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

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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

[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 21st 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 11^{th} 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.

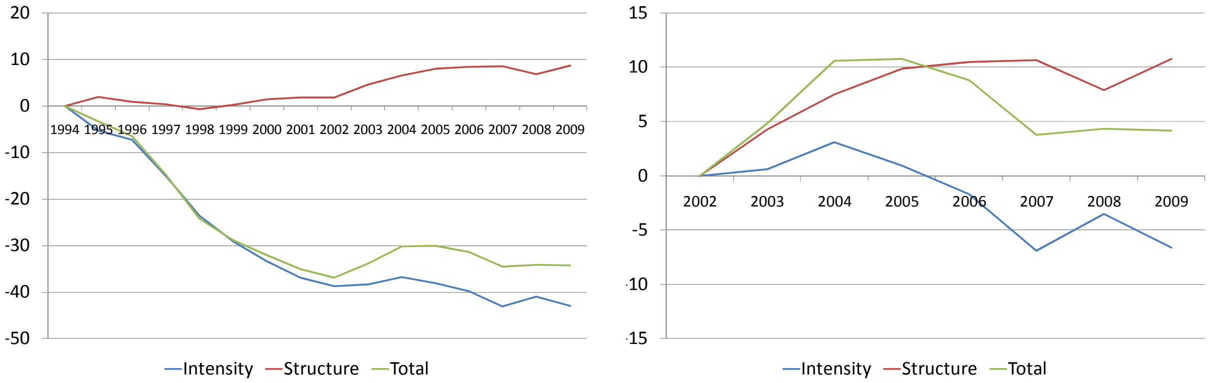
Table 1: Dimensions of China's Revised Development Strategy during the 11^{th} Five Year Plan

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.