased presence of renewables and recent gains in energy efficiency, but does mention the upward pressure on gas from pairing increased wind capacity with gas-fired plants as reserve capacity.

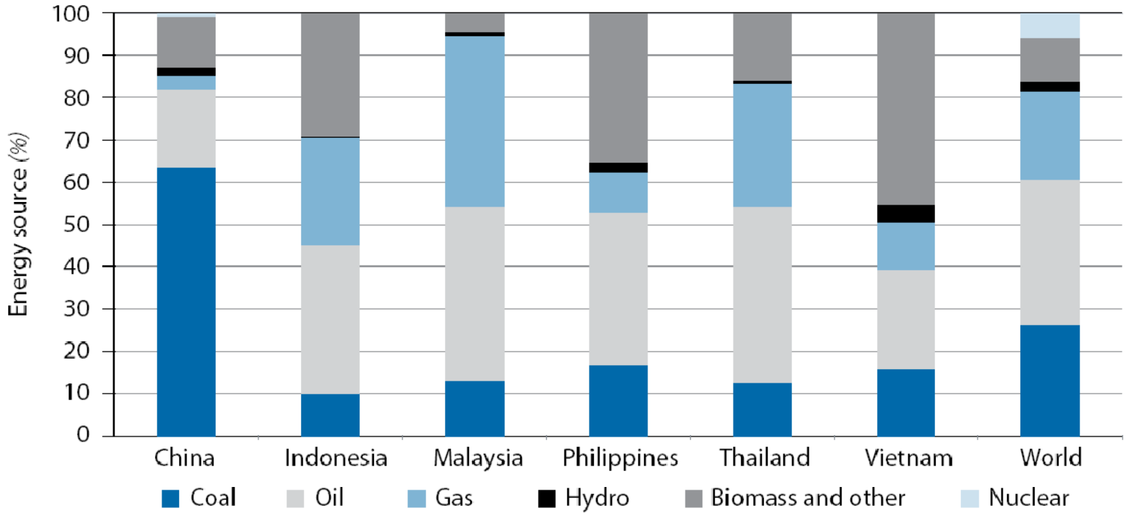
[29] In 2009, China and US signed up to a cooperation agreement on exploring the future potential supplies of CBM and sharing technology. The US shares a similar predicament with China in having large coal bed methane and shale deposits whilst searching for an alternative to a heavy domestic dependence upon coal and oil.

According to the IEA (2009a), the expansion of unconventional gas and the existing under-utilisation of inter-regional pipeline and LNG capacity wield significant consequences for the structure of gas markets, including a lower gas price and the possible de-coupling of gas and oil prices. As a result, the IEA suggests suppliers to Europe and Asia-Pacific markets are likely to modify pricing terms under long-term contracts and sell more gas on a spot basis. The outcome for gas industry investment in infrastructure and the development of new fields shall remain dependent upon the extent of growing gas demand, especially from emerging economies and the pressure to move away from coal.

Asia Pacific Developments in Gas

South East Asian countries, such as Vietnam, Malaysia and Indonesia, all have significant gas reserves and resources and are expected to further develop their respective gas policies and regulations as well as their gas production and consumption capacity. Demand for gas in the Asia Pacific is expected to steadily grow as countries strive to provide greater energy security whilst they become increasingly dependent upon energy imports. This will be especially the case for China, India, Malaysia, Vietnam, Thailand and the Philippines. As such, gas is likely to meet much of the region's growing energy demand, especially in large cities and for power generation.

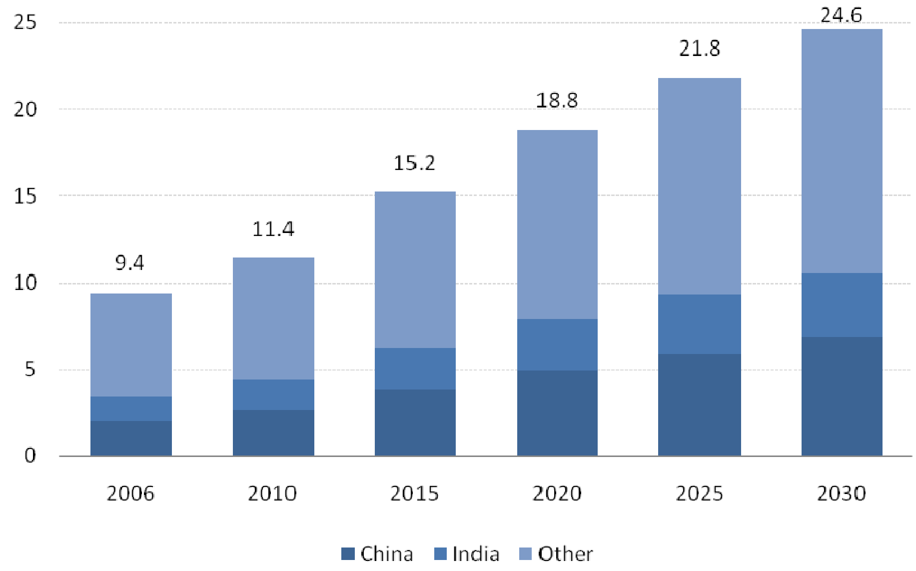
Fig. 24. Energy Mix in Selected Asian Economies, 2007, %



Source: World Bank, 2010

As shown in Figure 24, the region's larger economies heavily rely upon oil and gas, with the exception of China where coal dominates. It is expected that in the next two decades most countries are expected to gradually switch away from the increasingly expensive oil and towards gas. Combined with the growth in gas demand from China and other regional economies (Figure 25), some gas price volatility is likely.

Fig. 25. Projected natural gas consumption in non-OECD Asia, 2006-2030, trillion cubic feet



Source: EIA World Energy Projections, 2009

In 2009, Wood Mackenzie updated the expected supply and demand outlook for natural gas, LNG and CSM over the next 10 years (see Harris 2009, Quinn 2009, Wood MacKenzie 2009, and McManus 2009). The key conclusions which are of relevance to China include:

- indigenous unconventional gas production from CSM will pressure both LNG supply and pricing in the next decade (Harris 2009);
- 90 mmtpa of new LNG capacity is due to come on-stream during the next few years especially in the Asia Pacific region including exports from Sakhalin and Pluto (under construction);
- the market is expected to soften by 2010/11 reflecting a combination of significant new supply and weaker demand;
- a market tightening is expected temporarily through 2013/14, but then major softening as significant capacity extensions come on stream from Gorgon PNG LNG and QCLNG, as well as Gladstone, Icthys, APLNG, GLNG, Sulawesi, Sakhalin and Tangguh extensions; and
- Pacific Basin demand is expected to grow steadily and also become more diverse.

As Harris (2009) concludes "The wave of oil parity deals has passed … those projects expected to start post-2015 are likely to secure lower prices and may have to make other concessions to buyers".

It is expected that global oversupply will pull spot prices below oil indexed levels in the short term. Whilst Asia has commanded a premium to European prices in recent times, the arrival of new Australian supply is expected to remove this premium in the next few years. However, as mentioned, if the price falls too low then investment levels will also decrease.

Natural gas in Australia

Natural gas is one of Australia's key energy resources with abundant natural reserves of both conventional and unconventional gas. In 2009, gas reserves with reasonable prospects for commercialisation were estimated at around 60,000 petajoules (PJ), comprising more than 39 000 PJ of conventional natural gas and more than 21,000 PJ of unconventional coal seam gas (AER, 2009). Currently, most of the conventional reserves are located in off-shore fields in north-western Australia with recent discoveries in Queensland doubling the commercially viable reserves of CSG. Potential tight gas and shale gas reserves have been identified in West Australia, South Australia and the Northern Territory but are not currently being developed.

In 2008, Australia was the world's sixth largest LNG exporter, accounting for 9% of global LNG trade, but only 2% of natural gas reserves and production (GeoScience et al., 2010). However, according to the IEA (2009a), Australia is rapidly emerging as a key global natural gas player. Moreover, Australia is expected to dominate gas exports to China by 2030 with around 55 bcm of LNG shipped annually. This will equal the combined total of Russian and Central Asian piped gas into China by 2030 if the Russian pipeline is complete by 2020.[30] Australia and other Asia Pacific producers have proven LNG technology and resources and so can be seen as reliable long term suppliers contracted reliably at sub-world market prices, which are likely to remain below the current US$6-8 mmbtu in the medium to longer term. Australia's LNG export capacity is expected to increase from around 16 million tonnes at present to around 24 million tonnes by 2011-2012 and 76 million tonnes by 2029-2030.

According to Robinson, the CEO of the Australian Petroleum Production and Exploration Association, in 2009 natural gas is "the key to assisting Australia and the world make a smooth transition to the substantially lower or no emissions future that must lie ahead." Her comments epitomise the commitment of the petroleum industry to the development of natural gas based power generation and the use of gas more generally. Much of this optimism is a result of multi-billion dollar LNG agreements between China and Australia.[31]

The institutional arrangements in Australia for gas and electricity are quite different to international experience. Moreover, recent investment evidence demonstrates that the Australian energy market environment is facilitating the entry of gas and renewable based power generation capacity as a commercial priority. The Federal and State or Regional governments of Australia have combined to oversee a National Energy Market (NEM) for Electricity and Gas. In the former case electricity generators are required to bid their energy from different sources and operating costs into a wholesale market, which sets posted prices by volume of power (GWh) and time of day against which electricity customers can buy their energy. The same process applies for gas, and the prices of the two markets have the potential to be interconnected, post their move to supervision under the National Regulator and Market Operator – AER, and NEMMCO respectively - as from 1 July 2009.

That means at the wholesale level, there is a different price applying at different peak and off peak times during the day, and the price path is higher at peak – that encourages higher cost peaking

[30] If delays continue to impede negotiations for the construction of the Russia-China pipeline (Chen, 2010), then China would most likely consider increasing the capacity of existing Central Asian (mainly Turkmenistan) contracts beyond the existing 40 bcm annually.

[31] Following the signing off of the Gorgon LNG and Gladstone CBM projects, the Australian Minister for Resources and Energy, Martin Ferguson argued that "Australia is a safe place for investment, there is no sovereign risk and we are a major energy player internationally when it comes to clean energy, namely LNG" (Kirk, 2010).

capacity to be economic. Due to these features in the NEM, gas fired power generation is acknowledged and plays a key role for its superior operating features:

- immediacy of connection to the grid, compared to other base load generators that take time to both fire up and be brought on line, as well as the reverse;
- 50-70% less carbon dioxide than conventional coal fired generation;
- gas fired generation uses very little water – as little as half to 1/2000th of the water used by coal fired power stations;
- a smaller environmental footprint – 15 hectares per 100 MW plant compared to 7000 hectares on average for solar and 10,000 hectares for wind; and
- gas is the perfect complement for intermittent renewable energy sources feeding into a power grid - South Australia's Electricity Supply Planning Council notes that every 5000 MW of wind power requires around 2000 MW of gas fired generation to ensure a reliable supply to the energy grid.

The Australian NEM has led to more diversified electricity sourcing and use. For example, more than 6000 MW of open cycle and combined cycle gas turbines and traditional gas power generators are proposed for addition to the national energy grid during the next four years, and the regulator is already working on a pro forma code for the market to adopt carbon pricing, subject to the final shape of policy decisions from the Australian federal government and parliament.

There is considerable scope for ongoing and enhanced cooperation between China and Australia on gas. In addition to the commencement of a strong gas supply relationship and Chinese investment in Australia's gas resources, the value Australia has to add in this field is primarily through the opportunity to apply learnings in this country from recent developments in Australia's energy resources and markets, as well as the adoption of smarter environmental approaches to ensure these energy markets provide cleaner and greener energy solutions. At the same time, LNG from Australia is currently offering the lowest price and will therefore play an increasingly important role in Chinese gas imports.

The CSM market has grown significantly since its formative stages of the 1990s. As from 2006, significant reserves in Australia have been upgraded across the board, and major oil and gas producers like BG, Santos, Petronas, Origin, Conoco Phillips, Arrow Energy and Shell have moved to secure CSM resources, as the race is on to develop the first CSM to LNG project. The technology to do this is known, and fit for purpose rigs are available for the task. Modern water management innovation technologies and systems also make this form of resource more accessible today. Whilst the immediate challenge is to develop such resources commercially, the mood of optimism is high. It reached its peak following the March 2010 signing of a major gas deal by CNOOC for the supply of 72 million tonnes of coal seam methane over 20 years. The Australian Minister for Resources and Energy, Martin Ferguson, then announced that from an "energy and a resource point of view, Australia's very important to China's future economic development" (Kirk, 2010).

The recent growth in gas exploration in Australia is led by offshore exploration in the north west shelf and the development of new coal seam methane fields in Queensland. These two major developments have lifted investment in gas exploration to its highest levels on record in recent years.

Australia is set to become the largest exporter of unconventional gas with the announcement over the past few years of several multibillion-dollar offshore gas projects in the north west shelf and coal seam methane to liquid natural gas projects in Queensland (Smith and Hoyos, 2010).[32] Rather than develop the gas for domestic markets, most of the gas is to be used for long-haul exports to China, Korea, Japan, Singapore and Taiwan.

CNOOC signed a deal in 2009 with BG for the delivery of 5.3 bcm annually over 20 years from the planned Queensland CBM development. The recent 20-year gas supply contract between Exxon Mobil and CNPC from the Gorgon fields was greeted with much debate in China due to the one third higher price paid by China compared to a similar deal reached with India. China analysts suggested Exxon's shareholdings in the India partner, Petronet8, ensured that a preferential price was achieved.

7. Policy Options for the Increased Utilisation of Natural Gas in China

This note presents seven major policy suggestions that may contribute to the existing Chinese Government's actions to reduce carbon emissions through the increased utilization of natural gas. The Chinese Government acknowledges the substantial benefits natural gas offers to China as: (i) an ideal low-carbon transition fuel for the shift away from coal and oil and towards renewable energy offering a 50% to 70% reduction in CO_2 emissions per unit of energy in many uses compared to coal and oil; (ii) a potentially low cost fuel for pairing with intermittent power generation, such as renewable energy sources; and, (iii) an effective, modern and cleaner fuel source for residential, commercial and industrial uses with significantly lower levels of SO_2, NO_x and particulates.

The policy options presented in this note draw upon CSES and other analysis of actual and proposed policy responses in China and other jurisdictions and include the following suggestions:

1. Adopt a national low-carbon energy policy
2. Prioritise pairing of natural gas with intermittent renewable energy
3. Incremental phase-in of regional and national gas market
4. Directed state investment in strategic international investments and partnerships in the gas sector and natural gas infrastructure
5. Trial new financing techniques for energy infrastructure
6. Provide clear direction for future natural gas utilisation
7. Encourage distributed generation of low carbon gas sector

As mentioned earlier in this report, China acknowledges the benefits of natural gas and is moving actively towards realising many of these policy suggestions by developing a comprehensive energy framework supportive of natural gas. It is important that these policy suggestions are assessed against this framework.

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[32] Smith (2009) noted that CBM could account for up to one-third of Australia's gas projects by 2020.

Implement a national low-carbon energy policy

i. Proposed policy

Fully implement existing national energy policies with a priority on promoting the increased utilisation of low carbon energy sources, especially renewables.

ii. Rationale

The existing national energy policy should further consolidate the existing regulatory and pricing framework of energy policies, plans and legislation (including the draft Energy Law) to facilitate the transition towards a low carbon economy. Such a policy could incorporate a carbon tax, an emissions trading scheme, renewable energy targets and be linked into a global climate change agreement to facilitate international financial and technical assistance. Identifying natural gas as a "clean and reliable" priority fuel for the transition to a low-carbon economy should be considered.

iii. Policy details and implementation

A. The establishment of a national carbon tax and emissions trading scheme ensures that pricing of resource use includes economic, social and environmental externalities. A carbon tax should incorporate social/environmental externalities and measuring energy intensity; GHG (CO_2) emissions; particulates; water use etc. Such a measure will curb the expansion of black coal fired power plants and facilitate the further development of power generation from renewable sources and substitute power sourcing more towards gas based plants. [33]
B. Government to assist energy industry in identifying strategic pilot cities for development of integrated low carbon and renewable energy supplies together with cogeneration and even tri-generation capacity.
C. Develop pricing and regulatory support for development of distributed power generation of low carbon energy resources, such as the use of ceramic fuel cells powered by natural gas. Unit subsidies, feed-in tariffs and VAT rebates should be directed towards providing sufficient incentives for investment in reliable and low carbon power generation.[34]
D. Government funded infrastructure for pipelines, energy storage facilities.

Prioritise pairing of natural gas with intermittent renewable energy

i. Proposed policy

Prioritise natural gas as a complementary load power source for intermittent renewable energy

ii. Rationale

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[33] Evidence published by Australia's leading upstream and downstream energy producer and retailer, Origin Energy, shows that the current indicative global benchmark price for carbon emissions of $US20/tonne equalizes the short run marginal costs of base load power generation from coal and gas sources, and carbon prices above this will both favour and facilitate a substitution towards gas based power generation, and away from black coal.

[34] In May 2010, the State Council (2010) announced that CBM would be eligible for feed-in tariff support.

Pairing dispatchable natural gas generation with renewable energy, such as wind and solar, offers a natural symmetry due to the intermittent nature of renewables and natural gas' reliable, fast start and stop and flexible operation features.

Pairing improves energy mix security through diversification and provides a stronger incentive for grid connectivity and utilisation rates for renewables, as well as reduces CO_2 emissions and other pollutants, such as NOx, SOx and particulates in comparison with coal power plants. Pairing offers additional benefits, such as improving economic viability of new transmission lines to connect wind and solar resources into the electrical grid. In addition, the reliability of pairing power sources provides added leveraging in contract price negotiations, which can keep costs low, particularly if gas is supplied through trunk feed line with generous maximum daily quantities (MDQs) to ensure greater flexibility.

iii. Policy details and implementation

A. Government can provide additional tax incentives, soft loans, VAT rebates, feed-in tariffs, technical assistance and target regions for development. The Government could consider introducing preferential loan and tax policies for the development and use of natural gas with renewables in power generation. Support should be available during construction stage as well as power generation with tax exemptions and VAT refunds. The existing 50% reduced rate for loans to the renewable sector could be extended to include projects involving paired renewable-natural gas power generation.

B. Prioritise pairing in areas with local gas supplies or access to tap into gas pipelines and significant renewable capacity, such as Xinjiang, Gansu, Inner Mongolia and Qinghai.

C. Pairing natural gas with renewables should be incorporated within broader reforms to pricing and policy measures. The draft Energy Law should replace the existing 'Policy for Natural Gas Use' (2007) which only provides a temporary bridge for the natural gas sector in China. The new Energy Law should include sufficient detail to promote the pairing of natural gas with renewable as a priority area for natural gas utilisation. If the promulgation of the Energy Law is delayed then the 2007 Policy should be reviewed to: firstly, support the transition from an allocated and 'price plus cost' system to a market orientated one; and secondly, to expand the categories of priority natural gas use to include measures to promote the pairing of natural gas with renewables.

This study suggests that natural gas can play an increasing role in China's power generation mix by replacing old, less efficient and more polluting coal power plants as well as being cited with large scale renewable sites to maximise the capacity of renewable energy generation with back-up secure and reliable base load power. Unless policy and pricing reforms are undertaken to provide incentives for shifting towards a complementary relationship between gas and renewables, then it is unlikely to occur. Firstly, investment for building a new gas plant needs security in terms of utilisation rates of capacity, which has been seriously weakened during the past two years. Secondly, the experience to date has shown that rather than complement each other, gas is actually competing with renewables due to their similar higher pricing levels; making them only attractive during demand peaking periods.

Incremental phase-in of regional and national gas market

i. Proposed policy

Accelerate the current shift towards establishing a regional and national natural gas market on a progressively staged basis to eventually replace existing allocation and "cost-plus" system of pricing.

ii. Rationale

The advantages of future national or regional electricity and gas markets for China would be:

- feeding in gas fired generation to an optimised electricity grid with a full range of wholesale sources of primary energy; and
- building a deeper and more flexible market for gas itself by having a focus for more rational wholesale and retail price determination, that would restructure current customer price rigidities impeding the development of gas.

Furthermore national and regional energy markets in China would facilitate the NDRC taking a position to oversee the introduction of carbon pricing across the placement of various bids into the respective energy markets at the wholesale and retail level. These carbon cost (tax) impositions and subsidy credits would enable a more transparent pricing of the environmental impacts of various primary energy forms and also cement the relatively advantaged environmental position of gas, both for power generation and for other uses. Use of a wholesale market in this way would simplify and allow an efficient carbon tax collection, as on line market data and bidding / supply sources would facilitate live tax data and collection 'on line'. See Appendix 1 for a more detailed description of Australia's energy market, including details of the gas market Bulletin Board and the Short-term Trading Market.

Pricing systems should be increasingly transparent to improve efficiency in supply and demand relationship and promote energy investment stability. The current 'Policy for Natural Gas Use' (2007) remains a stop-gap measure which insufficiently resolves existing structural and pricing problems within the natural gas supply, distribution and demand systems. The existing "cost-plus" based domestic pricing system has kept domestic gas prices below international levels. The greater reliance on higher priced gas imports will weaken the viability of the existing system. However, it will be necessary to maintain the existing policy to foster higher investment in infrastructure and use during the transition period to greater marketisation.

iii. Policy details and implementation

A. Review the restraints with the existing 'Policy for Natural Gas Use' by progressively establish pilot regional markets for electricity trading at the wholesale level along the eastern seaboard as gas and electricity infrastructure capabilities integrate and as wholesale energy markets and applications progressively mature.

B. Sector based policies could include the following:

   a. *Domestic* – retail consumers should be paying the full economic costs of using natural gas in all major urban centres by 2015. Where possible, exclusive mandates should be provided for gas based reticulation only in new urban developments for power, heating and cooking using distributed generation, such as ceramic fuel cells or solar-gas cogeneration units for example.

   b. *Light Industrial and Commercial* – energy taxes and subsidies should be developed and used to ensure gas based power is the most economic for the majority of these customers by 2020. It will be feasible for many users to adopt distributed generation, such as ceramic fuel cells.

   c. *Heavy industrial users* – e.g. power generation, metal smelting, large chemical, cement and other manufacturing plants. The State should support, at least for a transitional period, the infrastructure costs and delivered prices to encourage large scale users to switch to natural gas, without significant penalty, so that natural gas becomes the preferred primary energy form

   d. *Fertiliser Subsidies* – the current scheme of perverse subsidies for the use of gas in fertilizer and related rural industries should be phased out within 5-7 years.

C. Initially, large electricity suppliers and customers in a nominated major region should be compelled to put their supplies through by a bid and offer process within a wholesale operator / market regulator, on a time of day basis. All new contracts could be required to be put through the wholesale regulator. The Australian Energy Market provides a possible model for this first stage of wholesale electricity trading in China.

D. Accelerate work on connecting national electricity grid to support energy diversity.

E. Introduce pricing system that progressively incorporate the full transparency of economic costs for the various primary energy forms in use to deliver electricity to domestic consumers, light industrial and commercial, heavy industrial users and fertiliser industry.

F. Domestic retail gas supply and demand sources by region can be factored in after the market has been developed. Market orientated reforms need to incorporate strategic consideration of seasonal, regional and inter-sectoral variations between supply and demand which are presently causing structural problems.

G. Continuing to reduce the gap in prices between international and domestic prices ensures gas prices better reflect actual costs to ensure the most efficient utilisation of natural gas.

H. Carbon taxes and green energy tariffs can be introduced to improve the functioning of the market from a sustainability perspective.

I. The energy market exchanges can then be interlinked to become multi-regional, and then finally to be national in nature.

J. Undertake a national natural gas resources assessment and review to assess demand/supply and cost/benefit energy relationship for natural gas covering, for example: i) supply through pipeline, terminal, or local domestic source (including CSM); ii) industry value chain; iii) low carbon cities (use by industry, heating, cooling, power generation and industry); iv) power generation; and v) state investment in IGCC/CCGT/CSM/CCS.

K. Commit resources to rigorously assess, refine and progressively develop an economic profile for the proving of reserves, confirmation of calorific values, extraction costs per GJ, wellhead values, treatment and transmission costs, and estimated city gate prices from its most economic CSM fields.

iv. Advantages and limitations

It is envisaged that such a system would provide significant economic benefits including securing ongoing levels of investment in energy supply (generation and transmission), competitive electricity prices and improved productivity with improved efficient allocation of energy resources and capital utilisation. Should result in the removal of perverse subsidies for fossil fuel use (consider phasing out where social welfare implications are identified).

Intensify directed state investment in strategic international investments and partnerships in the gas sector and natural gas infrastructure

i. Proposed policy

Further boost state investment in natural gas infrastructure and supply at the domestic and international level. Develop stronger alliances and partnerships with leaders in the global natural gas industry, especially with companies involved in emerging areas of natural gas technology and development across the gas spectrum of exploration, extraction, processing, transmission and distribution, storage and utilisation.

ii. Rationale

By investing in natural gas supply and infrastructure the state will cover the significant initial set up costs for natural gas which can act as a hindrance for investment and market access, as well as ensure access to reliable supplies and state of the art technology and world’s best practices in an emerging resource recovery sector. State support for research and development as well as targeted investment in new technology and emerging areas of natural gas supply and utilisation, such as coal seam methane, Combined Cycle Gas Turbines (CCGT), Integrated Gasification Combined Cycle (IGCC) and distributed generation, should be promoted to ensure China is utilising state of the art processes.

China currently adopts an "engaged investment" policy approach in negotiations regarding long-term commitments to gas purchases often involving underwriting the construction of transportation infrastructure up to the delivery point. The currently depressed natural gas market provides an ideal period for China to proactively engage in strategic mergers/partnerships (including 'production sharing agreements') for diversifying NG supplies. It is likely that oil prices will return to the peak prices of 2008 within the next 3-4 years as demand from China grows as the global economy recovers. Ongoing Government support for the partnerships approach adopted by China's gas players of China National Petroleum Corporation (CNPC), Sinopec and China National Offshore Oil Corp (CNOOC) is essentially, especially in developing economies and will position China ahead of competing bids from Europe and North America in particular. Continued diversification of NG supplies with multiple import options is critical for sector stability in terms of supply and pricing. Moreover, such diversification increases leveraging with potential and actual suppliers of gas.

iii. Policy details and implementation

A. Commit to further investment in and ownership of long-term contracts for natural gas supply beyond existing minimum requirements.

B. Continue to accelerate the development of an integrated gas based infrastructure, combining both natural gas and LNG treatment facilities. This could include prioritising the integration of gas supplies with gas based power plants operating in the largest and fastest growing urban centres.

C. Develop demonstration power plant / grid projects from natural gas and renewables. Such demonstration projects should possibly be located within smaller rural communities with currently limited but emerging power needs, and where adjacent to potential or actual off-take points from nationally commissioned gas transmission, distribution and other infrastructure facilities. The recent announcement of a totally solar city of the future should be taken further with the development of a regionally based power generation system, where gas and renewable (e.g. wind and solar) primary energy sources form the greatest share.

D. The NDRC's four point natural gas plan requires companies signing long-term import contracts for overseas LNG to hold equity in the upstream resource. For instance the 2010 announcement by CNOOC to purchase 3.6 million tonnes of LNG over 20 years from Queensland's CBM fields involved a 10% stake in infrastructure and a 5% stake in the field. This vertically integrated requirement has been somewhat onerous due to the strategic nature of such investments in some countries and the potential delays in developing overseas partnerships, but with further government support should.

E. Complement policy with the introduction of renewable and low carbon energy targets and carbon pricing.

F. Targeted energy efficiency measures for industry could promote adoption or switch to natural gas utilisation. For example, a tightening of the scheduling system and the introduction of differential prices for industrial and residential users, as well as preferential on-grid price for generation using natural gas and coal-bed methane as feedstock whilst encouraging power generation with industrial waste heat (combined heat and power).

iv. Advantages and limitations

Provide increased energy security in terms of access to NG supplies at reliable prices.

The provision of gas infrastructure, such as underground gas storages, port facilities and terminals, pipelines and liquefaction will ensure optimal capture of the most economic set of natural gas sources and delivered costs of supply – especially from the second West East Pipeline, and also the Central Asia and Eastern Siberian pipelines.

The very large number of potential investments and development projects in LNG will offer significantly improved long term contractual pricing opportunities to match or significantly improve upon the $3.05/BTu gas that China has purchased from Woodside in the north west shelf of Australia, and which currently is transformed via the Shenzhen terminal into gas used to generate and supply electricity to Hong Kong.[35]

The development of demonstration projects provide experience in managing a power grid where the complementary diversity of gas and renewables can be trialled, and learning experiences documented and used to underpin similar and larger developments elsewhere.

An expansion of the domestic use of gas will give both demand diversity and load factor that will help amortise China's large capital investments in gas pipelines and treatment facilities, and encourage larger scale applications for gas, as other initiatives, such as those suggested above, have time to take effect through the progressive removal of the current price disparity for gas, vis-à-vis other fossil fuels.

Current evidence is that the consumer sector in major cities like Beijing and Shanghai are prepared to pay close to world benchmark domestic prices for using natural gas with heating, cooking and other consumer applications.

[35] In 2008, prices for imported NG varied from $3.05 MBtu to $20.60 per MBtu.

Trial new financing techniques for energy infrastructure

i. Proposed policy

Prioritise the trialling of Public Private Partnerships (PPP) and 'Alliance' structure arrangements in the energy sector.

ii. Rationale

New financing techniques can strategically attract investment that includes both soft and hard technologies and processes.

iii. Policy details and implementation

Public Private Partnerships (PPP), and 'Alliance' structure are two forms of financing that may be of value to the priority being set for developing China's gas based infrastructure. These structures began in the United Kingdom in the 1990s, and have been extensively used in Australia over the last decade. They are essentially joint financings between the public and private sectors.

Alliance structures are more like an unincorporated joint venture, and are used more widely in infrastructure developments – where a high degree of innovation is required; where the asset is complex to construct, and the ultimate owner, e.g. a Chinese Government entity both wishes to own the ultimate commissioned asset but also to learn from the best in the international industry that specialises in the relevant plant or process development. Whilst China is well advanced in LNG terminal development and has some gas powered generation, the latest technology in these areas together with recent innovations in CCGT, OCGT, and CSM development may make PPPs/Alliances worthy of further review and potential application to China's energy future.

Prioritise the construction of SCGT/CC (semi-closed gas turbine/combined cycle) dual-fuel gas and coal power generators, Combined Cycle Gas Turbines (CCGT) and Integrated Gasification Combined Cycle (IGCC), with and without carbon capture and storage (CCS) capabilities, for new power generating capacity.

The expansion of CCGT and IGCC will improve resource efficiency, reduce CO_2 emissions and curb the expansion of black coal fired power plants and substitute sourcing more towards gas based plants. More aggressive policies are necessary if China is to shift away from its current unsustainable trajectory of continuing to rely upon coal.

iv. Advantages and disadvantages

PPs and Alliance structures are designed to leverage both the quantum of finance and mutual skills and experiences in project design, development, construction, commissioning and operation. Other characteristics which improve the suitability of a PPP are:

- complex and long term infrastructure;
- clearly defined outputs;

- scope for innovation;
- balancing of risk between public and private participants;
- opportunity to bundle contracts; and
- complementary commercial development, for example, as may be applicable in CCGT developments.

There are tax features that can advantage the private participants that reflect the distinction between an operating lease and financial lease, with PPPs being more like the former.

Provide clear direction for natural gas utilisation in future energy mix

i. Proposed policy

Set transition targets for the utilisation of natural gas across regions and power utilities between 2020 and 2050. For example, the Government could propose a primary energy source peaking target composed of "three one-thirds" by 2050: 1/3 coal; 1/3 NG/nuclear; 1/3 renewables/ hydro.

ii. Rationale

Clarifying the role of natural gas as a transition fuel towards the shift to a low carbon economy should provide added security of investment, supply and utilisation rates within the sector. Current estimated primary energy share of 3-5% from natural gas and 70% from coal by the end of the decade is not sustainable, particularly when world current primary energy shares from natural gas average 20%, and are targeted to increase from this, having regard to recent discoveries of extensive and economically recoverable coal seam methane (CSM) deposits, and gas reserves capable of economic conversion to LPG.[36] By way of example, Hong Kong currently averages 'one third' targets for each of coal, gas, and nuclear.

iii. Policy details and implementation

Set progressive targets for provincial/municipal levels and energy utilities especially for the pairing of natural gas with renewables, including incentives and bonuses for exceeding targets or penalties for non-compliance. For instance, interim low carbon energy targets of 20% paired renewables-natural gas in the energy mix by 2020. This policy should be incorporated within the new national energy law.

The economics of such decisions will be enhanced as and when carbon pricing becomes either a national and /or global standard. Opportunities for availing such projects of CDM funding should be seriously considered due to the abatement benefits of increasing the currently low utilisation rates of low carbon energy sources.

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[36] Domestic natural gas resources are based on a 2005 national survey which identified 56 tcm of domestic gas with 22 tcm of recoverable resources. CNPC announced in 2008 that proven reserves are estimated at 5.94 tcm. Coalbed methane resources are estimated at 37 tcm within geological resources and 134.3 bcm of proven resources. Source: IEA (2009) *Natural gas in China: market evolution and strategy.*

iv. Advantages and limitations

Ensure meeting desired economic and environmental goals. Result in substantially reduced, cleaner and more sustainable carbon footprint.

Resistance from coal sector and regions due to loss of income and employment can be reduced through increased utilisation of CSM resources.

The significant majority of new and economic additions to Australia's electricity grid are from committed investments in CCGT and related plants.

CDM could be utilised to facilitate low carbon technology transfer through investment/ financing/R&D protocols, which could encourage CSM, CCCG, IGCC or CCS activities.

This policy could reduce the resistance from the coal sector and coal regions of a low carbon policy (due to loss of income and employment), through strengthened investment in the development and technologies in reducing the GHG emissions from coal.

Encourage distributed generation of low carbon gas sector

i. Proposed policy

Review existing 'Policy for Natural Gas Use' to support distributed generation capacity.

ii. Rationale

It is expected that the natural gas power sector will diversify in the coming decade and undergo a gradual shift away from centralised power generation and move towards distributed generation due to the development of more efficient localised generation capacity, such as gas-powered fuel cells and solar-gas units which can provide cogeneration and eventually trigeneration cooling, heating and power (CHP). Distributed generation offers lower costs an[37]d a more efficient utilisation of remote and localised gas fields without the significant investment in infrastructure, such as pipelines, technology and liquefaction. Distributed generation and the use of fuel cell technology will suit new residential developments and existing commercial sites particular the replacement of industrial heating and power generation boilers.

The successful example of Broad Air Conditioning, which utilises natural gas for central chillers and waste heat provide a useful platform for linking up with solar systems or new high temperature ceramic fuel cell technologies which also utilise natural gas and have the potential for trigeneration

CHP. These units only produce around 20% of the carbon emissions of coal-powered electric equivalents.

iii. Policy details and implementation

- Review existing 'Policy for Natural Gas Use' to support distributed generation capacity.
- Provide purchase subsidies, feed-in tariffs and discounted VAT for the purchase of distributed units, such as ceramic fuel cells with CHP capacity of 2kW or greater.
- Local conventional and unconventional supplies of gas need to be included in this policy. For example, the government's closure of small scale coal mines in recent years could be accelerated by focusing upon the utilisation of Abandoned Mine Methane (AMM) in feasible circumstances.

8. Conclusion

China's natural gas market is entering an exciting period against a background of LNG capacity developments, significant infrastructure expansions, long term low global prices, strong prospects of further unconventional gas resources in the form of CSM and additional diversity on the supply side. China has matched its growing need for energy with a proactive overseas search for diverse energy supplies, including joint ventures, direct investments, acquisitions and resource-loan deals for access to new oil and gas fields. China's increasing interest in overseas oil and gas ventures has coincided with a lull in international investment in the area following the global financial crisis and tightening financial conditions. Even under a high global gas price scenario, it is likely that a combination of higher oil costs and the ongoing rapid expansion of energy demand will result in gas demand exceeding the capacity of gas supplies. Therefore, gas is more likely to flow into higher value added streams, such as power generation, residential heating and cooking use in wealthier coastal cities and as a mass-transit transport fuel.

The impact of international gas prices on China's ability to secure long-term low-cost supplies of gas is an important consideration. The difficulties experienced globally due to the rising cost of developing natural gas and LNG projects, including transport infrastructure, combined with the tightening of global credit markets and lower gas prices have pushed up the cost and delayed many gas projects. In the short-term, this could benefit China's domestic gas market as well as overseas investments. If China is unable to meet expected future gas demand through LNG imports, then it will accelerate the development of domestic CBM resources and piped gas from Central Asia. Moreover, China is able to mitigate to some extent the international cost and financing difficulties, due to its lower construction costs and strong local lines of credit.

This study suggests that natural gas can play an increasing role in China's power generation mix by replacing old, less efficient and more polluting coal power plants as well as being cited with large scale renewable sites to maximise the capacity of renewable energy generation with back-up secure and reliable base load power

Further Work

On the basis of this research report, the following issues are suggested for further consideration:

- Identify the necessary costs, barriers and opportunities for installing and utilising complementary load power source for intermittent renewable energy and the potential of distributed natural gas based power generation facilities;
- Consider adjustments to existing and future pricing and wholesale and retail markets for both electricity and gas trading which facilitate cleaner primary energy usage, and an improved system for determining wholesale and retail prices;
- Examine global supply perspectives and Australian developments of gas, LNG, and coal seam methane (CSM) relative to their potential applicability for the adoption of new technologies in these areas and of relevance to China;

- Review and assess global and Asia Pacific opportunities for supply – demand balances with gas, as well as short, medium and longer term scenarios for LNG pricing, having regard to CSM;
- Examine the role of wholesale electricity markets in applying carbon pricing, and the adoption of a broader mix of power generation sources from black coal, gas, and renewables (solar, wind geothermal and biomass);
- Review relative prices and uses for gas products between the broad groups of fertilizer production, industrial applications, and consumer market uses; and,
- Review the potential applicability of alternative infrastructure financing mechanisms, such as those currently in use in Australia that could be of relevance to China, including 'Alliance' funding structures and other 'Public-Private-Partnership' (PPP) vehicles.

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Appendix A

Briefing Paper on the Australian Energy Market prepared by the Department of Resources, Energy and Tourism

Australian Energy Market

Australia's institutional arrangements are underpinned by a number of energy market reforms, the direction of which have been determined by two intergovernmental bodies, the Council of Australian Governments (COAG) and the Ministerial Council on Energy (MCE). COAG is the peak intergovernmental forum in Australia, and comprises the Prime Minister, state premiers, territory chief ministers and the president of the Australian Local Government Association. The MCE comprises Australian, state and territory energy ministers. Ministers from New Zealand and Papua New Guinea have observer status.

The process of energy market reform has been steadily unfolding over the last two decades. Since 2004, the COAG-agreed Australian Energy Market Agreement (AEMA) has formed the basis for a transition to national energy regulation; the most recent wave of reform is underpinned by revisions to that agreement in 2006.

Regulator and Market Operators

The national energy framework in Australia is underpinned by three key agencies, the Australian Energy Regulator (AER), the Australian Energy Market Commission (AEMC), and the Australian Energy Market Operator (AEMO).

The AEMC has responsibility for the rule-making process and market development in the national energy market, as legislated by the National Electricity Law and National Gas Law. The AEMC also undertakes reviews of the energy market framework and provides policy advice to the MCE.

The AER is the national energy regulator. In the National Electricity Market (which includes all jurisdictions except Western Australia and the Northern Territory) the AER is responsible for both the regulation of electricity transmission networks and electricity distribution networks. For Australian gas networks, the AER regulates covered gas transmission and distribution pipelines in all states and territories of Australia (except Western Australia). The Economic Regulatory Authority is responsible for regulation in Western Australia.

The AEMO is a single, industry-funded national energy market operator for both electricity and gas, which commenced operation on 1 July 2009. AEMO merged the role of the current National Electricity Market Management Company (NEMMCO) with the gas market functions of the Victorian

Energy Networks Corporation (VENCorp), the Gas Market Company (GMC) (which previously operated in New South Wales and the Australian Capital Territory), and the Retail Energy Market Company (REMCo) (which previously operated in South Australia and Western Australia).

National Electricity Market

The National Electricity Market in Australia is operated by AEMO (previously NEMMCO) in the following Australian states and territories: South Australia, Tasmania, Victoria, the Australian Capital Territory, New South Wales and Queensland. It operates as a wholesale pool market through which generators and retailers trade electricity. AEMO coordinates a central dispatch to manage the wholesale spot market. The process matches generator supply offers to demand in real time. AEMO issues instructions to each generator to produce the required quantity of electricity that will meet demand at all times at the lowest available cost, while maintaining the technical security of the power system.

National Gas Market

Natural gas in Australia is mostly sold under confidential, long-term contracts. There has been a trend in recent years towards short-term supply, but most contracts still run for at least five years. Wholesale gas contracts typically include *take or pay* clauses that require the purchaser to pay for a minimum quantity of gas each year regardless of the actual quantity used. Prices may be reviewed periodically during the life of the contract. Between reviews, prices are typically indexed, and therefore do not tend to fluctuate on a daily or seasonal basis.

There is some secondary trading in gas, in which contracted bulk supplies are traded to alter delivery points and other supply arrangements. *Backhaul* can be used for the notional transport of gas in the opposite direction to the physical flow in a pipeline. These arrangements are most commonly used by gas-fired electricity generators and industrial users that can cope with intermittent supplies. A *gas swap* is an exchange of gas at one location for an equivalent amount of gas delivered to another location. Shippers may use swaps to deal with regional mismatches in supply and demand.

A gas market Bulletin Board further provides transparent, real-time and independent information to gas customers, small market participants, potential new entrants and market observers (including governments) on the state of the gas market, system constraints and market opportunities. The Bulletin Board commenced on 1 July 2008 and is a website (www.gasbb.com.au) covering major gas production fields, storage facilities, demand centres and transmission pipelines, in southern and eastern Australia. Information provision by relevant market participants is mandatory and covers:

- gas pipeline capacity and daily aggregated nomination data;
- production capabilities (maximum daily quantities) and three-day outlooks for production facilities; and
- storage capabilities and three-day outlooks for storage facilities.

In addition, the MCE has approved the development of a short-term trading market in gas, to commence by winter 2010. The proposed market is intended to facilitate daily trading by establishing a mandatory price-based balancing mechanisms at defined hubs. The market would initially cover network hubs in New South Wales and South Australia and replace existing gas balancing arrangements. Victoria has had a transparent balancing market since 1999.

Source: AER (2008) *State of the Energy Market 2008*, Melbourne, Australian Energy Regulator (AER).