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Task Force Report

China's Pathway Towards a Low Carbon Economy

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0. Introduction

The move towards a low carbon economy is inevitable for China if it is to realize its development goals. There are significant and immediate economic benefits to be gained from improving energy and resource efficiency levels, and it has already adopted rigorous policies to realize those benefits: these policies are important tools for kick-starting a low carbon economy. Further, China stands to benefit significantly from a transformation of its pattern of economic growth. Such a transformation will allow it to capitalize on new growth opportunities as a supplier and satisfy the increasing global demand for low carbon technologies.

Today it is widely accepted that global climate change presents one of the biggest challenges to human development. At the global level, scientific consensus is driving global action towards emissions reduction and the transition to a low carbon economy. Some developed countries have substantially adjusted, and continue to change, their socio-economic policies in a move towards low carbon development. Trade-related greenhouse gas (GHG) emissions are also likely to come under increasing scrutiny in the coming decades. Their reduction is especially problematic for emerging economies dependent on export-led growth. These concerns bring structural changes to the global economy and trade patterns that imply a new paradigm for economic development.

Without mitigation, global climate change impacts would impede China's long-term development prospects. China's growth has brought significant impacts on the global economy, many of which are positive. The resulting rise in resource consumption has, however, incurred negative externalities. As the world's centre of manufacturing, China emits greenhouse gases when exporting commodities.

China is frequently stricken by natural disasters, and a further increase in the number of climate-related natural disasters would incur not only ecological and economic losses to it but also threaten domestic social stability and national security. Growing industrialization and urbanization together with China's continuing coal-based energy structure impose (at least in the short run) tremendous pressure on its resources and environment. Dependency on imports of oil raises uncertainties for economic development and also worsens energy security. With global economic imbalances causing financial crises, the pattern of economic growth in China is facing unprecedented challenges. Many of the drivers supporting China's economic growth are weakening.

China confronts two major challenges in the future. The first is to maintain domestic stability. This means ensuring that the benefits of economic development can be shared by all. The second is to act as a responsible stakeholder in the international community and assume its share of responsibilities. This means that in addition to promoting stable economic growth and securing energy supplies to meet growing energy demands, China must tackle the negative consequences of its sub-optimal energy structure and inefficient energy consumption. China needs to keep in check further environmental damage in order to reduce the real costs of economic development and to sustain people's increases in welfare. Without these measures the global scramble for key energy resources is likely to lead to higher prices and volatility, as well as to limited availability in the longer term. The transition away from fossil fuels is complex and will not occur rapidly (estimates suggest that the move away from dependency on liquid fossil fuels will take at least two decades), and therefore the quicker the process begins the less disruptive it is likely to be.

0.1. A low carbon economy: compatible with existing Chinese development concepts

The development of a low carbon economy in China is necessary and urgent because it is aligned with not only world political and economic trends but also the fundamental realities and national interest of China.

This report argues that a low carbon development pathway is the best way for China to create employment while achieving a resilient and prosperous society and to build on and enhance national priorities such as the Scientific Outlook on Development, the construction of a resource-saving, environmentally friendly society and the development of a circular economy. Efforts to maintain a safe climate are in line with the priority of developing a harmonious society, and are fully consistent with existing Chinese efforts on energy saving and environmental protection. The low carbon economy provides a path to the new industrial and economic growth model that China urgently seeks.

Following the traditional economic model is not an option for China: resource, social and environmental constraints make it impossible. The up-front investment costs of moving to a low carbon economy should thus not be compared with a 'business-as-usual' (BAU) scenario – that is not possible. The costs and challenges should be seen instead in the context of huge opportunities. Just as Japan built a new economic model in the wake of the 1970s oil crises, China's response to current challenges will set its course for decades to come.

China has a strong interest in acting soon. The innovation and application of high energy efficiency and low emission technologies is at the core of the low carbon economy. The country is already a world leader on critical low carbon technologies such solar power and heat, wind turbines and electric vehicles. Choices made in China will shape the global markets for such goods.

0.2. Defining the low carbon economy

Although the notion of a low carbon economy (LCE) has been receiving more international attention, especially since the publication of the Intergovernmental Panel on Climate Change's Fourth Assessment Report *Climate Change 2007* and *The Stern Review on the Economics of Climate Change* in 2006, there is yet to be a universally accepted definition of what a low carbon economy would entail.

In this report, a 'low carbon economy' is defined as a new economic, technological and social system of production and consumption for conserving energy and reducing greenhouse gas emissions (compared with the traditional economic system) while maintaining momentum towards economic and social development.

This definition is underpinned by three principles:

1. An LCE would decouple economic growth from greenhouse gas and other polluting emissions through technological and other innovations, changes in infrastructure and behavioural changes.

2. At China's current stage of development – it is still undergoing industrialization and urbanization – 'low carbon'[1] is a relative rather than an

[1] 'Low carbon' is shorthand for 'low greenhouse gas'. Although CO_2 is the main contributor to global warming, the role other

absolute concept. Emissions per unit of economic output are reduced more rapidly under an LCE than under a continuation of the status quo.

3. A low carbon economy achieves many key development objectives, including long-term economic growth, creation of jobs and economic opportunities, reduction of resource consumption and enhancement of technological innovation.

Many countries, including those of the Major Economies Forum,[2] have accepted that if we are to avoid dangerous levels of climate change, global temperature rises need to be restricted to no more than 2˚C above pre-industrial times. This requires global emissions to peak in the next decade and then decline to half of recent levels by 2050 (see Table 1.1 below). In order to achieve this, energy systems that are close to zero emissions will need to be developed. Eventually these will need to be implemented globally. Every country needs to avoid becoming locked in to high carbon options, which will be extremely costly to reverse in future

Different development situations mean that countries have different pathways to a low carbon economy. Consequently this report does not make specific recommendations on absolute emissions pathways for China. It focuses instead on relative measures of carbon and energy intensity. However, scenario analyses in Chapter 4 and pathway descriptions in Chapter 5 indicate a range of futures that significantly reduce the energy and carbon intensity of China's economy, and some of them do include the possibility of attaining peak emissions.

The scenarios indicate the types of technology that will be required over different periods if the calculated emissions and energy demand curves are to be significantly changed. This can act as a guide to policy recommendations by highlighting key factors that will help to shape future emissions profiles.

In practice, the overall costs of CO_2 reduction are likely to be relatively low, at levels that the economy can withstand. In many sectors clean technologies already exist, and reduction measures are low cost or even profitable, for example in industrial and domestic energy conservation and energy efficiency and in clean and renewable energy production. But cost estimates vary quite widely. This is partly because technology costs are uncertain, particularly for new technologies that are still undergoing development.

Some estimates, such as McKinsey's CO_2 abatement cost curve,[3] suggest that approximately one third of the 36 Giga tonnes (Gt) CO_2 affordable global abatement opportunities in 2030 are achievable at negative cost (i.e. they represent a net economic benefit even without considering reduced climate caused damages). McKinsey also estimate that the total costs of mitigation will be on the order of 0.6–1.4% of global GDP by 2050.[4] The negative cost options are mostly associated with energy efficiency improvements; but there is an important simplification made in their analysis that all technologies are evaluated at the same discount rate, despite differences in terms of investment risk and barriers to implementation. In practice, some low cost efficiency

greenhouse gases must not be overlooked.

[2] It includes Australia, Brazil, Canada, China, the European Union, France, Germany, India, Indonesia, Italy, Japan, the Republic of Korea, Mexico, Russia, South Africa, the United Kingdom and the United States

[3] McKinsey & Co, 'Pathways to a Low Carbon Economy: Version 2 of the Global GHG Abatement Cost Curve'.

[4] McKinsey Global Institute, 'The Carbon Productivity Challenge: Curbing Climate Change and Sustaining Economic Growth' 2008.

improvements are not always easy to access.

Nevertheless, many other analyses (e.g. Princeton 'wedges'[5]) also show that sufficient abatement is available using known technologies if deployed widely enough, and the consensus is that new technologies will also come down in cost as they are deployed more widely and benefit from economies of scale (e.g. IEA learning curves[6]). A review of cost estimates in the Stern Review indicated that the total global costs of meeting a stabilization target sufficient to avoid the worst effects of climate change could range from -3.9% of world GDP (i.e. a net benefit) to +3.4% of world GDP in 2030.[7]

0.3. Overview of report

Chapter 1: The global shift to a low carbon economy Several developed countries have proposed and introduced specific emissions reduction targets as well as policies to meet them, including emissions trading schemes, carbon taxes, energy efficiency regulation and R&D spending. Some large developing countries have also announced initiatives for addressing climate change. This chapter briefly examines policies pursued elsewhere for moving towards an LCE. It also looks at how the global financial crisis has presented both obstacles to and opportunities for a low carbon transition.

Chapter 2: The urgency and necessity for China to develop an LCE Changes in international trade patterns will reinforce China's aim of moving away from an export-led heavy industrial economic structure. The move towards more sustainable production and energy consumption will bring significant industrial and economic advantages that will enable it to enhance its status as a global manufacturing leader. China needs to act urgently in order to avoid locking itself into an expensive and insecure energy future and to take advantage of the opportunities now arising from the rapid growth in global demand for low carbon technologies, goods and services.

Chapter 3: Meeting the challenges Although an LCE is feasible from the technological, economic and resource perspectives, it will require significant national commitment to decarbonize the processes of urbanization and industrialization. Improving China's capacity for scientific and technological innovation will be essential. Changes to policy and institutional frameworks will be needed in order to address financial barriers and to create incentives for decision-makers in enterprise and local government to encourage the widespread deployment of low carbon technology.

Chapter 4: Reduction potential and cost-benefit analysis Four scenarios illustrate the impact of different development pathways open to China: 1) business as usual; 2) a high GDP, low carbon scenario; 3) a high GDP, enhanced low carbon scenario; and 4) a low GDP, low carbon scenario. Each scenario details the technologies that will need to be deployed in order to bring about the necessary transformation, its economic implications and its relative emissions.

Chapter 5: Pathways to LCE development in China Examples of what an LCE will look like for China's key sectors are presented, drawing in part from existing international experience. Detailed case studies are provided for low carbon industrial production, urban planning, infrastructure, transport, energy development and

[5] See http://www.princeton.edu/wedges/
[6] IEA , 'Experience curves for energy technology policy', 2000.
[7] Stern Review, 'The Economics of Climate Change' (Table 10.1).

diversification, carbon capture and storage, low carbon technologies, consumer behaviour, agricultural production and land use.

Chapter 6: Policy recommendations The analysis has shown that there is considerable potential for the inclusion of an LCE development strategy in China's 12th national five-year plan. Its inclusion could be supported by further medium- and long-term policies.

1. The global shift to a low carbon economy

1.1. Business as usual: not an option

At the global level, the transition to a low carbon economy is no longer a choice but a necessity. Governments and businesses are incorporating this new reality into decisions on trade, financing and production planning. Fluctuating prices and supply volatility are motivating the more efficient use of energy. The tightening global supply of oil and natural gas, as well as the imperative of climate change mitigation, is fuelling the development of new technologies. The United States National Petroleum Council think that the oil and natural gas sources we have relied upon historically are unlikely to be able to meet projected demand.[8] The US magazine *Business Week* declared that 2006 'was the year global warming went from controversial to conventional for much of the corporate world'.[9]

Central to the vision of a low carbon economic future is an increasing appreciation of the potential economic, social and political benefits – rather than the costs – of the transition. Many of the costs are in fact investments that will deliver efficiency gains in future. A global shift to a low carbon economy would create lucrative new opportunities for countries involved in providing market solutions for such a shift. Countries that have understood the structural nature of the issue and have provided sustained, effective support for low carbon alternatives are benefiting most from the early opportunities of low carbon transition.

This is just the beginning. As pressure for transition mounts, investment in low carbon goods and services is set to expand rapidly. The countries that are moving fastest on low carbon transition, particularly those large enough to influence international markets, stand to gain important competitive advantages. Growth in demand for low carbon energy products will be significant. A recent study estimates that China alone will need $25 billion per year for investment in low carbon technologies.[10] Globally the value of low carbon energy products by 2050 is estimated by the Stern Review to be worth at least $500 billion per year, and perhaps much more.[11] According to the International Energy Agency (IEA), meeting a 450 ppm CO_2e[12] concentration limit would require an increase in investment of 18%, averaging an additional $1 trillion per year up to 2050 compared to BAU requirements.[13] A significant proportion of this additional expenditure would be made by consumer investment in low carbon vehicles and other appliances.

Table 1.1 shows the expected effect of increases in concentrations of CO_2 and other GHG on the global temperature. In order to keep global temperature increases in the range of 2^oC, the CO_2e must be around 450 ppm but also peak by 2015. Delaying the peak by a decade and allowing the CO_2 ppm to reach 550 is likely to result in a 3^oC increase in global temperatures

[8] The United States National Petroleum Council, *Facing the Hard Truths About Energy*, July 2007.
[9] *Business Week*, 'Best of 2006', images.businessweek.com/ss/06/12/1207_bestideas/source/11.htm.
[10] Guiyang Zhuang, *Low Carbon Economy: No Alternatives Left for China*, Chinese Academy of Social Science, May 2007.
[11] HM Treasury, *Stern Review: The Economics of Climate Change*, Executive Summary, 2006.
[12] ppm is parts per million, and refers to the concentration of greenhouse gases in the attmosphere. CO_2e is a measure of the effects of all the greenhouse gases measured in one unit, CO_2.
[13] IEA (2008), *Energy Technology Perspectives 2008*, International Energy Agency

Table 1.1: Characteristics of various emissions trajectories to achieve stabilization of greenhouse gas concentrations

Temperature rise	CO_2	CO_2-eq.	Year of peak emissions	% change in global emissions
Global average temperature increase above pre-industrial at equilibrium, using "best estimate" climate sensitivity	CO_2 concentration at stabilisation (2005 = 379 ppm)	CO_2-eq. concentration at stabilisation including GHGs and aerosols (2005 = 375 ppm)	Peaking year for CO_2 emissions	Change in CO_2 emissions in 2050 (percent of 2000 emissions)
°C	ppm	ppm	year	percent
2.0 - 2.4	350 - 400	445 - 490	2000 - 2015	-85 to -50
2.4 - 2.8	400 - 440	490 - 535	2000 - 2020	-60 to -30
2.8 - 3.2	440 - 485	535 - 590	2010 - 2030	-30 to +5
3.2 - 4.0	485 - 570	590 - 710	2020 - 2060	+10 to +60
4.0 - 4.9	570 - 660	710 - 855	2050 - 2080	+25 to +85
4.9 - 6.1	660 - 790	855 - 1130	2060 - 2090	+90 to +140

Source: IPCC/Stern 2009.[14]

Polling evidence shows an increasing appetite for a low carbon economy in most parts of the world. According to an international poll of 21 countries undertaken for the BBC, in all but four countries the majority of the population felt it necessary to take early action on climate change. Of those polled in China, 79% expressed their support, compared with 59% in the US, 50% in Germany and 43% in Russia.[15]

Research published by HSBC bank found that citizens' concern about climate change was far higher in China (47%) than in the European countries reviewed: France (37%), Germany (26%) and the UK (22%). Also, the percentage of people who thought that we could stop climate change was 39% in China but only 5% in France, 6% in the UK and 11% in Germany.[16] A Eurobarometer report has shown that climate change is the second most important issue to European citizens after poverty and access to water.[17]

Today innumerable low carbon initiatives have sprung up at different levels of government – from national to local level. Business leaders are also active in helping to promote an atmosphere of imminent yet enduring change. A *McKinsey Quarterly* article warns that 'over the next 5 to 15 years the way a company manages its carbon exposure could create or destroy its shareholder value'.[18] With deeper acceptance of the findings of climate-related science, the question today is less about whether low carbon transition is needed than about how fast can it be implemented and on what scale.

The state of the global economy in 2009 is fuelling concern about meeting the additional costs of a low carbon transition. However, the low carbon economy is not only a useful

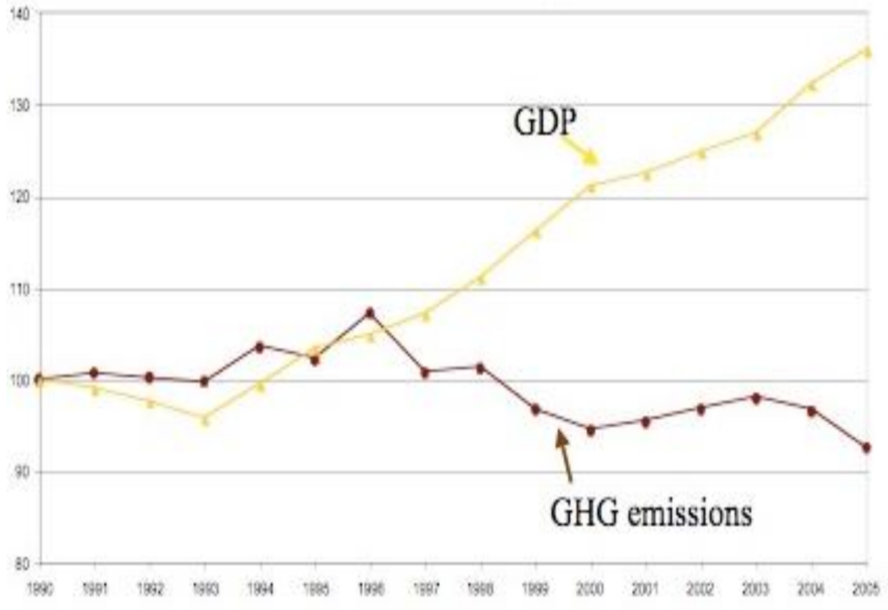
[14] Lord Nicholas Stern, 'The Cost of Delaying Action', published in 'Climate Change, Global Risks, Challenges and Decisions', Synthesis Report, Copenhagen, 10–12 March 2009.
[15] GlobeScan, 'All Countries Need to take Major Action on Climate Change', published by BBC World Service, 2007.
[16] HSBC 2007: Climate Conference Index 2007, HSBC
[17] Eurobarometer, 'European Attitudes toward Climate Change', Special report 300, September 2008.
[18] Christoph Grobbel, Jiri Mali and Michael Molitor, 'Preparing for a Low Carbon Future', *McKinsey Quarterly*, Number 4, 2004.

way through the current economic crisis but also the most viable way by which to ensure sustained growth in the medium term. Investment opportunities in low carbon goods and services may become increasingly appealing compared to the risks associated with investing in traditional sectors. Many low carbon solutions – in particular those relating to improved efficiency – come at little or no additional cost, and the costs of renewable energy technologies will come down over time.

As attention moves from the problems of the financial sector to the real economy, fears over job losses are likely to rise up the political and public agenda. Research in the US found that renewable energy creates more jobs per megawatt (MW) of power installed (per unit of energy produced and per dollar of investment) than a predominantly fossil fuel energy-based sector.[19] A New York State Energy Office study states that wind energy creates 27% more jobs in the state than the amount produced by a local power plant and 66% more jobs than a natural gas power plant.[20] A global assessment undertaken by Greenpeace International and the European Renewable Energy Council pointed to a net increase of nearly 2 million jobs in the power sector by 2030 as a result of increased use of renewable energy.[21]

As the case of Sweden demonstrates in Figure 1.1, it is possible to achieve GDP growth while emissions fall, although not many developed countries have so far been able to emulate Sweden's example.

Figure 1.1: Sweden: Growing GDP, declining GHG emissions, 1990–2005



Source: Swedish Energy Agency

1.1.1. Avoiding high future costs

Since the Intergovernmental Panel on Climate Change (IPCC) published its Fourth Assessment Report in 2007, doubts about the links between human activity and climate

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[19] *Putting Renewables to Work: How Many Jobs can the Clean Energy Industry Generate,* Renewable and Appropriate Energy Laboratories, April 2004, at http://rael.berkeley.edu/files/2004/Kammen-Renewable-Jobs-2004.pdf.
[20] National Wind 2009: Why Wind Power?, at http://www.nationalwind.com/why_wind.
[21] European Renewable Energy Council and Greenpeace International, 'Working for the Climate, Renewables Energy and the Green Job Revolution', August 2009.

change have all but evaporated. The threat of dangerous climate change has become a key political driver for the transition to global low carbon. As reaffirmed by new scientific evidence, dealing with these threats requires serious policy measures in order to minimize global temperature rises.

For the countries of the Major Economies Forum,[22] these measures mean minimizing the probability of a 2°C rise in global average temperatures over pre-industrial levels[23]This implies bringing long-run greenhouse gas concentrations back down to about 450 ppm, comparable to today's figure of around 455 ppm.[24] Another way to express the emissions constraint is that total cumulative anthropogenic emissions of greenhouse gases into the atmosphere should be limited to less than 3,700 $GtCO_2e$, approximately half of which has already been emitted since industrialization began, giving a remaining 'budget' of 1,850 $GtCO_2e$.[25] By comparison, annual emissions are currently more than 50 $GtCO_2e$ and increasing. Tighter constraints would be required in order to produce a greater probability of staying within the 2°C limit. Allowing temperature increases above 2°C presents unacceptable risks. Harmful effects are likely to increase rapidly in frequency and scale, and there is a risk of passing 'climatic tipping points' beyond which catastrophic damage is irreversible. These findings informed the G8 agreement on mid-century global targets: to give a 50:50 chance of staying within the 2°C limit, global CO_2 emissions will need to peak in the next two decades and fall by over 50% by 2050 compared to current emissions levels.[26] To achieve the 50% reduction, it is anticipated that all major emitting countries will need to begin radical decarbonization within the next 20 years.

The economic case for immediate transition to a low carbon economy is compelling. As noted previously, the macroeconomic cost of transition is likely to be manageable. On the other hand, the Stern Review puts the costs of inaction on climate change at between 5% and 20% of global GDP: the combined cost of both world wars and the Great Depression. One need look no further than the losses associated with extreme weather-related events in order to comprehend the potential scale of impact resulting from inaction. The year 2005 saw the highest-ever global financial losses owing to weather-related disorders, amounting to $185 billion. The United Nations projects that weather disasters could cost a trillion dollars (or 3% of current global GDP) per year by 2040.[27] In just one example in China, the 2005 drought in Ningxia Hui Autonomous Region cost an estimated 1.27 billion RMB, 2% of its GDP, and damaged 289,000 hectares of crops.[28]

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[22] The MEF countries (see fn. 2) signed a joint statement at their July 2009 meeting in L'Aquila stating: 'We recognize the scientific view that the increase in global average temperature above pre-industrial levels ought not to exceed 2 degrees C.'

[23] A concentration level of 450ppmv CO_2 equivalent would maintain a 50% chance of staying below 2°C, with a 400ppmv CO_2 equivalent providing a greater than 50% chance. To achieve either of these targets, global emissions would need to be at least 50% below 1990 levels by 2050. This would imply cutting developed country emissions to at least 30–35% below 1990 levels by 2020 while allowing developing economy emissions to grow until 2010 or 2020 but reducing them substantially thereafter. BAU scenarios, however, are projecting concentration levels of 650–750ppmv CO_2 equivalent, a pathway that would probably result in irreversible climate change and the onset of climate impacts at such a rate that global adjustment would be difficult.

[24] IPCC Fourth Assessment Report (table SPM6, Synthesis Report, Summary for Policy Makers).

[25] M.R. Allen et. al. 'Warming caused by cumulative carbon emissions towards the trillionth tonne'. *Nature*, vol. 458, issue 7242. The report notes that this cumulative emission level 'results in a most likely peak carbon-dioxide-induced warming of 2 °C above pre-industrial temperatures, with a 5–95% confidence interval of 1.3–3.9 °C.'

[26] M. Meinshausen and W. Hare (2004), 'How much warming are we committed to and how much can be avoided?', PIK Report 93, figure 8. According to the Swedish Scientific Council on Climate Change, 'A Scientific Basis for Climate Policy' (2007), the 2°C target can probably be achieved if greenhouse gas concentration in the atmosphere is stabilized in the long term at 400ppmv CO_2 equivalent. If it is stabilized at 450 ppmv CO_2 equivalent, there is a significant risk that the 2°C target will not be achieved. Full report available at: www.sweden.gov.se/content/1/c6/08/69/68/f8d98215.pdf.

[27] Daniel Wallis, 'Disasters losses may top $1 trillion/yr by 2040-UN', Reuters, 14 November 2006.

[28] Ministry of Civil Affairs in Ningxia. See Li Yue, Wu Yanjuan, D. Conway, F. Preston, Lin Erda, Zhang Jisheng, Wang Taoming, Jia Yi, Gao Qingzhu, Shifeng and Ju Hui, Climate and Livelihoods in Rural Ningxia: Final Report, AEA Group (2008), www.china-climate-adapt.org.

1.1.2. Avoiding dangerous carbon lock-in

Carbon 'lock-in' describes a situation whereby owing to current industrial practices and economies of scale, a country's technological and institutional infrastructures co-evolve towards long-term dependency on fossil-fuel-based systems by building infrastructure that will last for 50–100 years.[29] This 'lock-in' to fossil fuels inhibits the diffusion of carbon-saving technologies despite their apparent environmental and economic advantages.

The increase in CO_2 emissions expected over the next decade means that much deeper cuts will be needed in subsequent years in order to stabilize global temperatures. Work undertaken for the Dutch Environmental Assessment Agency suggests that delaying the peaking of global emissions by 10 years doubles the maximum emissions reduction rates needed, from 2.5% to over 5% per annum, when compared to immediate action. This leads to far higher costs, as high carbon infrastructure and equipment installed over the next decade would subsequently need to be scrapped before the end of their economic lifetime.[30]

Our decisions in the next 10–15 years will determine whether or not a climate-safe future will be possible. From the global perspective, we shall not be able to avoid serious climate change if we do not replace ageing energy infrastructure with high carbon options in the next few years. Lock-in is equally important for decisions on public transport, urban design, construction standards and major industrial investments.

Countries that find themselves locked in will expose themselves to a higher risk of energy insecurity as resource constraints tighten and will also be exposed to increasing global measures to raise the price of carbon. Lock-in will also blunt attempts to capitalize on possibilities of competitiveness. It will be enormously expensive to correct poor decisions.

Box 1.1: Building sector initiatives

The building sector accounts for nearly 40% of energy consumption in EU countries and is growing fast in many developing countries. The IPCC's Fourth Assessment Report estimates that the potential exists to reduce emissions related to energy use in buildings by 29% cost-effectively by 2020. A recent report by the WBCSD showed that green building technologies can be used to achieve significant reductions of energy use over the life-cycle of buildings at only 5% extra cost, instead of the commonly supposed 17%.

Globally many initiatives have been introduced to enforce new energy efficiency standards for buildings. In late 2008 the EU began a revision of the directive on the energy performance of buildings in order to set more ambitious goals. In India, the country's first national action plan on climate change, released in June 2008, calls for an extension of the Energy Conservation Building Code, among other policy measures. In Germany energy-related requirements for new homes and fully renovated older homes have been tightened with a view to reducing energy use by 30% from 2009.

1.1.3 Ensuring energy security

Achieving energy security is a major driver for China's low carbon development.

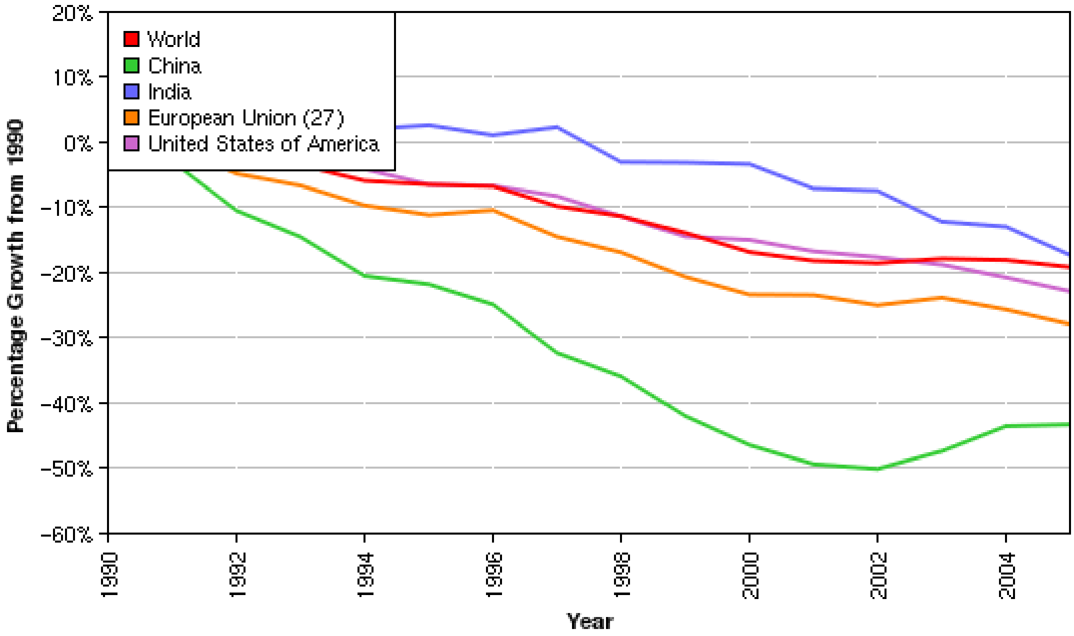
[29] G.C. Unruh, 'Understanding carbon lock-in', *Energy Policy*, vol. 28, 2000, pp. 817–830.
[30] M.G.J. den Elzen, M. Einshausen, *Meeting the EU 2^{0}C climate target: global and regional emissions implications*, Netherlands Environmental Assessment Agency, 2005.

Policies such as diversifying energy sources and improving end-use efficiency – both necessary to ensure energy security – are contributing to the shift into low carbon options. The oil shocks of the 1970s dramatically propelled energy security on to the global political stage, a concern that was reignited by the dramatic increases in energy prices during the past 5–10 years.

Oil and electricity consumption dropped in 2008 in the wake of the economic crisis, but the strength of the underlying growth trend can be seen in the rapid rise in fossil fuel consumption in major emerging economies such as the so-called BRICS countries (Brazil, Russia, India, China and South Africa) in recent years. The global climate and security challenge is to push forward on energy efficiency, meeting any remaining increase in demand with secure low carbon supply options wherever possible.

The Chinese economy is over four times less energy efficient than that of the EU measured in terms of consumption per unit of GDP at current prices. This reflects the inefficient processes and machines used in the production and consumption of energy, the large scale of the construction of new infrastructure and also the energy-intensive structure of the economy and the manufacturing sector. To achieve low carbon development and energy security together, China can continue to place great emphasis on energy efficiency while investing in low carbon options in the power and transport sector to reduce dependence on fossil fuels.

Figure 1.2: Global carbon intensity trends, 1990–2004



Source: Earth Trends Portatal – World Resources Institute 2009

At the global level, there is as yet little sign that energy demand will abate in the near future. Under the BAU scenario, the IEA forecasts a 55% increase in global energy consumption by 2030.[31] Energy markets remain tight and rigid, and oil prices moved from $12 per barrel in 1998 to a high of nearly $150 per barrel in mid-2008. Prices have since dropped from that high, partly as a result of the global financial slowdown.

[31] International Energy Agency, *World Energy Outlook 2006*, 2006.

However, structural factors relating to underinvestment in energy production and supply infrastructure prevent a return to prices of the 1990s. A recent Chatham House Report suggested that the world will experience a serious oil supply crunch within five to ten years unless there is a collapse in oil demand.[32]

The output from existing reserves is declining at 6.7% per annum. This figure, from the IEA, is in marked contrast to their assessment in 2007, which estimated a 3.7% per annum decline. The IEA have compared this to existing reserves and stated that even if demand remains steady, the world would have to find and then exploit the equivalent of the oil of four Saudi Arabias in order to maintain production and the oil of six Saudi Arabias if it is to keep up with the expected increase in demand between now and 2030. This will require a massive programme of exploration and investment, which is currently not being undertaken. If energy demand rises quickly with a global economic upturn, 'there is a real danger that sustained lower investment in supply in the coming months and years could lead to a shortage of capacity and another spike in energy prices in several years time',[33] with a subsequent threat to economic recovery.

On the positive side, policy options such as diversifying energy sources and improving end-use efficiency are contributing to the shift into low carbon options – not least because major alternatives to fossil fuels (renewable energy sources and nuclear power) both have significantly lower greenhouse gas emissions.

1.1.4 Trade in a carbon-constrained world

Amid the protectionist rhetoric – and genuine environmental concerns – it is easy to overlook the important role that trade and investment can play in facilitating the worldwide transition to a low carbon economy through the creation of new market incentives. Trade and investment also enhance access to countries' comparative advantages, leading to cheaper inputs and prices.

Despite the benefits brought by global trade, trade-related CO_2 emissions are likely to come under increasing scrutiny in the coming months. This is especially challenging for emerging economies dependent on export-led growth. Many US legislators have championed proposals to impose border tariffs on exports from developing countries not taking 'comparable actions' to limit GHG emissions.[34] These ideas are also favoured by a number of European governments and legislators.

In late 2008 the United Nation's International Maritime Organization (IMO) voted to clean up harmful particulates from vessel smokestacks but reached no agreement on a reduction in carbon emissions starting in July 2010. The global shipping industry accounts for 3% of the global total – around 912 million tonnes of CO_2 a year – more than the much-maligned aviation sector, which provides around 2%. This lack of progress contributed to a decision by the European Union to include aviation within the EU Emissions Trading Scheme, causing some distortion of price signals for flight routes via Europe compared to alternative routes, although the ICAO has since responded by

[32] Paul Stevens, *The Coming Oil Supply Crunch*, Chatham House Report, 2008, www.chathamhouse.org.uk/publications/papers/view/-/id/652/
[33] International Energy Agency, The Impact of the Financial and Economic crisis on Global Energy Investment, April 2009
[34] The Climate Security Act and the Low Carbon Economy Act; debates in June 2009

continuing to develop its own plans for a global scheme.[35]

Table 1.2 indicates a range of actions by both developed and developing countries either to achieve a particular level of abatement or to cap national emissions. All these policy developments and the abatement initiatives taken to meet them – whether from governments, businesses or consumers – are redefining the calculus for exporting countries. To ensure long-term survival, it is becoming critical for exporters to understand and adapt to the dynamics of an increasingly carbon-constrained world.

1.2. Policies and measures: ever more ambitious

Ambitious policies and measures have been put forward by governments around the world to support a low carbon transition. In many countries, domestic emissions targets set the overall framework for these policies. The array of policies and measures in the EU, for example, is focused on meeting its proposed 2020 target of either a 20% or 30% cut, depending on action by other major economies.

Long-term targets set the overall context, but medium-term targets are used to drive short-term action. For example, the South African government has announced that its GHG emissions will stop growing at the latest by 2020–2025, stabilize for up to 10 years and then decline in absolute terms.[36]

Table 1.2: Strategic actions for a low carbon economy – selected countries

Country	***Action***
Australia	Cap-and-trade ‘Carbon Pollution Reduction Scheme’ to be phased in from 1 July 2011 and a commitment to reduce carbon emissions by 25% below 2000 levels by 2020 (pending UNFCCC post-Kyoto agreement).
Brazil	Implementation of ‘National Policy for Energy Efficiency’, which will result in a gradual energy saving up to 106 TWh/year; to be reached by 2030, in which year a reduction of emissions of around 30 million tonnes of carbon.
Costa Rica	Pledged to be carbon neutral by 2021.
France	Emission reductions on the order of 75–80% before 2050 if other countries do the same.
UK	2008 climate change law requires legally binding 5-year carbon budgets to be set by an independent expert committee. The law requires emission reductions through action in the UK and abroad of at least 80% by 2050. The carbon budget for 2020 is set at a 34% reduction compared to 1990 and 42% following a global deal on climate change. Pledge to build no new coal-fired power stations without carbon capture and storage (CCS) to capture at least 25% of carbon emissions and 100% of emissions by 2025.
Mexico	Planning a domestic cap-and-trade system by 2012 to cut emissions from certain sectors (cement, oil refining etc.). The government has pledged to halve carbon emissions by 2050 on 2002 levels.
Norway	Aim of being carbon neutral by 2030. Has committed €140 million over 5 years to CCS projects in selected EU member states.
South Africa	A plan to halt its growth of greenhouse gas emissions at the latest by 2020–2025 and to adopt various economic and policy measures so that emissions will eventually stabilize and decline.

[35] ‘ICAO presses on with global emissions trading plan’, Reuters, 16 January 2009.
[36] www.environment.gov.za/NewsMedia/MedStat/2008Jul28_2/28072008-2.html.

Sweden	In 2000 Sweden discussed a target of reducing own emissions by 50% from 1990 level before year 2050. The government has said that Sweden should work internationally to stabilize the concentration of greenhouse gases at a level below 550 ppm CO_2 equivalents. Swedish per capita emissions should be below 4.5 tonnes CO_2 equivalents before 2050. This represents a reduction of just over 40% compared to today's level. The 2008 budget included 7 billion krona for climate and energy initiatives between 2009 and 2011.
United States	The government has suggested a 14–15% reduction in carbon emissions from 2005 levels by 2020. The Waxman-Markey Bill (recently passed US House of Representatives, now in the Senate) calls for an absolute cap covering 85% of the US economy, resulting in a 17% reduction by 2020 and a more than 80% reduction by 2050 compared to 2005 levels. The Bill requires electric utilities to meet 15% of their electricity demand through renewable energy sources and energy efficiency by 2020 and outlines $90 billion in new investments in clean energy technologies and energy efficiency by 2025.
Japan	Prime Minister Hatoyama has stated that Japan would seek to reduce CO_2 emissions by 25% below 1990 levels by 2020. This target would be contingent on a deal involving all major emitters in Copenhagen in December 2009
EU	Committed to cutting carbon emissions by 30% of 1990 levels by 2020 (pending UNFCCC post-Kyoto agreement). The 2007 EU climate and energy package has set three additional targets to be met by 2020: a 20% reduction in energy consumption compared with projected trends; an increase to 20% in renewable energies' share of total energy consumption; and an increase to 10% in the share of petrol and diesel consumption from sustainably produced biofuels.

1.2.1. Energy efficiency

According to both the IPCC and the IEA, cost-effective energy efficiency improvements could contribute to half the potential emissions reductions by 2020 and beyond. Furthermore, energy efficiency addresses all aspects of energy policy, environmental sustainability, security of supply and competitiveness largely at a lower cost than new supply options. According to the IEA, end-use fuel efficiency and end-use electricity efficiency could provide 36% of emissions savings by 2050. As the IPCC said in its Fourth Assessment Report, it is often more cost-effective to invest in end-use energy efficiency improvements than in increasing energy supply to satisfy demand for energy services. Improved energy efficiency since 1990 has led to energy savings of more than 16 exajoules (EJ). in 2005 in 16 IEA countries; this is equivalent to 1.3 Gt of avoided CO_2, representing an estimated $180 billion in energy cost savings.[37]

The EU energy efficiency action plan proposes a 20% improvement in energy efficiency by 2020. If successful, this would mean that the EU could reduce absolute energy consumption by 13% by 2020, saving €100 billion and around 780 million tonnes of CO_2 each year. The European Commission has been asked by the member states to examine areas where economic instruments, including VAT rates, can have a role in increasing the use of energy-efficient goods and energy-saving materials. EU member states have introduced bans on the use of inefficient lighting systems.

Owing to its low energy resource endowment, Japan has always been aware of the importance of security of supply. The 1970s oil shocks led to the introduction of strong domestic efficiency programmes. According to the Ministry of Economy, Trade and

[37] IEA, Worldwide Trends in Energy Use and Efficiency, Key Insights for IEA Indicator Analysis, 2008. In support of the G8 Plan of Action.

Industry (METI), there was a 40% decline in energy intensity in the economy between 1974 and 2005. But recently the rate of improvement has slowed. In response, the former prime minister Taro Aso has pledged to make sure that Japan will become ‘a low carbon society compatible with economic growth ahead of other countries’ and will ‘lead efforts to establish international rules as a country that is on the cutting edge of environmental protection and energy conservation’. In September 2009 the incoming prime minister, Yukio Hatoyama, announced that on conclusion of an international agreement in Copenhagen, Japan would pledge to cut its emissions by 25% from 1990 levels.

In China, the 11th Five-Year Energy Plan stresses the critical importance of energy efficiency. It proposed that between 2006 and 2010 there should be a 20% increase in the energy efficiency of the economy. This requires a decrease from 1.22 to 0.98 tonnes of coal equivalent per unit of GDP. Results so far in the first half of 2009 indicate that energy intensity fell by 3.35% year on year, 0.47 percentage points more than in the same period of 2008, according to the National Development and Reform Commission.

1.2.2. Systemic change

As well as changing the way in which electricity and fuels are produced and consumed, progress on the low carbon economy will increasingly require significant shifts in the way that systems are designed and operated. In some cases this will mean fundamental changes rather than incremental improvement.

In the electricity sector, progress on the deployment of renewable energy is partly dependent on extensions to more remote areas and the ease of connecting to the grid; and as wind power spreads, more efforts are required on grid management.

For example, a strong shift towards electric vehicles would require significant investment in charging infrastructure and the involvement of new actors in the transport sector – including electricity companies (Vattenfall is partnering with the car-maker Volvo in Sweden) and retail outlets offering charging facilities (McDonald’s has already opened one in the US).

The development of smart grids will potentially enable electricity consumers to also become generators and feed back their excess power into the grid. Such developments could revolutionize the way in which power is managed.

These new systems will require new institutions and regulatory frameworks, as they represent fundamental changes to the way markets operate. Establishing these new market rules, and making the transition from the existing ones, will require bold interventions. They are a significant part of the policy challenge.

1.2.3. Emissions trading

Cap and trade systems play a significant role in the international experience of low carbon transition. They create a national cap of emissions in key sectors driving emissions reductions over time and through trading based on a price set for carbon. The largest cap-and-trade scheme is currently the mandatory scheme covering around half the EU that requires companies to surrender an allowance for every tonne of CO_2 they emit. This creates a stimulus for investment in low carbon alternatives and makes high carbon options less attractive. The EU trading scheme also provides the main source of demand for emission reduction credits generated under the Kyoto Protocol clean development mechanism, creating a global market for clean energy projects.

New Carbon Finance has suggested that, depending on the design, the value of the US carbon market could be on the order of $1 trillion per year by 2020, which would be about double that of the EU Emissions Trading Scheme (EUETS).

Other countries considering similar schemes include South Korea, which issued framework legislation in 2008 that will establish a mandatory domestic emissions trading scheme; Australia, with July 2011 the expected start date; New Zealand, set to phase in a scheme between 2008 and 2013;[38] South Africa, which is exploring whether to implement a carbon tax or a trading mechanism as part of a new strategy on climate change;[39] and Japan, which announced plans to assess the practicalities of an emissions trading scheme in June 2008.[40]

1.2.4. Carbon taxation

For decades governments around the world have used energy taxation to generate revenue and to encourage efficiency. More recently policies have aimed specifically to encourage a switch to lower carbon fuels. Proposals for carbon taxation in the EU, the US, New Zealand, South Africa and parts of Canada have emerged at various times over the past 10 years. However, it has proven to be a highly contentious political issue, and most proposals have been withdrawn.

Nevertheless, several European countries have introduced new carbon taxes as part of a broader trend of environmental tax reform. Norway has had a carbon tax of approximately $50 per tonne of CO_2 covering about 60% of national emissions since 1991. Other notable examples exist in Sweden, Finland, the Netherlands, Denmark, Germany and the United Kingdom. A recent study concluded that the introduction of carbon or energy taxes with revenue recycling in most of these countries has had a positive effect on GDP compared with the counterfactual reference case of no environmental tax reform, but there was a neutral effect in the United Kingdom.[41]

1.2.5. Renewable energies

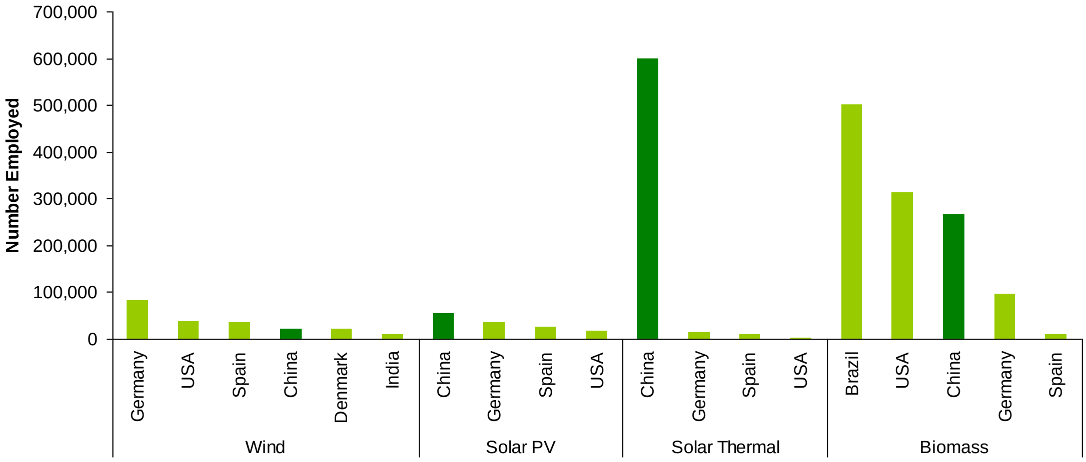
The growth of the global renewable energy industry has been rapid. Direct investment in

[38] New Zealand official ‘Climate Change Solutions’ website, www.climatechange.govt.nz/emissions-trading-scheme/implementing/index.html.
[39] www.environment.gov.za/NewsMedia/MedStat/2008Jul28_2/28072008-2.html.
[40] See http://www.kantei.go.jp/foreign/hukudaspeech/2008/06/09speech_e.html.
[41] T. Barker, S. Junankar, H. Pollitt and P. Summerton, ‘The macroeconomic effects of unilateral environmental tax reforms in Europe, 1995–2012’, in *Innovation, Technology and Employment: Impacts of Environmental Fiscal Reforms and Other Market-Based Instruments*, edited volume of ‘Critical Issues in Environmental Taxation, vol. VI, Oxford University Press (forthcoming).

new renewable capacity rose from $8 billion in 1997 to $30 billion by 2004. Today it stands at about $66 billion.[42] Economic investment in sustainable energy systems (including renewable capacity) is larger still, with $148 billion invested in 2007, a 60% increase over 2006.[43] Although growth has of course slowed, investment in the sustainable energy market has in some ways defied the global recession, growing by approximately 5% to around $155 billion in 2008.[44] This was the first year that investment in new power generation capacity sourced from renewable energy technologies capacity exceeded investment in fossil-fuelled technologies – over 25% higher.

Renewables are also making a significant and growing contribution to employment, particularly in China, as shown by Figure 1.3

Figure 1.3: Comparative international employment in renewables



Source: UNEP and ILO (2008).

Europe continues to have the largest investment in renewable energy of any region in the world: in 2007 new investment was $55 billion and, including mergers and acquisitions, totalled $80 billion. In the same year wind accounted for more new generation capacity in Europe than any other power source. The main reason for this level of investment is the clear, and now binding, requirement for member states to increase the contribution of renewable energy. The introduction of a target calling for 20% of the EU's energy to come from renewable energy sources by 2020 is undoubtedly extremely ambitious, as it will require a more than threefold increase from current levels. However, the experience of some member states, in particular Denmark, Germany and Spain, shows that the right policies, those that create market certainty in the medium and long term, can rapidly drive the diffusion of technology.

Box 1.2: Emerging economies: taking strong steps

India

The Indian government unveiled the National Action Plan on Climate Change in June 2008, to pursue eight national missions for sustainable development: pursuing solar energy, urging energy

[42] Renewable Energy Network 21 Renewable 2007 and 2005 Global Status Reports .
[43] New Energy Finance 2008: Global Trends in Sustainable Energy Investments, 2008.
[44] UNEP, at http://sefi.unep.org/fileadmin/media/sefi/docs/publications/Global_trends_report_2009.pdf.

efficiency, creating a sustainable habitat, conserving water, preserving the Himalayan ecosystem, creating a 'green' India, creating sustainable agriculture and, finally, establishing a strategic knowledge platform for climate change. At its launch, India's prime minister said that over time India must shift from economic activity based on fossil fuels to that based on non-fossil fuels and from reliance on non-renewable and dwindling sources of energy to renewable ones.

India was the first country to have a separate government ministry for non-conventional energy. Initial policies focused on awareness raising, financial subsidies, fiscal incentives and technology development. The Electricity Act of 2003 specifies renewable portfolio obligations for electric distribution companies with feed-in tariffs. The National Steel Policy of 2005 emphasizes 'aggressive R&D efforts to be mounted to enhance material and energy efficiency, utilize waste, and arrest environmental degradation'. The Energy Efficiency Act 2001 also recommends energy efficiency labelling; norms for energy efficient processes; enforcement of standards for the manufacture, sale, purchase and import of equipment, devices and systems; and innovative financing of energy efficiency projects. India also pursues other measures to encourage improvement in energy efficiency for manufacturing, transmission/ transportation and end use; technology upgrade for existing facilities; and adopting best practices. It has also put in place policies to encourage compressed natural gas use in vehicles and public transportation, which can reduce emissions as a result of the lower carbon intensity of the fuel.

South Africa

South Africa's Minister of Environmental Affairs and Tourism Marthinus van Schalkwyk announced on 29 July 2008 that a 'progressive, ambitious and far-reaching' policy on climate change had been agreed upon by the South African cabinet in order to help ensure that South Africa plays its part in preventing global temperatures from rising by more than 2˚C.

Under the scenario planning presented by the South African government, South Africa will see its greenhouse gas emissions increasing gradually from 2003 levels of 446 Mega Tonnes (Mt) CO_2 over the next few years before reaching a plateau of about 550 $MtCO_2$. There will then be a decline, towards a level appropriate for a low carbon economy, if South Africa acts today. This means that South African GHG emissions must stop growing at the latest by 2020–2025. Studies by the Ministry of Environment and Tourism have shown that there will be no net loss of jobs for the economy as it undergoes transition to a low carbon economy. Although some traditional jobs may be lost, new jobs in the new low carbon sectors will be created.

Brazil

Brazil has the world's largest renewable energy market as a result of its hydropower and bioethanol programmes. The government has mandated that 25% of all liquid transport fuel must come from bioethanol. This target is being exceeded, with production in 2008, of 22 billion litres, contributing nearly 40% of the total. The vast majority of this production is for domestic use: only 3.8 billion litres were exported in 2007.

Mexico

Mexico has become one of the first developing countries to set a specific carbon reduction target, pledging to halve greenhouse gas emissions by 2050. The pledge is based on 2002 levels. It is reported that the target would be met with clean and efficient technologies, such as wind and solar power. Mexico also plans a domestic cap-and-trade system by 2012 so as to cut emissions from certain sectors, for example cement and oil refining.

1.2.6. Nuclear power

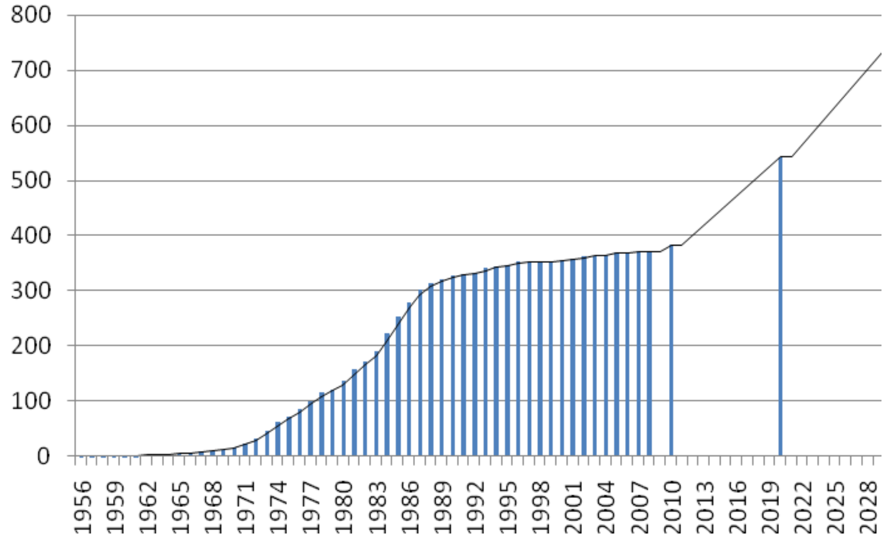
Nuclear power has experienced boom and bust in global orders. Figure 1.4 shows both the start-up of new reactors globally since the beginning of commercial nuclear power in the 1950s and projections by the International Atomic Energy Agency of the installation of nuclear power to 2028. Their projections will require a significant increase in the rate of commissioning of new reactors. Over the past few years the number of reactors coming on line has been approximately matched by those being closed, although net generating capacity has increased owing to the introduction of reactors larger than those being closed and to engineering changes on operating reactors to increase their output. In order to meet the IAEA's forecasts, the rate of new reactor orders will have to increase year by year between now and 2030, faster than the largest-ever annual increase in newly installed capacity achieved by the nuclear industry to date.

In recent years, largely since the introduction of liberalized energy markets, orders of new reactors have slowed markedly (see Figure 1.4). However, a number of institutions have noted that nuclear power will or should make a contribution to the future global energy supply and that the current trend must be revised.

The scaling up of nuclear power to that proposed by the IAEA, or to higher levels noted by the IEA and others, would require the removal of a number of market and technological barriers.

Nuclear power plants have higher capital costs and lower fuel costs than coal-fired power plants. The capital cost and the length of time required for approving a nuclear facility both contribute to the investment risk of nuclear power. Favourable government policies can help to overcome these barriers. The trend today in the US is to certify specific reactor designs that could then be used by any utility, subject to the specifics of the selected site. The US is also introducing an early site permit procedure so as to address public issues earlier in the approval process. Even so, that process for nuclear power plants is likely to be longer than for conventional plants.

Figure 1.4: Historical and projected installed global nuclear capacity (GW), 1956–2028



Source: IAEA 2009.[45]

The uncertainty over fossil fuel prices could increase the economic attractiveness of nuclear power. However, historical and recent experience regarding cost overruns and delay has reduced the perceived economic attractiveness of nuclear power. Construction of the Areva EPR reactors in Finland and France has been beset by major delays. In the former country, the estimated construction price has increased by 50% to over €4.5 billion after just three years of construction. In the United States, even prior to the start of construction, the estimated costs of the Lee nuclear station increased to $11 billion, excluding financing costs for an 825 MW reactor, double the original estimate.[46]

Industry officials cite the need for greater public acceptance in order to increase the number of reactor orders and in particular confidence that a change in government will not necessarily result in a change in political support for nuclear power and/or regulatory changes. This is true for all technologies, but especially for nuclear power owing to the long lead and construction time (approximately 10 years).

Uranium is a finite resource, and its availability will determine future reactor designs. Current forecasts predict that known reserves will be sufficient for some 80 years of operation of nuclear power at today's levels of output. Increased levels of nuclear production and/or new deposits/mining techniques would alter this timeline. Future reactor designs, Generation IV, are being developed to reduce uranium requirements through the widespread use of a 'closed fuel cycle'. The majority of the Generation IV reactors use plutonium fuels, and their widespread use would much increase the volumes of nuclear weapons-usable nuclear material that was separated and used. Considerable technological hurdles still need to be overcome before the economic competitiveness of the technology is proven.

[45] IAEA, 'Energy, Electricity and Nuclear Power Estimates for the Period to 2030'. 2008, PRIS Database (2008/9).
[46] J. Downey, 'Duke doubles cost estimate for nuclear plant', *The Business Journal of the Greater Triad Area*, 4 November 2008.

The global scaling up of nuclear power would also exacerbate other technical and issues yet to be resolved about nuclear power. In particular, there is no commercially operational high-level nuclear waste facility in operation in the world. This lack of operational experience raises concern over the long-term viability and economics of the management options proposed.

The cost of encouraging the use of nuclear power can be significant. In July 2005 the United States, which has not seen a reactor ordered and subsequently completed for a number of decades, adopted the US Energy Act, aimed at stimulating investment in new nuclear power plants. Measures include a tax credit on electricity generation, a loan guarantee of up to 80% for the first 6 GW, additional support in case of significant construction delays for up to six reactors and the extension of limited liability (the Price-Anderson Act) until 2025. These measures are expected to amount to $12–20 billion for the first 6–8 reactors.

1.2.7. Public support for innovation

Total government research and development by the G7 countries has decreased by about 30% in real terms over the past two decades, but public investment in clean energy is now on the rise. It is understood that in competitive markets, firms tend to underspend on R&D relative to the optimal level for society for fear of being unable to capture adequate returns to justify the upfront investment.[47] Governments have sought to correct this market failure by offering some type of reward to encourage innovation. Both 'push' and 'pull' instruments can be used to shape and accelerate the innovation chain.

Market 'pull' efforts include granting innovators (temporary) monopoly rents through, for example, patent protection. This is often complemented by other inducements and subsidies for research in priority areas. Market 'push' incentives can include research grants, tax credits and direct or partnership-based research by government agencies. Making these incentives credible and accessible to new entrants is critical because it is unlikely that transformative innovation will emerge from established industry players.[48]

The transition to a low carbon economy will require sustained innovation over a very long period.[49] Specific measures could include setting a credible long-term carbon price, establishing regulatory standards, targeting government procurement and offering technology prizes etc.

1.2.8. Standards and labelling

Energy efficiency gains can be highly cost-effective, although unlocking the market potential has proved challenging for businesses and policymakers alike owing to non-

[47] C. I. Jones and J.C. Williams, 'Measuring the Social Return to R&D', *Quarterly Journal on Economics*, vol. 113, no. 4 (1998). pp. 1119–1135. See http://www-econ.stanford.edu/faculty/workp/swp97002.pdf.
[48] N. Ashford, 'Innovation – The Pathway to Threefold *Sustainability*', in *The Steilmann Report: The Wealth of People: An Intelligent Economy for the 21st Century,* F. Lehner et.al. (eds), *Brainduct* (2001), pp. 233–74. See http://dspace.mit.edu/bitstream/1721.1/1584/1/3-fold_sustainability.pdf.
[49] Tom Delay, 2007: 'The Low Carbon Economy'. The Carbon Trust, at www.carbontrust.co.uk/climatechange/policy/lce.htm

financial barriers. Product standards and labels have been widely used to address market information failures, principal agent problems and other barriers. These measures have a track record of success in driving efficiency and emission reductions, whether applied by setting minimum standards for products, sector-specific benchmarks or encouraging best- available technology (such as the Top Runner programme in Japan).

The most notable standard setting organization is the International Organization for Standardization (ISO). Businesses across the world widely use the ISO 14000 standard for environmental management systems in an effort to reduce their environmental footprint and to decrease pollution and waste. The European Union has also developed the Eco-Management and Audit Scheme (EMAS).

The Greenhouse Gas Protocol (GHG Protocol), developed by the World Business Council on Sustainable Development (WBCSD) and the World Resources Institute (WRI), is the international accounting tool most widely used by government and business leaders to understand, quantify and manage greenhouse gas emissions. It provides the accounting framework for nearly every GHG standard and programme in the world – from the ISO to the Climate Registry – as well as hundreds of GHG inventories prepared by individual companies, NGOs and governments. Following its past success, the WRI/WBCSD GHG Protocol is developing two new standards for product and supply chain GHG accounting and reporting.

The new GHG Protocol standards will provide a standardized method for inventorying the emissions associated with individual products across their full life cycles and with corporate value chains, taking into account impacts both upstream and downstream of a company’s operations. By taking a comprehensive approach to GHG measurement and management, businesses and policymakers can focus attention on the greatest opportunities to reduce emissions within the full value chain, leading to more sustainable decisions about the products we buy, sell and produce.

Energy efficiency standards and labelling for appliances are already commonplace, as are emissions standards in the automobile industry. It is likely that with increasing consumer pressure, further standard development and consolidation of standards will take place.

Driven by mounting consumer pressure, a number of private and public initiatives are also underway in the EU and the US to assess the embedded carbon content of specific products with a view to developing carbon labelling schemes for consumers. The UK government and the Carbon Trust are developing a methodology for evaluating the carbon impact of products, with labels that display the grams of carbon per kilogram produced during the entire lifecycle of the product. The methodology takes into account product shelf life, country of origin, infrastructure in the country of origin and how far the food product must travel.

In addition, a number of voluntary standards, such as the Global Compact, the Global

Reporting Initiative, the AA Assurance Standard etc., cover aspects related to codes of conduct, accounting and reporting.

1.3 Leadership from businesses

Since the 1990s certain parts of the business community have recognized their crucial stake in being part of the solution to sustainable development. By way of organizations such as the WBCSD, businesses have increasingly become active participants in the transition to a sustainable world.

Given that the private sector is the major source of capital, innovation and technology as well as of the investments that can transform the global energy system, business has a crucial stake in taking the lead on these issues and sharing its in-depth knowledge of various sectors with stakeholders. Business involvement in discussion on a low carbon economy is made all the more relevant in view of the fact that business makes investment decisions that will impact the climate issue for 20, 30, 50 years or more into the future. Indeed, businesses will be the main 'solution-implementer' for the challenges of achieving the transition towards a low carbon, resource-efficient economy.

Businesses need clear guidance from governments on the future direction regulations might take. It is for that reason that many companies are joining forces to campaign for stronger or more coherent climate change policies.

Under the auspices of the WBCSD and the World Economic Forum, over 100 CEOs of major companies worldwide developed climate policy recommendations for the G8 summit in 2008. These urged 'strong leadership from all governments' towards the rapid adoption of a fundamental strategy to bring about a low carbon world economy and called 'for all leaders of government and business to take action now'.

At the Climate Change Summit at the UN headquarters in September 2009, 500 heads of top global companies urged world governments to rise to 'a new level of leadership' and articulated a strong business case for an efficacious climate change framework.

Furthermore, companies are, in the absence of regulation, voluntarily reporting on their GHG emissions as well as making concerted efforts to reduce them. The Carbon Disclosure Project (CDP) collects and distributes information on GHG emissions that is designed to motivate investors, corporations and governments. The CDP requests information on emissions from more than 3,700 corporations around the world. In doing so it creates a framework to develop new company and government strategies on climate change. As a result the CDP has assembled the largest corporate GHG emissions database in the world, and its analytical report provides insights into how the largest companies are responding to climate change. According to the most recent CDP report, 51% of the Global 500 companies report emission reduction targets.

Much of the above-mentioned information also feeds into the ranking of companies listed on various stock exchanges. Summarized under the sustainability indexes (Dow

Jones, FTSE), the most advanced companies in various sectors are grouped together so that investors can easily invest in them. Certain sovereign wealth funds use these indexes as stock-pools for long-term investment.

In addition, various sectors have set up industry initiatives/organizations in order to help their member companies to anticipate trends in sustainability and carbon issues. Examples of these exist in almost all business sectors (cement, steel, automobile, airline, mining, telecoms, banking etc.) These initiatives provide detailed and industry-specific recommendations on standard and policy development to governments and also take concerted voluntary action on data gathering and emissions reduction.

Much attention is focused on the carbon emissions by different energy- intensive sectors, such as cement and iron and steel, which each account for about 5% of global emissions. The steel industry has launched a task force to develop global sector-specific approaches to CO_2 reduction in the post-Kyoto period.

In 2008, the steel industry's largest trade association aimed to publish GHG emissions data from three quarters of its members by year-end, with suggestions that these data can be used by steel companies in each country to set sectoral targets. The WBCSD's Cement Sustainability Initiative, representing the collective effort of 18 leading cement companies from around the world, has developed the Getting the Numbers Right (GNR) system. The GNR is a sector-wide global information database that provides accurate, verified data on the cement industry's CO_2 emissions and energy performance. To date, the GNR is the system with the widest data coverage in the cement industry, providing aggregated data on more than 800 individual cement facilities worldwide from more than 100 countries. Cement production by companies participating in the GNR initiative increased by 53% from 1990 to 2006, whereas absolute net CO_2 emissions increased more slowly, by only 35%, showing evidence of a decoupling of production and related emissions.

The Asia-Pacific Partnership on Clean Development and Climate set up specific working groups in December 2006 to address energy-intensive sectors such as steel, cement and aluminium. The working groups are developing unified benchmarking systems and exchanging data, with the objective of setting standards, sharing research and development and engaging in joint support for innovative technologies.

Members of the global airline body, the International Air Transport Association, have drawn up four pledges: to reduce net carbon dioxide emissions by 50% by 2050, compared with 2005 levels; to make all industry growth carbon-neutral by 2020; to cut carbon dioxide emissions by 1.5% per annum over the next decade; and to submit plans for joining a global carbon trading scheme to the UN by November 2010.

Box 1.3: The aviation industry and biofuels

The aviation industry is responsible for about 3.5% of greenhouse gases emitted globally. This, according to the IPCC, could increase to up to 15% of global GHGs by 2050 owing to the increase in demand for air travel. Boeing estimates that biofuels could reduce flight-related greenhouse gas emissions by 60–80%. The solution would be to blend biofuels with existing jet fuel. Algae-derived biofuels, in particular, are being investigated by the aviation industry as a potential substitute.

Virgin Atlantic has successfully tested a biofuel blend made from 20% babassu nuts and coconut and 80% conventional jet fuel fed to a single engine on a 747 flight from London to Amsterdam. Boeing and Air New Zealand are collaborating with the leading Brazilian biofuels maker Tecbio and with Aquaflow Bionomic of New Zealand and other jet biofuel developers around the world. Continental Airlines will fly a Boeing 737 on third-generation biofuel in 2009.[50]

1.4 Capitalizing on innovation

With higher energy prices and the global economic crisis, the consequences of bad policy choices are receiving greater attention. We are increasingly aware that even though certain policy measures can simultaneously address energy and climate concerns, others might help one but undermine the other. Fractured policies on energy, water and food are not just stories in the business pages. They lie at the heart of major foreign policy discussions and conflicts. They have caused distrust, have changed geopolitical landscapes in politically fragile regions and have the potential to undermine multilateral action in promoting global public goods such as global energy and climate security.

The global financial and economic crisis has caused unprecedented declines in both new investments in the energy sector and the level of energy demand. The IEA predicts a decline in annual electricity consumption for 2009 (unprecedented since 1945). Within the OECD there is a large range of consumption, with France continuing to expand but others showing rapid decline (a drop 10.2% in Japan). In China it is reported that in the last quarter of 2008 electricity demand fell by 7.1% and in the first quarter of 2009 by 4%. Investment in the electricity sector is correspondingly lower, with several projects in coal, nuclear, gas and renewables being cancelled or postponed and overall investment levels being reduced.

In the oil sector globally there was a decline in demand in 2008 of half a million barrels per day compared to 2007. Global oil and gas investment budgets for 2009 are already 21% lower than in a comparable period in 2008 (a reduction of $100 billion), with investments in non-conventional oil and gas particularly affected.

The reduction in energy sector investment is broadly seen as commensurate with the reduction in demand owing to the recession. The key question in terms of a transition to a low carbon economy is whether the financial and economic crisis will cause a shift in investment patterns in the future once the global economy starts to recover. The fiscal stimulus packages that governments across the world are implementing provide an unprecedented opportunity to influence the direction of investments during this period of economic recovery. The United Nations Environment Programme (UNEP) has estimated that over the next 1–2 years the value of these packages will total between $2–3 trillion.[51]

The UN Secretary General Ban Ki-Moon has said, ‘We urgently need a Green New Deal,

[50] Stern Team, Office of Climate Change.
[51] UNEP, A Global Green New Deal, United Nations Environment Programme, February 2009.

this is a deal that works for all nations, rich as well as poor. Our response to the economic crisis must advance climate goals, and our response to the climate crisis will advance economic and social goals.'

A number of studies have tried to assess the extent to which these recovery plans are directed towards green initiatives, among them global assessments by UNEP and by HSBC[52] and European assessments by the European Renewable Energy Federation[53] and by Ecofys.[54] These reports reach somewhat different conclusions over the levels of expenditure and therefore the percentage of the total package that can be deemed to be green. The table below, produced by HSBC, gives a useful guide to the ranges of the packages involved and the degree to which they can be classified as green.

Table 1.3: The climate change investment dimension of stimulus plans

Country	Fund	Period	Green Fund	% Green Fund	Low-Carbon Power		Energy Efficiency (EE)				Water/Waste
	USDbn	Years	USDbn		Renewable	CCS/Other	Building EE	Lo C Vech+	Rail	Grid	
Asia Pacific											
Australia	26.7	2009-12	2.5	9.3%	-	-	2.48	-	-	-	-
China	586.1	2009-10	221.3	37.8%	-	-	-	1.50	98.65	70.00	51.15
India	13.7	2009	0.0	0.0%	-	-	-	-	-	-	-
Japan	485.9	2009 onwards	12.4	2.6%	-	-	12.43	-	-	-	-
South Korea	38.1	2009-12	30.7	80.5%	1.80	-	6.19	1.80	7.01	-	13.89
Thailand	3.3	2009	0.0	0.0%	-	-	-	-	-	-	-
Sub-total Asia Pacific	**1,153.8**	**0.0**	**266.9**	**23.1%**	**1.8**	**0.0**	**21.1**	**3.3**	**105.7**	**70.0**	**65.0**
Europe											
European Union	38.8*	2009-10	22.8	58.7%	0.65	12.49	2.85	1.94	-	4.85	-
Germany	104.8	2009-10	13.8	13.2%	-	-	10.39	0.69	2.75	-	-
France	33.7	2009-10	7.1	21.2%	0.87	-	0.83	-	1.31	4.13	-
Italy	103.5	2009 onwards	1.3	1.3%	-	-	-	-	1.32	-	-
Spain	14.2	2009	0.8	5.8%	-	-	-	-	-	-	0.83
United Kingdom	30.4	2009-12	2.1	6.9%	-	-	0.29	1.38	0.41	-	0.03
Other EU states	308.7	2009	6.2	2.0%	1.9	-	0.4	3.9	-	-	-
Sub-total Europe	**325.5**	**0**	**54.2**	**16.7%**	**3.5**	**12.5**	**14.7**	**7.9**	**5.8**	**9.0**	**0.9**
Americas											
Canada	31.8	2009-13	2.6	8.3%	-	1.08	0.24	-	0.39	0.79	0.13
Chile	4.0	2009	0.0	0.0%	-	-	-	-	-	-	-
US EESA	185.0**	10 Years	18.2	9.8%	10.25	2.60	3.34	0.76	0.33	0.92	-
US ARRA	787.0	10 Years	94.1	12.0%	22.53	3.95	27.40	4.00	9.59	11.00	15.58
Sub-total Americas	**1,007.8**		**114.9**	**11.4%**	**32.8**	**7.6**	**31.0**	**4.8**	**10.3**	**12.7**	**15.7**
Total	**2,796**		**436**	**15.6%**	**38.0**	**20.1**	**66.8**	**15.9**	**121.8**	**91.7**	**81.6**

(*Only EUR30bn from direct EU contribution considered for calculation as the rest (EUR170bn) is contributed by member states; **USD700bn under TARP not considered for calculation as the fund is mainly for bank bailouts not for fiscal stimulus) + Low Carbon Vehicles

Source: HSBC estimates

Source: HSBC 2009

The fraction of the stimulus plans dedicated to green measures varies enormously. China shows by far the highest total amount dedicated to green measures (over $200 billion), and ranks among the highest in terms of the percentage of total stimulus funds (38%) that are green. The Chinese green fund amounts to approximately half the world's total and gives a significant opportunity to change its energy infrastructure, for example by making available more public.

A number of studies have identified essential areas where this expenditure should be focused. For example, an analysis by the Deutsche Bank Group produced recommendations for investment in four key areas,[55] and similar conclusions were reached by the World Energy Council.[56]

1) Energy-efficient buildings. In tough economic times, these projects, which have a long-term positive payback and are low-tech but labour-intensive, make even

[52] HSBC, A Climate for Recovery; The Colour of Stimulus Goes Green, February 2009.
[53] The European Renewable Energy Federation, Financial crisis, Rescue Packages in EU 27 and Renewable Energy, February 2009.
[54] Ecofys, Economic/climate recovery score cards: How climate friendly are the economic recovery packages?, April 2009.
[55] Deutsche Bank Group, Economic Stimulus: The Case for 'Green' Infrastructure, Energy Security and 'Green' Jobs, Deutsche Bank Group, November 2008.
[56] WEC, Green Investing Towards a Clean Energy Infrastructure, World Energy Council, January 2009.

more sense;

2) The smart electric power grid. Without a modern and optimized power grid, it is not possible for renewable power to scale up. As 7–9% of electric power is also lost in transmission, there would be significant potential savings from efficiency;

3) Renewable power. Funding for technologically proven renewables allows scale-up and a long-term shift away from fossil fuels; and

4) Public transportation. It reduces emissions and adds to the efficiency of the economy.

Box 1.4: Smart grids

Smart grids involve a greater level of information technology being embedded into electricity transmission and distribution systems so as to enable more efficient and flexible operation. The concept is rather broad. At its simplest, a smart grid could be one where better information is gathered from local distribution stations and nodes in the transmission system in order to allow more efficient coordination of the dispatch of generators and to allow the pricing of electricity to be better matched with the cost of delivering that electricity while taking into account transmission constraints. This can be particularly important when there is greater use of distributed generation in the system and when a significant fraction of the generation capacity is intermittent in nature (e.g. wind and solar).

At a more ambitious level, the concept of smart grids includes automated real-time interaction between electricity generators and consumers. Smart meters allow individual centres of demand (e.g. appliances in the home or particular industrial applications) to be switched on or off quickly in response to supply conditions, switching on when there is ample supply (and low-price electricity) and switching off when supply levels are low (and price high). This would allow a greater level of demand response to supply fluctuations, reducing the problems associated with intermittent generation.

The Stern Review has stated that some $400 billion in additional funding should be spent on energy infrastructure over the next 1–2 years. This equates to about 15–20% of the overall stimulus expenditure anticipated by UNEP over the same period. The IEA estimates that the current stimulus packages have allocated approximately $132 billion for what it defines as clean energy, namely renewables, carbon capture and storage, nuclear power, improved grids and energy efficiency, and a further $108 billion for rail infrastructure. (Many of these projects are over longer periods, up to 10 years in the US case.) The clean energy projects comprise of about 5% of the total stimulus, and 9% if rail infrastructure is included. The IEA estimates that in order to meet a 450 ppm CO_2e atmospheric concentration target, the level of investment for clean energy would need to be six times higher than is currently budgeted for in global stimulus packages, although this does not need to be public-sector financed.

As pressure for transition mounts, investment in low carbon goods and services will continue to accelerate. Economies that are run with high levels of efficiency and are less exposed to the volatility of fossil fuel markets are at a competitive advantage. Consequently the companies and governments that are moving fastest on low carbon transition will reap the rewards. This is a two-fold strategy, one that relies on implementing best-available technologies and practices while also developing the next generation of technologies. The scale of China's domestic market and its dominant position as a supplier of consumer and industrial goods to international markets put it in a unique position to bring new, clean energy technologies to maturity. China is in a position both to drive, and benefit from, shifts in global investment patterns towards low carbon products and production methods. There is mutual global benefit in ensuring that stimulus packages fully support such a shift.

A focus on developing and deploying advanced climate technologies is also consistent with China's aspiration to move up the global value chain of economic production. A spokesperson from the Chinese National Development and Reform Commission, which oversees economic development policy, says China will 'strive to realize a shift by foreign investors away from simple processing, assembly and low-level manufacturing and into research and development, high-end design, modern logistics and other new areas. This will help our country become one of the world's manufacturing bases for high value added products.' [57] This vision for the quality, rather than quantity, of foreign investment is also supported by China's National Medium- and Long-term Science and Technology Development Plan, outlining the strategic direction from 2006 to 2020.

China's choice today will determine our global future. Requirements of the transition to a low carbon future are consistent with China's strategic aspirations for an innovation-based economy. For the rest of the world, ensuring that China gains a sizeable piece of the low carbon pie is central to the global challenge.

[57] Andrew Batson, 'Beijing Redraws Road Map on Foreign Investment', *Wall Street Journal,* 10 November 2006.

2. The necessity and urgency of developing a low carbon economy in China

Developing a low carbon economy presents China with an opportunity to leapfrog the process of resource-intensive, heavily polluting growth experienced by Western countries. Developing a low carbon economy would conform to stated government goals on development and conservation, promote national energy security and spur the creation of a resource-efficient and environment-friendly society while addressing the risk of climate change. It is appropriate for China's basic national situation and fully in line with its national interests.[58]

In short, China's move towards a low carbon economy is inevitable, necessary and urgent:

- **Inevitable**, because a low carbon pathway will enable China to satisfy its need for economic growth. International economic structures and trade rules are changing in response to energy and resource constraints, as well as in response to financial instability caused by unsustainable trade flow imbalances. China is already responding. These changes will re-enforce China's domestic aims of becoming less dependent on exports of heavy energy-intensive goods and becoming a market leader in higher value-added technology- and information-based goods and services.

- **Necessary**, because current trends are clearly unsustainable. Current growth rates in energy consumption will lead China to be increasingly dependent both on imports of coal and on imports of oil and gas with higher world prices. Climate change already threatens to reduce crop yields through water-stress and extreme weather; and if it goes unmitigated, climate change will severely impede China's development.

- **Urgent**, because there are considerable benefits to China from taking early action. China needs to avoid lock-in to energy-intensive urban and industrial infrastructure. Investments made now and over the next decade will determine its exposure to energy security and climate change risks for decades to come. By acting now on R&D and commercialization activities, China can take a leading role as a supplier of equipment and know-how to rapidly growing international markets for low carbon technologies, goods and services.

[58] 'We believe that there are five factors in the process of realizing basic national interests and goals: national security and territorial integration; economic development and stability; social justice and human security; political sobriety and social stability; and ecological balance and environmental protection.' From Hu Angang, Wang Shaoguang and Zhou Jianming (eds), *Second Transformation: National System Construction* (Beijing: Tsinghua University Press, 2003).

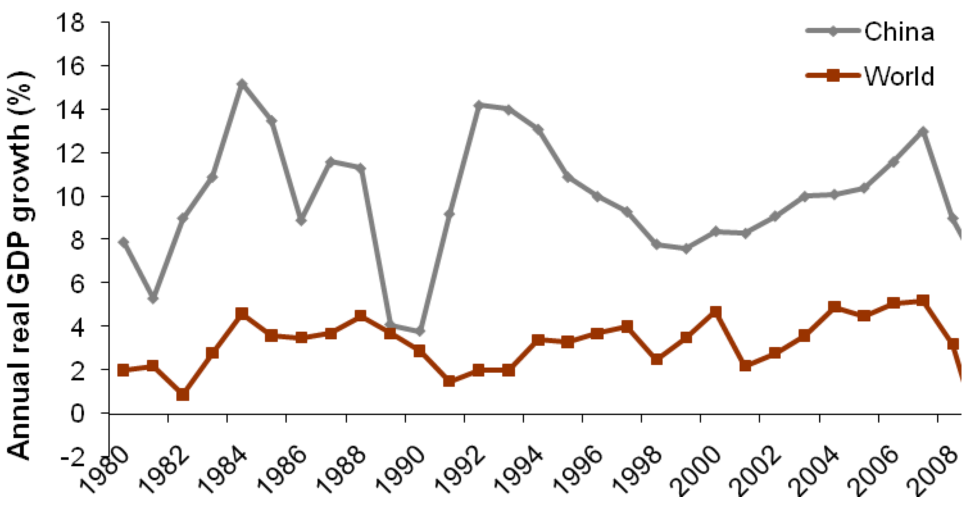
2.1 A low carbon economy: inevitable for China's future development

China has experienced a remarkable economic expansion over recent decades. That has been triggered by domestic policies targeted at rapid industrialization and urbanization coupled with an opening of China's economy to international trade. Because of its sheer scale, China's development has made an important contribution to the accelerating pace of globalization over this period. Its increase in manufacturing capacity has affected business models of companies all over the world. These economic trends have so far encouraged an energy-intensive pattern of industrialization in China, but shifts in international economic priorities and a rapid expansion of global markets for low carbon technologies, goods and services will create different drivers for China's future development.

2.1.1. An unparalleled scale of development over the past 30 years

Since the launch of market reforms to open up its economy and introduce competition 30 years ago, China has experienced an unprecedented economic boom: in the 29 years from 1978 to 2007, its total GDP increased by 14 times, with annual growth averaging 9.8% (see Figure 2.1). The total industrial output of China grew by 23 times, or 11.6% per annum.[59] No major established economy has ever grown as fast.

Figure 2.1: The economic growth rates of China and the world, 1980–2008



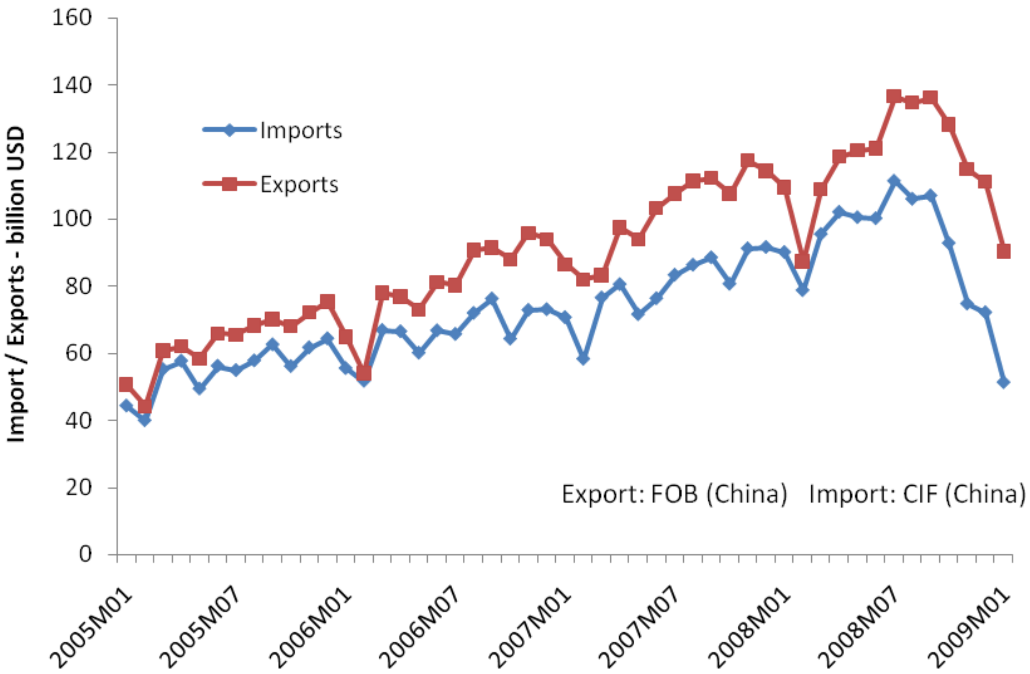
Source: *IMF World Economic Outlook* (April 2009).

China accomplished this by making full use of its comparative advantages, refining its policies for economic openness, attracting foreign investment and introducing advanced technologies, management experience and machinery and equipment from abroad. It carried out domestic reforms, implementing step-by-step marketization, protecting private property rights, partly breaking industrial monopolies and generally encouraging economic activity.

[59] *China Statistical Summary 2008*, Beijing China Statistics Press (2008), p. 23.

By keeping the original dual structure of city and countryside and using land reform and a family-based responsibility system to protect the basic livelihoods of peasants, China was able to provide a virtually unlimited labour force for urbanization and industrialization. The centralized financial system, with revenue- and, later, tax-sharing, allowed local governments to exploit local conditions and attract investment and develop the economy while following the broad direction set by the central government.

Figure 2.2: China's imports and exports, 2005–2009



Source: IMF World Economic Outlook (April 2009).

2.1.2. Fundamental challenges to China's growth model

Trade imbalances between emerging economies in East Asia and Western economies have been an important contributing factor to the recent financial crisis and subsequent economic downturn. They reflect the unsustainable development of both China's economy and the broader patterns of global trade. China's path out of the current financial crisis and towards a more stable model of economic development is likely to go hand in hand with its approach to solving the current energy and climate crisis.

However, there were underlying challenges to China's growth pattern even before the crisis broke; the crisis simply exposed them.

First, China's export-orientated trade pattern left it with a foreign trade dependency higher than that of developed countries such as the US and Japan. A long-term trade surplus sharpens trade conflicts. Even more seriously, relying on foreign demand for economic growth is unsustainable. Enlarging domestic demand has become inevitable.

Second, its economic marketization has already reached a rather high level. According to the Institute of Economic and Resources Management of Beijing Normal University, China's yearly degree of marketization from 2001 to 2006 was 69%, 72.8%, 73.8%, 73.3%, 78.3% and 77.7% respectively.[60]

Third, the cheap labour supply is ageing: Cai Fang has pointed out that China's working-age population will stop increasing in about 2015, after three decades during which working-age people made up a growing share of the total population.[61]

Finally, competition among local governments has had some major, unintended negative effects: a blind focus on GDP, coupled with local politicians' desire to appear as though they are delivering major achievements, has resulted in low-efficiency investment with a lack of discipline and restrictions. In order to control resources and add financial revenue, the practice of land finance – officials acquiring land from farmers at low cost so as to control profits from urbanization – has become a common phenomenon. Rent-seeking corruption occurs frequently.

These internal challenges are exacerbated by international imbalances. Over the past decade or more, the US has transferred dollar-denominated debt to its major trading partners while other countries in the world have sold products to the US in the form of credit. Trading partners of the US, particularly those in East Asia which have saved rather than consumed incomes from this trade, have then reinvested their trade surplus in dollar-denominated assets, making dollars flow back to the US. This mechanism is helpful as long as there are productive capital expenditure opportunities for those reinvestments. But sustained over a long period, dollar reserve assets in East Asia have led to loose sources of credit in the US and other consuming nations and to the rise of price bubbles of assets such as stocks and real estate. These bubbles subsequently burst, causing significant damage to banking systems and government finances. This crisis represents an economic adjustment to recent patterns of economic growth, and therefore new patterns of economic growth need to be established urgently.

This crisis has affected many peripheral countries, which benefit from globalization but also bear the brunt of currency crises and financial crises. As these imbalances have negative consequences for all countries, there will be considerable pressure for the international system to change. The current economic structure and pattern of energy utilization and production in China will therefore shift for reasons unconnected with climate or energy security, meaning that there can be no 'business-as-usual'.

2.1.3. Keeping China at the forefront of international trade

Underlying the current unsustainable patterns of trade are two main factors: an East Asia-style export-led focus on fossil fuel-intensive production and US-style consumption, supported by the global currency system focused on the US dollar and low import prices.

Globalization has therefore led not only to an international redistribution of industrial production but also to a redistribution of energy and resource consumption and thus higher emissions. This process has seen China's demand for emissions-intensive commodities skyrocket even faster than its GDP. In 2006, China's GDP accounted for 5.5% of the world total; its energy, steel and cement consumption accounted for 15%, 30% and 54% of their global consumption respectively.

[60] Institute of Economic and Resources Management of Beijing Normal University, A Report on the Development of China's Market-Economy (2003, 2005, 2008).
[61] Cai Fang, 'China's Employment Increases and Structure Changes', *Management and Review of Social Sciences*, Issue 2, 2007.

But not all of this went to producing goods and services for domestic consumption. According to the *World Energy Outlook 2007: China and India Insights* the amount of energy 're-exported' by China in 2004 was 400 million tonnes of oil equivalent (Mtoe), amounting to 25% of the country's energy consumption. The amount of energy embodied in the commodities China imported in that year was 171 Mtoe, amounting to 10% of energy demand. The percentage of energy embodied in the commodities China exports is much higher than that for other countries (for the US, the EU and Japan, the figures are 6%, 7% and 10% respectively). This high proportion exacerbates the rise of China's carbon dioxide emissions.

A study by the Tyndall Centre for Climate Change shows that about 1.11 Gt of carbon dioxide emissions were caused by China's net exports in 2004, accounting for 23% of the country's total emissions in that year[62]. That figure alone equalled Japan's total emissions for the same year; it was more than twice the UK's emissions and was equivalent to the combined emissions of Germany and Australia.

In 2008, Li Liping, Ren Yong and Tian Chunxiu suggested that the Tyndall Centre study focused on direct emissions, to the exclusion of inputs that may produce significant emissions during production. They argued that the carbon emission intensity of the biggest exports was in fact slightly lower than average carbon emission intensity, so the share of exports in total emissions should be lower.[63] Nevertheless, these studies show that in a globalized trading environment, import and export patterns can make a big difference to a country's emissions profile.

In short, a significant part of energy consumption and its resulting carbon emissions for manufacturing in Europe, the US and Japan has effectively been transferred to China. This accounts in part for the rising share of China and India, and other big developing countries, in global emissions (see Table 2.1).

These two factors have combined to produce a global trend of overproduction and overconsumption of energy and high emissions of greenhouse gases; and these structural problems will remain even if the financial system can be restored to its status before the crisis. As long as this pattern of production-development is driven solely by fossil fuels, the risk of commodity price shocks will persist.

[62] Wang, T., and J. Watson. *Who Owns China's Carbon Emissions?* In *Tyndall Centre Briefing Note 23*., 2007
[63] Li Liping, Ren Yong and Tian Chunxiu, 'Analysis on China's Carbon Emission Responsibility from the Perspective of International Trade', *Environmental Protection*, Issue 3 B.

Table 2.1: Percentage of global carbon dioxide emissions from six major economies in the world's total, 1960–2030

	1960	1970	1980	1990	2005	2015	2030
China	8.98	5.65	8.08	11.29	19.16	25.34	27.32
EU	15.87	15.09	13.59	10.96	14.82	11.77	9.97
US	33.68	31.18	25.32	22.67	21.75	19.76	16.44
Japan	2.47	4.96	4.71	4.76	4.55	3.79	2.82
Russia				9.26[a]	5.74	5.28	4.71
India	1.28	1.30	1.79	3.01	4.14	5.28	7.88
Total					70.16	71.23	69.14

[a] Data for 1992.
Source: Data (1960-1990) source: World Bank, World Development Indicator 2006, CD-ROM; includes 11 EU countries.
Data (2005-2030) source: IEA, World Energy Outlook 2007, CD-ROM; referential background (developing according to current status, no policies published to restrain emissions); includes 25 EU member states.

As concern over climate change and energy resources mounts, the link between energy, climate and international trade will come under increasing scrutiny. Many developed countries have established emissions trading of greenhouse gases while others impose taxes for carbon emissions. In order to protect the international competitiveness of domestic manufacturers of energy-intensive products (such as steel, aluminium and basic chemicals), policymakers have started to consider border tax adjustments. For example, there are provisions for such measures to be taken in the Waxman-Markey bill of the US Congress.

Green procurement policy is also emerging in Europe, a kind of public procurement with the purpose of encouraging the trade of low carbon products. Many traded products are recognized as high carbon products owing to their production process, for example cement; others, such as light bulbs and air conditioners, are high carbon products because of their use. Some product standards, such as construction standards, promote the trade of low carbon products and effectively prevent the trade of carbon-intensive ones. Besides formal standards, there are also some informal ones with similar effects, such as the rating of Energy Star for home appliances.[64] As the climate issue attracts greater attention, consumers are beginning to note the GHG emissions caused by products, a trend that is being encouraged through greater use of labelling and the enforcement of product standards in many developed countries, as described in Chapter 1.

These trends create additional incentives for China to move towards more efficient manufacturing processes and towards a lower carbon industrial structure in order to stay at the forefront of international trade. The problem China faces is not so much *whether* to industrialize as *what kind* of industrialization. Instead of following the road that Western countries took to industrialization, with heavy energy consumption and pollution, China could, and should, chart a different, 'non-traditional' path based on low living consumption, low energy consumption and low pollution.

[64] Chatham House (The Royal Institute of International Affairs), Changing *Climates Change Interdependencies on Energy and Climates Security for China and Europe*, November 2007, p. 57.

2.1.4. *China: already shifting towards a low carbon economy*

China has demonstrated its seriousness in tackling climate change by action on energy conservation and energy intensity. Existing programmes provide a strong foundation for it to move along a low carbon economic pathway.

In July 2008, when attending the G8 Summit Leaders Conference, President Hu Jintao summarized the great achievements China has made in addressing climate change:

> We have made it a strategic task to build a conservation culture and we adhere to the basic state policy of conserving resources and protecting the environment. We are making efforts to ensure that our industrial structure, growth model and consumption pattern are energy and resource efficient and environment-friendly. We have, in line with our economic and social development plans and sustainable development strategy, formulated China's National Climate Change Program, set up the National Leading Group to Address Climate Change, promulgated a series of laws and regulations and adopted a host of measures to tackle climate change. We started our efforts by saving energy and cutting emissions. We have taken a series of measures, including conserving energy, optimizing energy structure, raising energy efficiency and promoting afforestation, and have achieved noticeable results.'[65]

China's policies on energy saving and emissions reductions include actions at various different levels, as outlined in the following sections.

2.2 Strategic objectives

China's Scientific Outlook on Development concept provides essential guidance for economic and social development. It emphasizes people-orientated development, which must be comprehensive, balanced and sustainable. This overall strategic approach sets the framework for more specific policies and actions.

For example, in the Report to the Seventeenth National Congress of the Communist Party of China, the promotion of a conservation culture was proposed as a new requirement for realizing the goal of building a moderately prosperous society. The report stressed:

> We will basically form an energy and resource efficient and environmental-friendly industrial structure, growth model and consumption pattern. We will have a large-scale circular economy and considerably increase the proportion of renewable energy sources in total energy consumption. The discharge of major pollutants will be brought under effective control and the ecological and environmental quality will improve notably. Awareness of conservation will be firmly established in the whole of society.

The report also emphasized that energy conservation and environmental protection are fundamental to national policy, indicating that the Communist Party and the government of China highly value these two aspects.

[65] Present Hu Jintao's address on G8 Summit Leaders Conference, Xinhua News Agency, 9 July 2007.

2.2.1. Existing policies and programmes

The 11th Five-Year Plan sets specific goals for a decrease in energy and resource intensity. It identifies 'substantially improving the efficiency of resource utilization' as one of the main goals of economic growth and social development during the period of the Plan and sets the following targets:

- energy consumption per unit of GDP to be cut by approximately 20%;
- water consumed per unit of industry value-sadded to be reduced by 30%;
- the effective utilization coefficient of field irrigation water to be lifted to 0.5; and
- the rate of industrial solid wastes utilized to be lifted to 60%.

China's National Climate Change Programme (CNCCP) outlines objectives, basic principles, key areas of actions and also policies and measures for addressing climate change for the period up to 2010. Guided by the Scientific Outlook on Development, China will carry out all the tasks in the CNCCP, strive to build a resource-conservative and environmentally friendly society, enhance national capacity to mitigate and adapt to climate change and make a further contribution to the protection of the global climate system.

The Comprehensive Working Scheme on Energy Saving and Emission Reduction outlines objectives and adopts methods for China to realize energy saving and emission reduction.

According to the State Renewable Energy Medium- and Long-term Development Programme, renewable energy is expected to account for 15% of China's total energy supply by 2020, up from 7% at present, with capital support of approximately 1.5 trillion RMB ($200 billion) from the government. Nearly 40 million households will use biogas around the country by 2010 under the State Rural Biogas Development Programme (2006–2010), and annual biogas production will reach 15.4 billion cubic metres, which is equivalent to energy consumption of 24.2 million tonnes of standard coal and 140 million acres of annual forest stock. Progress is on track: 31 million homes were using biogas sources for cooking and heating by the end of 2008, an increase of 5 million on the previous year.

On 29 October 2008, the State Council Information Office issued a white paper entitled China's Policies and Actions for Addressing Climate Change, outlining the impacts of climate change on China, and published China's policies and actions for mitigating and adapting to climate change.

2.2.2. Institutional-level actions

China set up the National Energy Leading Group, coordinating the work of ministries and commissions and other government organizations. The Office of the National Energy Leading Group is responsible for undertaking the day-to-day work of the Leading Group, and one of its main responsibilities is to formulate energy strategy and to draw up energy legislation.

China has also established the National Leading Group to Address Climate Change and Energy Conservation & Pollutant Discharge Reduction, responsible for integrating and coordinating action on climate change, energy conservation and emissions reduction.

2.2.3. Carbon offsets

China has already made full use of international markets for emissions offsets through the clean development mechanism. It is the world's largest supplier of such credits, as discussed in section 2.4.

In addition, the rapid growth of forest resources demonstrates China's carbon sequestration potential. According to the State Forest Administration of China, China had the fastest growth rate of forest resources in the world from 1999 to 2005, and it sequestered the largest amount of CO_2, creating enormous ecological value in the process. From 1980 to 2005, through afforestation and forest management, China added a net sink of carbon dioxide of 4.68 billion tonnes and reduced 430 million tonnes of carbon dioxide emissions by controlling deforestation. In 2004, the net sink of China's forest was approximately 500 million tonnes carbon dioxide equivalent, accounting for over 8% of the total greenhouse gas emissions nationwide in the same period.[66]

2.3. Climate change: a threat to China's development

The world is set to experience significant changes in its climate over the next few decades. Without the full engagement of all the major economies, there is no possibility of avoiding much worse (and perhaps even catastrophic) impacts, perhaps towards the end of this century or potentially sooner. No country will be immune from these effects, and climate change threatens the ambition of all countries to improve the quality of life for their citizens.

2.3.1. The impacts of global climate change

Climate change is a serious threat to global development. It promises to trigger ecological and agricultural disaster, exacerbating water shortages and rendering massive swathes of land unfit for cultivation. The IPCC projects increasing hunger and thirst across the developing world.

A one-metre rise in sea level by the end of the century would have a huge impact on global economic and social development. The IPCC calculates the likelihood of this at 70–80%. Climate change could cause the largest and fastest migration in human history, involving 200 million people.[67] Farm income in Africa could decrease by as much as 90% by 2100.[68] In the cruel irony of climate change, the social catastrophe would hit the poorest countries hardest, even though they are least responsible for greenhouse gas levels.

[66] The State Forest Administration of China, Report on Forest and Ecological Construction in China, 20 January 2008.
[67] See the discussion in International Organization for Migration, Migration and Climate Change, Migration Research Series No. 31, 2008. Available online at www.reliefweb.int/rw/lib.nsf/db900sid/ASAZ-7CGDBH/$file/iom_dec2007.pdf?openelement.
[68] IPPC Fourth Assessment Report (Working Group 2), p. 435.

Climate change not only threatens economic development but also undermines national security. An EU report states that climate change will exacerbate existing trends, tension and instability. These include seven new threats:

1) Conflict over resources;
2) Economic damage and risk to coastal cities and infrastructure;
3) Loss of territory and border disputes;
4) Environmentally induced migration;
5) Situations of fragility and radicalization;
6) Tension over energy supplies; and
7) Pressure on international governance. [69]

Box 2.1: The US focus on climate and national security

In October 2003, the US Department of Defense provided a secret report to the Bush administration named *An Abrupt Climate Change Scenario and Its Implications for United States National Security*.

In April 2007, the Military Consultative Committee of Center for Naval Analysis published *National Security and the Threat of Climate Change*. This assessed the potential threat of climate change to US national security from a military perspective.

In November 2007, the Center for Strategic and International Studies and the Center for a New American Security jointly launched the report *Era of Aftermath: Implications of Global Climate Change for Diplomatic Policies and National Security*.

In a report called *Climate Change and National Security: an Action Program* published in November 2007, the US Senate Foreign Relations Committee put forward specific suggestions to the American government and stated that climate change does not threaten the basic survival of the US but it does impose a direct threat to American national security.

In June 2008, the National Intelligence Council, on behalf of 16 intelligence agencies of the US, conducted a national intelligence assessment of the influence of global climate change on the future of American security. It proposed a secret report to the government entitled *National Security Implications of Global Climate Change Through 2030*. The report maintains that sub-Saharan Africa, the Middle East, Central Asia and South-East Asia will be the most seriously affected by climate change.

2.3.2. Understanding the impact of climate change on China

Average annual temperatures in China have increased by 0.5–0.8ºC in the past 100 years, just above the average global increase.[70] Warming trends have intensified in the past 50 years.

China is one of the countries most frequently stricken by natural disasters. From 1990 to 1999, 34,000 people died from natural disasters and 1.26 billion people were affected – 66% of the world's total. Strong disaster relief means that the death toll from natural

[69] Climate Change and International Security, Paper from the High Representative and the European Commission to the European Council, at www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/reports/99387.pdf.
[70] China's National Assessment Report on Climate, Change (I): Climate change in China and the future trend. Advances in Climate Change Research. Article ID: 1673-1719 (2007) Suppl. 0001-05, at http://www.climatechange.cn/qikan/manage/wenzhang/01.pdf.

disasters in China is lower than the global average, but its economic losses are higher than the global average. They have been in the region of $70 billion (about 1.6% of China's total GDP of $4.22 trillion in 2008) per annum over the past two decades.

Abnormal meteorological conditions pose a major threat to Chinese farmers. In the past five years, the decline of annual grain yields caused by natural disasters has been dramatically increasing. Climate change will influence crop variety distribution and yields[71] because of changes in the severity of winter and the availability of water.

Some areas have benefited from extended growing seasons for certain crops, and the increase of CO_2 concentration can in principle increase growth rates in plants (the fertilization effect). But these benefits depend on many other factors, such as plant respiration, soil nutrition, water moisture supply, nitrogen fixation, the growth stage of plants and crop quality.[72]

On balance, the impacts of climate change on agricultural production in China have been negative and are set to worsen. The IPCC projects about a 2.5– 10% decrease in crop yield for parts of Asia in the 2020s and a 5–30% decrease in the 2050s compared with 1990 levels without CO_2 effects. A major study by Chinese Academy of Agricultural Science indicates that owing to resource and socio-economic pressures, climate change could lead to a 9–18% decrease in cereal production by the 2040s, significantly affecting food security.[73]

Because rainfall is concentrated in a few areas, dry and semi-dry regions make up half of China's total territory and are directly and severely influenced far more than other countries at the same latitude. Since 1990, national annual rainfall in most years has been higher than normal, albeit unevenly distributed, with flooding in the south and drought in the north. Most parts of northern China, the eastern part of north-western China and north-eastern China suffer from water shortage, with rainfall declining at the remarkable rate of 20–40 mm every 10 years. Rainfall in southern and south-western China has significantly increased, at an average rate of 20–60 mm every 10 years.

In the past 50 years, there has been a conspicuous change in the frequency and intensity of major extreme weather events in China. Northern and north-eastern China are drier while the lower-middle reaches of the Yangtze River and south-eastern China suffer more from floods. These trends are exacerbated by a higher than global average annual rate of sea-level rise in China's coastal area, of 2.5 mm, and a rapid and accelerating shrinking of mountain glaciers, both of which will have negative consequences for the availability of water in China. Further studies predict that the Yangtze River and its southern area will experience an 8% decrease in annual runoff. Beijing, Tianjin and Tangshan are situated in the Hailuanhe River basin, where runoff is likely to decrease by 16%. (By contrast, runoff in the upper reaches of the Yellow River may increase by 15%.) The decrease in runoff may be over four times the decrease in rainfall.[74]

According to the IPCC's Fourth Assessment, freshwater availability in Central, South,

[71] Wang Futang et al. *Impact of Climate Change on Agricultural Ecology* (Beijing: China Meteorological Press), 2003.
[72] Wang Chunyi, *Climate Change Newsletter*, April issue, 2004.
[73] See http://www.china-climate-adapt.org/en/document/ICCCA_summary_final_Eng.pdf.
[74] Wang Chunyi, *Climate Change Newsletter*, April issue, 2004.

East and South-East Asia, particularly in large river basins such as the Changjiang, is likely to decrease because of climate change, along with population growth and a rising standard of living. This could adversely affect more than a billion people in Asia by the 2050s. It is estimated that between 120 million to 1.2 billion people in the region will experience increased water stress by the 2020s.

2.4. The benefits to China of a low carbon economy

China's move towards a low carbon economy will not be just a reactive response to external forces arising from shifts in the global economic structure and pressure to reduce climate impacts. There are also very significant positive benefits to be gained as it moves to tackle its internal energy resource and environmental constraints.

2.4.1 Alleviating resource and energy pressures

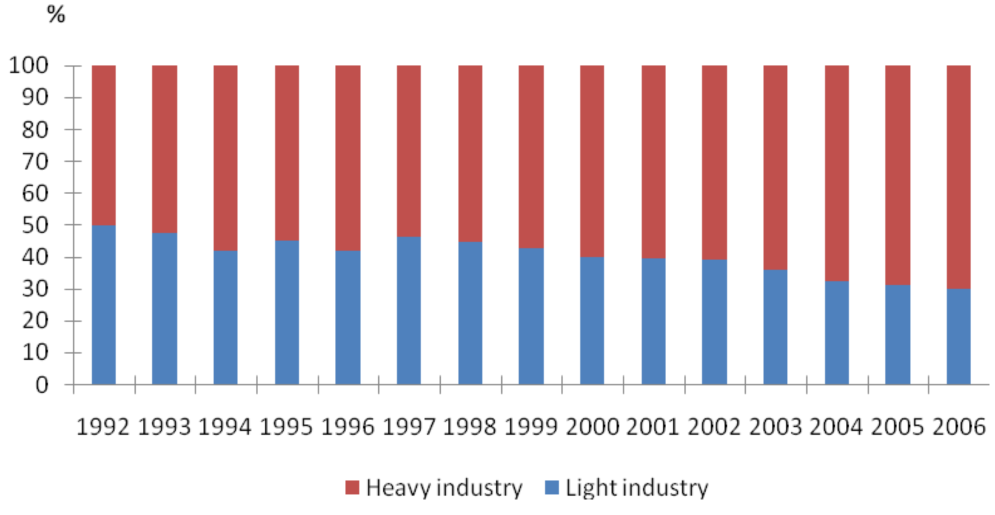
Since 1978, China has accounted for a growing proportion of the world's industrial output and total global exports. It has become the third-largest exporter in the world, and will soon surpass the US and Germany to become the largest.[75] Rapid industrialization and urbanization are driving up demand for energy in China. Moving towards a low carbon economy would help to relieve the stress on energy and other resources.

Since 1992, the development of heavy and chemical industries has been accelerating, resulting in a ratio between light industry and heavy industry of 3:7 by 2006 (Figure 2.3]). Energy-intensive industries have maintained high growth rates since 2005, and the trend will continue. In 2005–2007, the annual production growth rate of pig iron was 16.9% (although this represented a 4.4% decrease compared to the period of the 10th Five-Year Plan). Crude steel grew by 26.9% per annum, increasing by 4.5% compared to the 10th Five-Year Plan period. And cement grew by 12.8%, 0.5% faster than during the period of the 10th Five-Year Plan.

In 2005, national industrial energy consumption was 478 million tonnes of oil equivalent, accounting for 42% of total final energy consumption, much higher than the proportion in 1990 (36%) and much higher than the average proportion in OECD countries (22%).[76]

[75] Hu Angang: *Roadmap of China's Rising* (Peking University Press, 2007 edn), pp. 20–21.
[76] IEA, *World Energy Outlook 2007*. page 291

Figure 2.3: The ratio between light Industry and heavy industry during China's industrialization, 1992–2006



Source: China Statistical Yearbook, compiled by the National Bureau of Statistics.

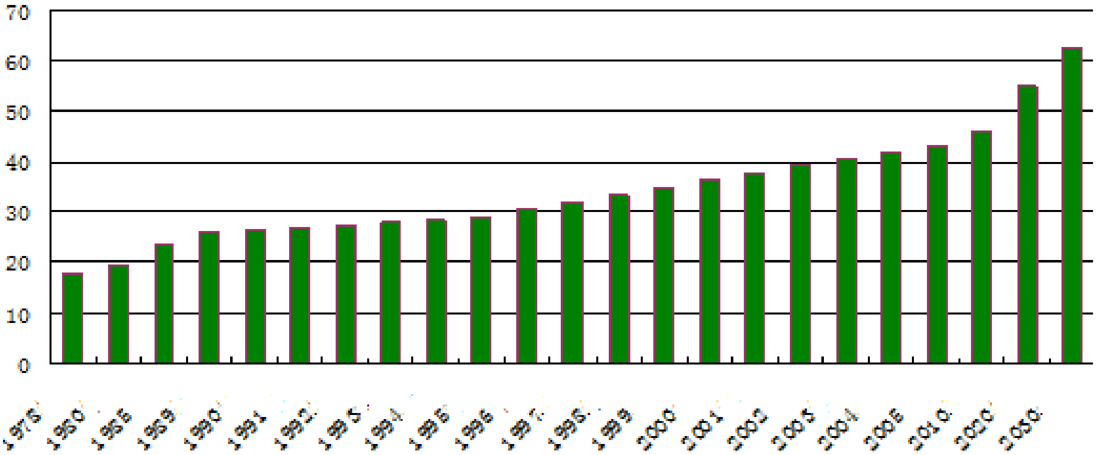
The constant increase in urbanization in China has also intensified the pressure on energy. Between 1978 and 2005, China's urbanization rose from 18% to 43%. Hu Angang estimated in 2003 that China's urbanization would increase to 46% by 2010 and to 55% by 2020, catching up the world's average level of 56%. After 2030, China's urbanization will stabilize at around 63%, surpassing the world's average of 61% (Figure 2.4).[77] The scenarios used for this study suggest even higher rates of urbanization, with levels reaching 80% by 2050.

Although industrial structures and development pathways have varied during different countries' periods of economic growth, there has tended to be a convergence in consumption patterns. When per capita disposable income increases to a certain level, individuals' consumption – especially that of urban residents – shifts from food and clothing to housing and transportation. This in turn affects industrial and urban structures. For instance, during the 10th Five-Year Plan, the area of per capita urban residential building increased by 29%, and car ownership among urban households increased by 5.7 times. At present, China's urbanization is increasing at an annual rate of 1.4%. Urban residents' per capita energy consumption is 3.5 times that of rural residents.[78]

[77] Hu Angang, 'Urbanization is the Main Impetus of Chinese Economic Development in Future', *Chinese Journal of Population Science*, issue 6, 2003.

[78] Feng Fei: 'Speeding up Construction of Resource-saving Society and Promoting Changes in the Mode of Economic Growth', Electric Power Technologic Economics, Issue 3, 2007.

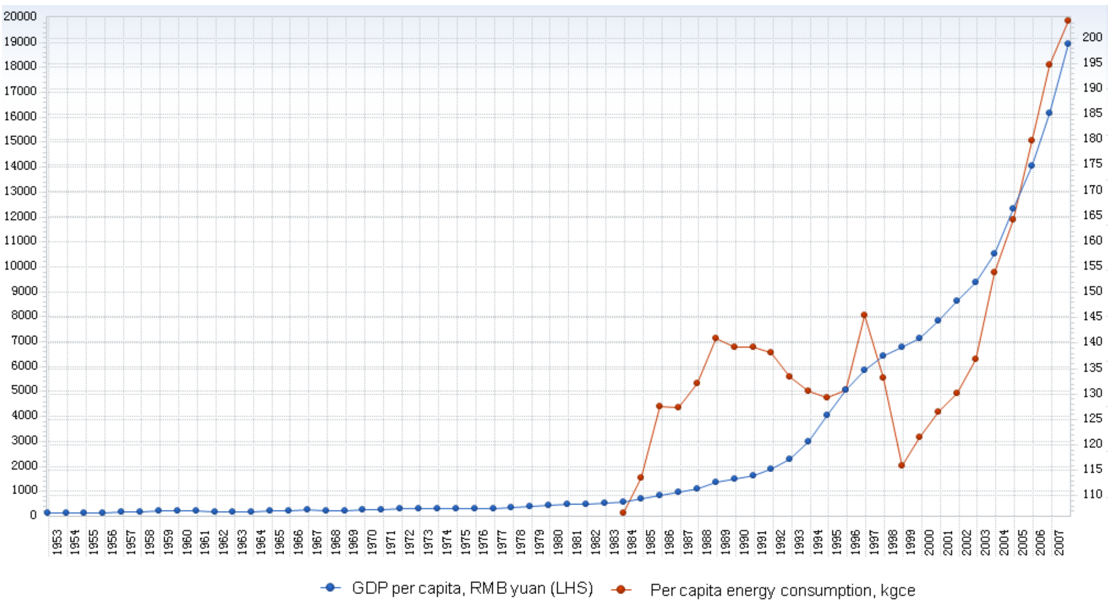
Figure 2.4: The rate of urbanization in China (%), 1978–2030



Source: China Statistical Yearbook, compiled by the National Bureau of Statistics. The data for 2010–2030 was estimated by Hu Angang (2003).

The challenge for China is that an increase in per capita energy seems inevitable when compared to historical patterns of economic development. The Chinese economy began to take off in 1978, and its per capita energy consumption by 2005 was 1.32 tonnes of oil equivalent, still much lower than the per capita consumption level of the US and the UK in 1870 and 74% of the world per capita level for the same period (see Table 2.2).

Figure 2.5: The per capita GDP and per capita energy consumption of China, 1953–2007



Source: CEIC database.

Table 2.2: An international comparison of per capita primary energy consumption[a] 1820–2005

Year	World	UK	USA	Japan	China
1820	0.21	0.61	2.45	0.20	
1870	0.31	2.21	2.45	0.20	
1913	0.61	3.24	4.47	0.42	
1950	0.84	3.14	5.68	0.54	
1973	1.54	3.93	8.19	2.98	0.48
1998	1.65	3.89	8.15	4.04	0.88
2005[b]	1.78	3.88	7.89	4.5	1.32

[a] Oil equivalent: tonnes.
[b]The data for 2005 are quoted from International Energy Agency, Key World Energy Statistics 2007.
Source: Maddison Data Set / GGDC Total Economy Database (2005), Table 4 and Table 5.

Currently, China is the world's second-largest energy consumer (the US is the largest), the largest coal consumer, the second-largest oil consumer (again, after the US) and the third-largest net oil importer (after the US and Japan).[79]

In 2007, the growth rate of primary energy consumption in China was 7.7%, much higher than the global average of 2.4%. China accounted for 52% of the world's increase in energy consumption.[80]

2.4.2. Improving the structure of energy consumption

China is very dependent on coal as its key source of primary energy. This high dependency creates problems that will be eased by moving to a low carbon economy.

Coal has supplied 65–70% of China's energy mix in recent years; petroleum has accounted for 20–22%. Natural gas consumption has grown rapidly in the past several decades. Hydropower production shows an overall upward trend, largely holding firm at about 5–7%, with a slight fall in recent years. Nuclear power has grown rapidly, although it does not exceed 1% of total primary energy consumption. China is still in the initial stages of developing terrestrial heat, geothermal resources, solar energy, wind energy and other renewable resources. These currently take only a tiny share of total energy consumption.

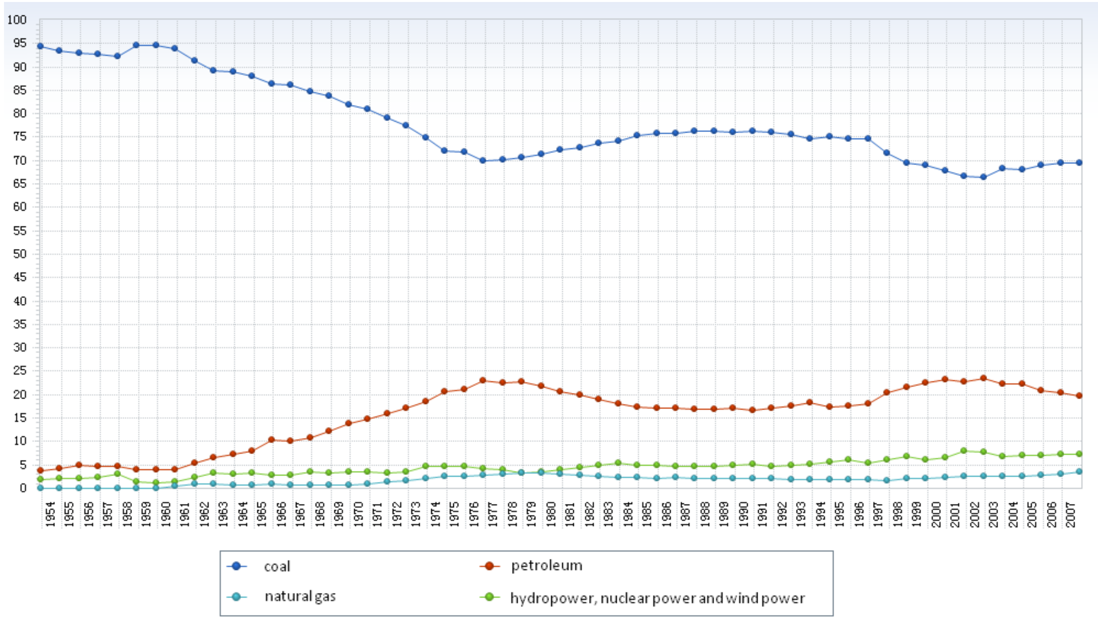
Figure 2.6 shows trends in China's fuel mix over the past 50 years. The share of coal peaked at 77% in 1989 but has remained high, increasing to 70% in recent years after a fall in the 1990s. Petroleum is currently at about 20%.

China has a much more coal-intensive energy structure than the international average. Globally, coal accounts for 25% of primary energy. Petroleum's share declined after the oil crises of the 1970s, but it had been more or less stable at 39% since 1990 until the recent spike in prices, and stood at 35% in 2005. Nuclear consumption has grown rapidly

[79] Energy Information Administration,
China Energy Profiles, at http://tonto.eia.doe.gov/country/country_energy_data.cfm?fips=CH.
[80] BP, *Statistical Review of World Energy 2008*.

from less than 3% in the 1980s to 6–7% today. Terrestrial heat, solar energy, wind energy and other renewable resources account for less than 1% of all consumption worldwide.

Figure 2.6: China's energy consumption structure: the share in total, percentage, 1954–2007



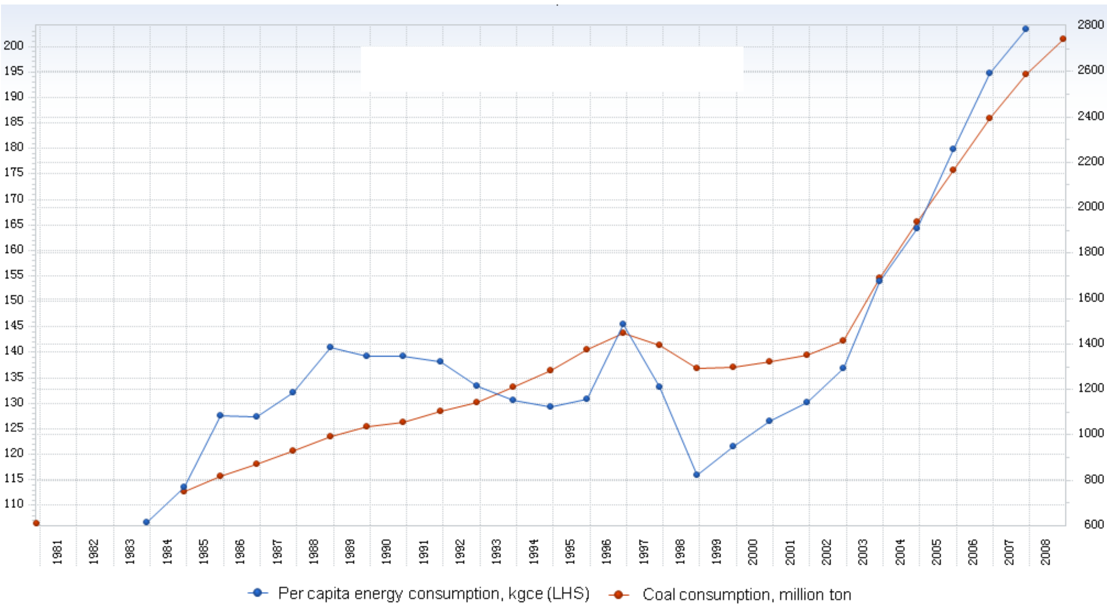
Source: CEIC database.

China is both the world's largest producer and consumer of coal, and its coal production rose to 1.29 billion tonnes of oil equivalent in 2007, up 7% from the year before. This accounted for 41% of coal produced around the world. Chinese consumption in 2007 rose to 1.31 billion tonnes of oil equivalent, a 7.9% increase from the year before. Even though this was the lowest percentage increase since 2002, it still accounted for 41.3% of global coal consumption and for over two thirds of new coal consumption around the world in that year.

The use of coal on this scale incurs large costs for China. The environmental externalities resulting from coal mining include water and air pollution, noise pollution, effects on water-bearing strata, destruction of the hydrological balance, ecological damage and costs in terms of human health. Coal processing and treatment pollutes water sources; coal transportation too involves externalities such as dust pollution. And coal burning pollutes the air with dust, nitrogen oxide, carbon dioxide and mercury; these pollutants induce asthma and other respiratory diseases, threatening public health. Some research estimates that the mining, transportation and use of coal cost China 1,826.4 billion RMB in 2007 alone, equivalent to 7.4% of GDP.[81]

[81] Greenpeace, the Energy Foundation, World Wildlife Fund, Real Cost of Coal, September 2008, pp. 4–8.

Figure 2.7: Coal consumption in China (million tons of coal equivalent) 1981–2008



Source: CEIC Database.

Reducing emissions would ease pressure on China's environment and lower the costs arising from environmental damage. According to data from the State Environmental Protection Administration and the National Bureau of Statistics, economic losses caused by environmental pollution amounted to 3.05% of GDP in 2004.[82] China is the world's largest emitter of sulphur dioxide; this caused approximately $60 billion of direct economic losses in 2005.[83] Sixteen of the world's 20 most polluted cities are in China, according to the World Development Report.[84] The World Health Organization notes that nearly one third of China endures heavy acid rain. Only 31% of Chinese cities meet that organization's air quality standards.

2.4.3 Safeguarding energy security

China's economic security is threatened by its rising dependence on imported petroleum. Since it became a net oil importer in 1993, its import dependency has risen every year, now reaching almost 52%. According to the IEA, China could import as much as 82% of the oil it needs by 2030. The figures for its more industrialized coastal regions may be even higher, exceeding 90%, and imports tend to be from countries with considerable political risk.

Therefore, China's dependence on petroleum imports adds uncertainty to its economic development. In recent years, world energy production and use has experienced great changes. High prices in 2008 changed the balance of power between petroleum consumers and producers, and the subsequent drop in prices was painful for energy

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[82] State Environmental Protection Administration, World Bank and National Bureau of Statistics, Study Report on the Loss of Environmental Pollution in China Research, material from the International Seminar on Loss of Environmental Pollution in China Study, 2007.

[83] Daniel H. Rosen and Trevor Houser, 'China Energy: A Guide for the Perplexed', A Joint Project by the Center for Strategic and International Studies and the Peterson Institute for International Economics, May 2007.

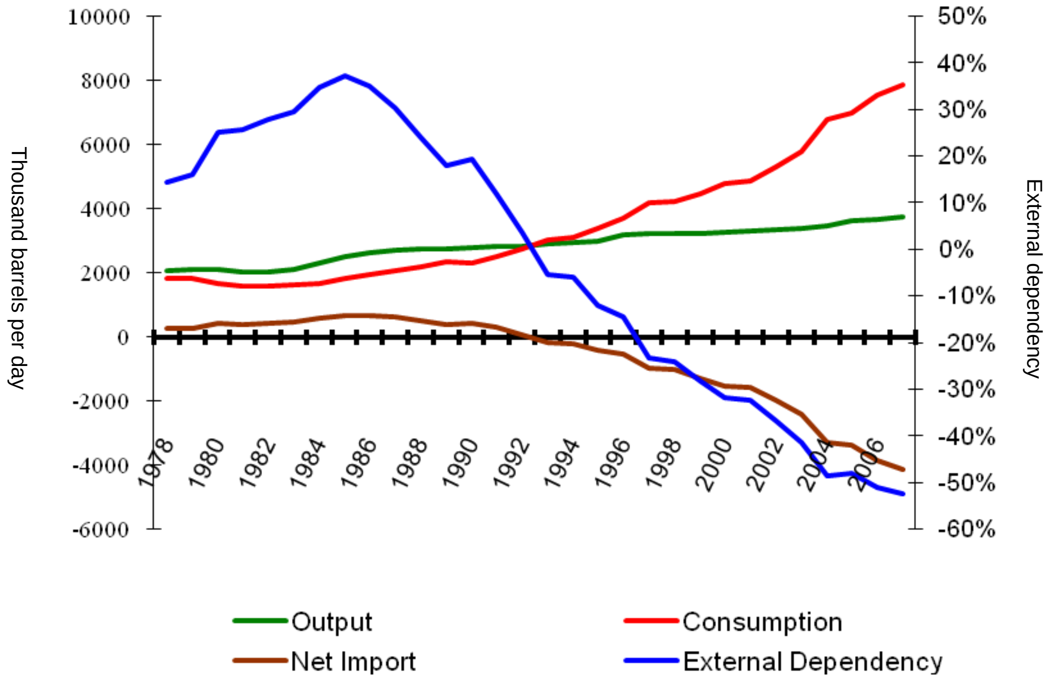
[84] World Bank, *World Development Report 2009.*

producing countries that had allowed costs to escalate. This very high price uncertainty puts pressure on the traditional relationship of mutual dependence between producers and consumers, but a new order is yet to take shape. In addition, China's relationship with oil producing countries could increase suspicion and hostility between Beijing and the US. Pressure on the bilateral relationship make security problems, including those of energy security, more urgent. In 2005, Matthew Yeomans suggested that increasing oil demand from China meant that competition with the US for the world's petroleum resources will become increasingly fierce.[85]

Furthermore, oil is far from the only mineral resource for which China has become increasingly dependent on imports. The country is set to grow ever more reliant on imports of iron, manganese, copper, lead and zinc; import dependency for each is projected to reach 52%, 38%, 82%, 52% and 69% respectively by 2020.

It is neither realistic nor sustainable to support resource-heavy growth by purchasing large amounts of resources from international markets. China's ability to rely on international markets is not unlimited. This means that greater attention must be paid to changing the pattern of economic growth and reducing resource consumption.

Figure 2.8: Oil consumption in China, 1978-2007)



Source: BP, Statistical Review of World Energy 2008.

China's energy policy is likely to swing between different priorities. When environmental and climate problems are at the forefront, it will tend to limit the proportion of coal in its energy structure and to advocate clean energy. When oil prices rise, it will support (and indeed has supported) using coal as an alternative. This highlights the conflict between the short-term goal of economic development and the long-term goal of energy development. Nevertheless, under current trends China is set to

[85] Matthew Yeomans, 'Crude Politics: The United States, China, and the Race for oil Security', *The Atlantic Monthly*, April 2005, vol. 295, pp. 48c–49.

increase its dependence not only on oil imports but also on coal imports. This means that reducing the intensity of coal consumption has considerable energy security benefits, and should be in both the short-term and long-term development interests of China. In its *World Energy Outlook 2007*, the IEA envisioned three scenarios for the growth of China's primary energy consumption between 2005 and 2030: a reference scenario assuming a continuation of current policies, a higher growth scenario and a reduced emission 'alternative policy' scenario. The growth of primary energy consumption under the three scenarios is shown in Table 2.3.

Table 2.3: Estimate of China's primary energy consumption,[a] 2005–2030

	2005	2015			2030			Average Growth Rate 2005–2030		
		High Growth	Reference	Alternative Policy	High Growth	Reference	Alternative Policy	High Growth(%)	Reference (%)	Alternative Policy (%)
Coal	1 094	2 037	1 869	1 743	2 910	2 399	1 842	4.0	3.2	2.1
Oil	327	626	543	518	1 048	808	653	4.8	3.7	2.8
Natural gas	42	125	109	126	276	199	225	7.8	6.4	6.9
Nuclear energy	14	34	32	44	82	67	120	7.4	6.5	9.0
Hydropower	34	63	62	75	100	86	109	4.4	3.8	4.8
Bio-energy and waste	227	235	225	223	231	227	255	0.1	0.0	0.5
Other renewable energy	3	13	12	14	43	33	52	11.1	9.9	11.9
Total	1 742	3 135	2 851	2 743	4 691	3 819	3 256	3.2	3.2	2.5

[a]Oil equivalent: million tonnes.

Sources: IEA , *World Energy Outlook 2007*.

Under the high-growth scenario, China's coal production in 2030 is 625 Mt of coal equivalent higher than under the reference scenario, an increase in coal volume equivalent to the combined production of Australia, India and Colombia in 2005. Despite this much higher growth, production fails to keep pace with demand in this scenario, leading to net coal imports rising to 199 million tonnes of coal equivalent (Mtce), more than twice the level of imports in the reference scenario. International oil prices are higher under this scenario, and imports reach 17.2 million barrels per day, an increase of 31% compared to the reference scenario.

By comparison, the World Energy Outlook 2007 alternative policy scenario indicates a set of policy measures that can be taken to reduce energy consumption relative to the reference scenario. In the alternative policy scenario, China remains largely self-sufficient in coal, in contrast to the reference scenario in which China becomes a net importer of coal by 2030. Coking coal exports from China under the alternative scenario increase owing to significantly lower domestic demand. Under the alternative policy scenario, oil imports still increase to 2030 but at a slower rate, reaching 9.7 million barrels per day compared to the reference scenario import level of 13.1 mb/d. The slower growth in imports would significantly reduce the level of emergency oil stocks that China would need to hold in order to maintain security of supply. Oil prices would also be expected to be lower. Gas consumption, on the other hand, is higher under the alternative policy scenario than the reference scenario, but not as high as under the high-growth scenario. In summary, the IEA's alternative scenario shows that an achievable, more sustainable energy path could have net economic benefits for China, in addition to significant energy security and environmental improvements.

2.5. The rationale for immediate action

Now is the time for China to make a decisive shift from its previous energy- and carbon-intensive development patterns to a more sustainable path. By acting now, China stands to gain by avoiding lock-in to inappropriate capital stock, positioning itself as a global leader and provider of low carbon technology and making use of emerging carbon markets and other international financing mechanisms.

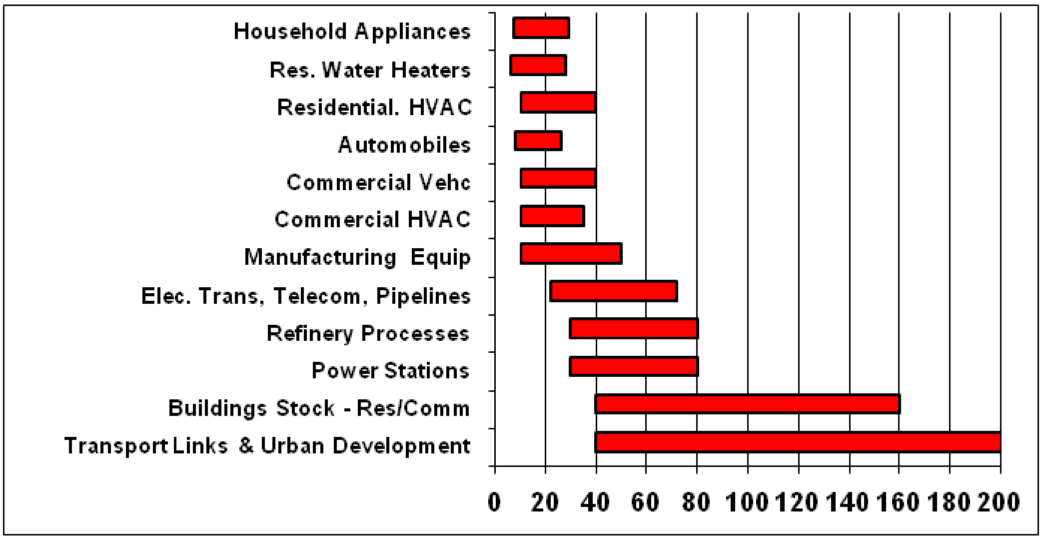
2.5.1. Avoiding lock-in

As a result of China's rapid industrialization and urbanization, massive amounts of infrastructure and equipment will be put into operation over the next two decades. Furthermore, in response to the global economic crisis, the Chinese government has launched a 4 trillion RMB direct fiscal stimulus plan. Together, this provides China with an extraordinary window of opportunity for reconstructing and upgrading domestic industries in China.

If this wave of investment fails to use advanced technologies, equipment and infrastructure, China will lock in high energy consumption, high pollution and high emissions for their entire life-cycle, possibly for decades. Figure 2.9 illustrates the typical asset lifetimes, showing that the types of energy infrastructure that China is investing in most heavily (i.e. urban infrastructure, buildings, and industrial and energy infrastructure) tend to be the categories of infrastructure that are most long-lived. China will therefore live with the decisions it is making during this decade for many decades to come.

Whether domestic industries switch to low carbon development by grasping this opportunity will depend to a significant extent on the relevant regulations and directional policies formulated by the Chinese state. De-carbonizing output can be achieved only through technological development and institutional constraints in favour of improved energy efficiency, optimized energy structures and better consumption behaviour.

Figure 2.9: Ranges of life spans for different energy assets (years)



Source: IEA

2.5.2. Establishing international competitive advantages

At present, China is a global leader in terms of R&D and commercialization for some low carbon technologies. However, public and private sectors from developed countries are also injecting large amounts of capital into low carbon R&D. Competition to develop and commercialize new technologies is fierce; China must keep up. Once low carbon technologies go into wide commercialization elsewhere, China would simply replicate its traditional pattern of becoming a home for low-cost competition instead of establishing new international competitive advantages based on home-grown innovation.

China's spending on research and development has risen at an annual rate of 19% since 1995, reaching $30 billion by 2005, among the highest levels in the world.[86] The 11th Five-Year plan (2006–2010) outlines its aim of increasing R&D to 2% of GDP. Today, only 10% of China's GDP comes from high-tech manufacturing, of which nearly nine tenths comes from subsidiaries of foreign companies or joint ventures with Chinese companies. Improving the domestic innovation base remains a priority.

China's 2006 National Medium- and Long-term Science and Technology Development Planning Framework spelled out specific targets for energy technology development. By 2020, Chinese researchers are anticipated to have achieved breakthroughs in energy development and conservation technologies and clean energy technologies as well as in the optimization of the energy mix. Over the same period, major manufacturing industries are expected to reach or approach the energy efficiency level of advanced countries.[87] The Ministry of Science and Technology draws up the technology R&D plans and provides funding for national programmes.[8889]

[86] See Bernice Lee, 'Strengthening the global innovation systems to deliver technological options for climate change', paper produced by Chatham House for the CCICED Low Carbon Economy Task Force,2009.
[86] 'Changing Climates', Chatham House, 2007.
[87] For a complete text of the plan, see, for example, http://politics.people.com.cn/GB/1026/4089311.html
[88] The objectives of the 873 program during the 10th Five-Year Plan period are 'to boost innovation capacity in the high-tech sectors, particularly in strategic high-tech fields, in order to gain a foothold in the world arena; to strive to achieve breakthroughs in key technical fields that concern the national economic lifeline and national security; and to achieve 'leap-frog' development in key high-

China's State Council put forward Several Suggestions for Accelerating Equipment Manufacture Development in China in 2006. A group of large Chinese equipment manufacturing companies are expected to be internationally competitive to meet the demands of energy, transport and raw material production by 2010.[90]

One possible model that China is considering for incubating these developments builds on the experiences of the early 1980s when it embarked on an extraordinary journey towards greater economic openness. Special economic zones (SEZs) – geographical regions with more liberal economic laws than the rest of the country – played a vital role. Building on this successful model, a consortium of European and Chinese research institutes (including LCE Task Force contributors the Chinese Academy of Social Science, the Energy Research Institute, Chatham House and E3G) developed the concept of 'low carbon zones' (LCZs),[91] and it is currently engaged in piloting and developing the methodology for LCZs in Jilin City Municipal Area.

LCZs aim to stimulate transformational regional political leadership, endorsed at the national level, so as to create an enabling environment for large-scale innovative low carbon private and public investment. Just as SEZs provided China with a laboratory to shape its participation in the global market economy, so the LCZs could pioneer approaches to decarbonization compatible with Chinese institutions and development approaches.[92]

2.5.3. Taking advantage of the global carbon market

Following the Kyoto Protocol's entry into effect in 2005, carbon markets have experienced exponential growth (see Table 2.4) This market is dominated by the EU Emissions Trading Scheme, a mandatory cap-and-trade scheme that creates a demand for emissions allowances among European power generators and large industrial energy consumers. Much of this demand is met through internally traded allowances, but international credits created under the Kyoto Protocol's clean development mechanism (CDM) are also allowed to be used by companies in the EUETS.

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tech fields in which China enjoys relative advantages or should take strategic positions in order to provide high-tech support to fulfill strategic objectives in the implementation of the third step of our modernization process.' See website http://www.most.gov.cn/eng/programmes/programmes1.htm.

[89] The '973 program' is the National Program on Key Basic Research Project. It seeks to build a solid scientific and technological foundation for the sustainable socio-economic development of China. Through the implementation of the Program, a contingent of scientific talents will be trained and a number of high-level national research bases will be established in order to upgrade the primary innovative capacity of the nation. See website http://www.most.gov.cn/eng/programmes/programmes3.htm.

[90] Cited in Jiang Kejun, Hu Xiulian, Liu Qiang, 'Clean Coal Technology: A Critical Choice for China', Appendix 4 of Jiang Kejun, Hu Xiulian, Liu Qiang, Zhu Songli, Zhuang Xing, *Modelling Development and Emission Scenario Analysis in China*, Energy Research Institute, China, 2005, at http://www.e2models.com/CD/china.htm

[91] 'Changing Climates', Chatham House, 2007.

[92] Matthew Findlay and Felix Preston, 'Low Carbon Zones: A Transformational Agenda for China and Europe', Chatham House and E3G, February 2009. [

Table 2.4: Overview of carbon trading market, 2004–2008

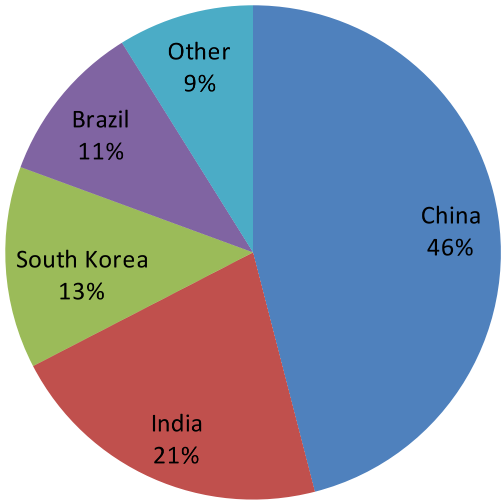
	Total volume (hundred million tonnes)	Total value (hundred million Euros)
2004	0.94	3.77
2005	7.99	94
2006	16	220
2007	27	400
2008	49	920

Source: Point Carbon annual reports.

These volumes could increase markedly as the US develops plans for its own cap-and-trade scheme. The global carbon market is therefore still developing, with the participation of more and more countries expected over the next decade. According to predictions by the United Nations and World Bank's Annual Carbon Market Report, the global carbon market could generate $60 billion per annum from 2008 to 2012. Its total volume is projected to reach $150 billion in 2012, which would position it to replace petroleum as the largest traded commodity in the world.

Up to now, China has dominated the trading market under the CDM (see Figure 2.10). Despite significant growth in other developing countries, China is still the leader by some distance, hosting around 46% of expected annual certified emissions reductions to date.

Figure 2.10: Distribution of CDM activities*



* Certified Emissions Reductions issued by host party, as of 22/10/09.

Source: UNFCCC CDM website.

The CDM process was conceived as a way of providing private financial flows for low carbon projects in developing countries that did not take on an absolute cap on emissions under the Kyoto Protocol. In this regard, it has been successful. However, despite recent growth, the scale of the mechanism is still nowhere near large enough to meet the levels of emissions reductions required to achieve global climate change goals.

There are various discussions on ways of scaling up the mechanism from project-specific approaches that incur large transaction costs to a mechanism that could credit emission reductions at a larger scale across whole industrial sectors or across broad programmes of emissions reduction.[93] These discussions on scaling up international mechanisms will continue to take shape as part of the international climate change negotiations.

Taking a proactive approach will allow China to take advantage of international financing mechanisms for funding early-action opportunities in the move towards a low carbon economy.

[93] See, for example,IEA 2007 'Sectoral Approaches to GHG Mitigation' IEA information paper available at http://www.iea.org/textbase/papers/2007/Sectoral_Approach_Info_WEB.pdf

3. Meeting the challenges and opportunities for China in pursuit of a low carbon economy

It is manifestly in China's interest to develop a low carbon economy. That would relieve China's reliance on imported oil, reduce resource wastage, particularly of water, and ease the environmental damage resulting from several decades of rapid economic growth and industrialization. It would also make a vital contribution to stabilizing global atmospheric GHG concentration. Low carbon industrial policy, including aggressive energy-efficiency standards, would help China to remain at the forefront of global manufacturing and to provide technological leadership in the world's fight against climate change.

Leaders at the highest levels of the Chinese government have recognized this, and have set the goal of constructing a resource-conservative and environmentally friendly society. They have also pledged that China would do its part to address climate change. President Hu Jintao and some of his ministers have specifically said that a low carbon economy, with efficient energy use and low emissions, will be crucial to meeting the objective of sustainable development.

But there are serious challenges facing China's pursuit of a low carbon economy. It is still a developing country with a varied and relatively low average level of income. Its population may continue to grow until about 2030 Despite perhaps the greatest rural–urban migration in history, the majority of the population still lives in rural areas, and the country is continuing to industrialize and urbanize rapidly. Social and economic development will improve people's income and quality of life, but the Stern Review tells us that early powerful policy interventions are necessary in order to prevent rises in per capita GDP from leading to increases in per capita emissions.

China has an extraordinary window of opportunity to create a low carbon economy, as discussed in Chapter 2, but there are real challenges and opportunities that it must meet if it is to step through the window.

3.1. Saving energy and reducing emissions

A country's GHG emissions depend on various factors: population, per capita GDP, energy structure (i.e. fuel mix), energy intensity (energy consumption per unit of GDP and land use.

China's population is above 1.3 billion, although its national population growth rate is well below the world average. Its energy structure remains coal-dominated, despite the quickened pace towards renewable energy resulting from Clean Development Mechanism (CDM) projects and the Renewable Energy Law. As for per capita income, which remains very modest by developed country standards, China's priority remains the improvement of people's living standards. It cannot reduce GHG emissions by slowing down economic development and lowering per capita income. Meeting people's demands for a better material and cultural life is necessary in order to ensure both social and political stability.

In the short term the key to controlling China's GHG emissions is primarily a reduction in energy intensity. It should be kept in mind that realistically China's emissions will increase for some time to come. Studies show that even if China meets the dramatic 20% cut in energy intensity targeted by the 11th Five-Year Plan (2006–2011), total emissions will increase – despite the move towards less carbon-intensive economic development.

For China, the notion of moving to a low carbon economy implies substantial improvements in energy efficiency and a reduction in carbon emissions per unit of GDP, ultimately making Chinese industry and technologies globally competitive. It does not imply an unrealistic and sudden abandonment of coal but a gradual movement away from high dependency levels.

But in the medium term, China's emissions will need to peak and start to fall if global climate change is to be kept within safe limits. Options for getting on a low carbon pathway are explored in Chapter 4.

3.1.1. Energy saving: a contribution to mitigating GHG emissions

Boosting energy efficiency would advance China's pursuit of domestic development goals. And by reducing emissions from what they otherwise would have been, it would also contribute to global goals for climate protection.

Zhuang[94] modelled how changes in energy intensity would affect total energy demand in 2010. He projected that energy demand in 2010 would be equivalent to 3.564 billion tonnes of standard coal (assuming a 9.48% GDP growth and a 9.9% growth in annual energy consumption). Successfully cutting energy intensity by 20% from the 2005 level – as per the target in the 11th Five-Year Plan – would reduce consumption by 702–1,029 million tonnes of standard coal compared to this projection. Despite these savings, China would still need 310–637 million tonnes of standard coal more than required at the 2005 level.

However, setting a target is one thing; realizing it is another. According to 2007 data from the National Bureau of Statistics, of 31 provinces, municipalities and autonomous regions in 2006, only Beijing met the annual target for energy savings.

Given that China failed to achieve its 4% reduction target for energy intensity in 2006, it would have had to make up the difference in 2007. But some high energy-consuming sectors developed very quickly in early 2007.

It is against this backdrop that in June 2007, China released a number of legal instruments and action plans on energy conservation, such as the National Climate Change Program, the Comprehensive Work Program on Energy-saving & Emission Reduction and also Scientific & Technological Actions on Climate Change.

Ministries took measures to encourage businesses to participate in energy-saving. For example, the National Development and Reform Commission reached several agreements with large-scale state-owned energy enterprises calling for strict

[94] Guiyang Zhang, 2007, China's Development Path under the Background of Low-carbon Economy and Climate Change.

implementation of differential pricing policies and prohibiting the transfer of sub-standard equipment between regions. The State Environmental Protection Administration introduced the 'regional restriction on production projects approval' policy in order to avoid pollution levels that exceed local environmental capacity. The financial and taxation departments reduced or even abolished export rebates for some polluting industries, raising their cost of doing business. They also increased the resources tax for certain products and rewarded some 700 enterprises for energy-saving technological transformation projects.

The policies appeared to work, albeit not to the extent necessary to meet the 20% target. In 2007, energy consumption per unit GDP was 3.27% lower than than in 2006. Chemical oxygen demand and total SO_2 (Sulphur Dioxide) emissions decreased by 3.14% and 4.66% respectively.

The 2008 Government Work Report observed progress in energy-saving and consequently avoided emissions. In the preceding two years, China had phased out, by law, a large number of low-efficiency production facilities, including 22 GW worth of small-scale coal-fired power generation, 11,200 small coal mines, 47 million tonnes worth of iron smelting capacity, steel smelting capacity of 37 million tonnes and cement production capacity of 87 million tonnes. The same period had seen 550 billion RMB in nationwide investment in environmental protection, worth some 1.24% of GDP. Ten key energy conservation projects had been started. Central government investment was supporting 691 water pollution control projects.

In 2008, energy intensity fell by 4.59%, according to the National Bureau of Statistics.[95] However, this drop, the largest in recent years, owed much to the effects of the economic crisis on heavy industry.

The industrial added value of high energy-consuming industries increased by 10% in 2008 – significantly less than the 19% growth in the previous year. The production of steel, crude steel, cement and electrolytic aluminum grew by only 3.4%, 2.4%, 2.9% and 6.8% respectively, representing dramatic declines from the growth rates of the previous year.[96]

Experts point out that a more serious slowdown in 2009 and 2010 could help to achieve the 20% energy intensity reduction target. China must take advantage of this opportunity to prepare for the long term, avoiding an even larger problem occurring once the economy recovers by locking in efficiency improvements. Energy intensity reduction will go hand in hand with robust growth.

3.1.2. Barriers to saving energy and avoiding emissions

A society-wide consensus on the need for energy-saving has been established, but China must go further in order to achieve the necessary reduction in energy and carbon intensity.

A major factor is China's industrial structure. A large share of its economy is in a stage of

[95] *2008 National Economic and Social Development Statistics Bulletin*.
[96] Notably, the decline in growth was less pronounced for high-tech manufacturing.

industrialization marked by heavy chemical industries, the development of iron and steel, vehicle and ship manufacturing and mechanical engineering industries, all of which require a large volume of materials and energy. The development of tertiary industry, with lower energy intensity, lags behind the world average by about 30%. On top of this, there are sharp regional variations in the degree of industrialization: China still needs to accomplish large-scale development in its western region.

China's energy-intensive industries are the pillars of the national economy. Employment pressures make it harder to speed up structural adjustment in the short term and to close inefficient production capacity. Local interests protect many small and medium enterprises using heavily polluting old technology that uses resources inefficiently. Many enterprises and local governments still approve some heavy chemical industry projects, ignoring government regulations.

All in all, this implies a relatively high degree of energy dependence. Compounding this is China’s natural endowment in terms of energy: it has huge reserves of coal, which encourage over-reliance on this carbon intensive source.

Another obstacle relates to a shift among China’s policy instruments for promoting energy saving – from the current, largely administrative tools such as centrally determined targets for local governments and enterprises to a market-orientated approach. There will be an inevitable time lag between the introduction and implementation of market-based policies on energy-saving and the resulting shifts in investment patterns.

The global financial crisis has also impeded energy-saving efforts. Heavily polluting industries such as chemicals, coke, iron and steel have been hit hard, and the Chinese government has moved to relax restraints on them, for example by increasing export tax rebates for several products and removing export tariffs on some energy-intensive products. Like governments elsewhere, China is facing huge pressure from many quarters to restore earlier growth, leading to trade-offs in the formulation of policies.

The crisis has made enterprises cautious about investment in general, especially new investments in energy-saving. The fall in domestic coal prices (linked to the decline in international oil prices) has reduced incentives for companies to invest in energy-saving. Furthermore, the recession has seen a collapse in the market price of some byproducts of energy-saving activities. For example, the price of sulpfuric acid, one byproduct of energy-saving for the Jiangxi Copper Company, has fallen from 1,600 RMB to 80 RMB per tonne. This has dealt a further blow to business confidence in the value of energy-saving activities.

3.1.3. Meeting the challenges of energy-saving in the building sector

China’s building sector currently accounts for about 28% of the country’s total energy consumption. Several challenges need to be met here so that China can achieve substantial energy-saving. It also has plans for major expansion of the housing sector, estimated to be 20 billion m^2 by 2020. This equates to all the current housing stock in the EU 15.

Engaging a broad group of stakeholders will be one of the keys to success. Potential energy savings in the building sector cut across many social groups, including a huge number of consumers, real estate developers, construction equipment developers, marketers, property companies, designers, researchers and providers of energy management and energy services.

In the long run, all will benefit from high efficiency standards, but complementary policies should be introduced so as to address any short-term negative consequences for the poor. Many people in both rural and urban areas have their homes in the large number of low-end, temporary buildings lacking the basic conditions for energy conservation. The residents of those buildings have very limited financial resources. Implementing strict efficiency standards across the building sector without providing additional support to ensure sufficient building rates and affordability could affect the basic shelter of this vulnerable group and even result in social unrest.

Financial resources can be substantially reorganized to drive energy efficiency in China. Part of the solution is to expand long-term fiscal and tax incentives for energy-saving in the construction sector, which are currently lacking. For example, the building-orientated fixed-asset investment regulatory tax was discontinued in 2000. The fund for new walling materials came to an end after 2005. And no fiscal or tax incentives are available for energy-efficient buildings or energy-efficient equipment used in buildings; nor are funds available for energy-saving improvement projects and the use of new efficient energy technologies.

At present, energy-efficiency improvements in buildings are funded mainly with treasury bonds or through international cooperation projects. And treasury bonds are used to support industrial energy conservation far more than for enabling energy-saving projects in buildings. The public benefit funds seen in other countries, which are funded through electricity surcharges, resource taxes or environmental taxes (carbon tax and ecological tax), do not exist in China. This is an important area for policymakers to consider.

Institutional barriers are a challenge, but the priorities are clear. Currently, charges for central heating and cooling are based on floor-space, giving users no incentive to save energy. This undermines demand in the market for energy-saving products. Energy metering and control facilities are often faulty and problematic, making it hard to implement energy conservation policies. Despite a new heating reform policy, most buildings with central heating, including new residential ones, do not have a heat meter or a thermostat, making it impossible for residents to save energy on heating even if they are inclined to do so. Many cities in China have introduced time-of-use (TOU) power policies, but these have gone nowhere, as many buildings are not installed with a TOU meter.

Public sector management systems should, as an urgent task, make energy-saving an item in their budgets, thus providing government agencies a source of funding for energy-saving improvements. At present, government agencies have their annual energy costs repaid or reimbursed based on expenditures incurred in previous years. As a result, energy-saving measures will ultimately lead to reduced budget allocations, thus dampening enthusiasm for conservation. This could easily be rectified by providing incentives for energy saving. Communication and coordination between government departments could also be substantially improved.

In the construction sector, energy-saving involves buildings, energy systems and equipment (such as heating, air-conditioning, lighting, household appliances and office equipment). Each, however, is overseen by multiple regulators with unclearly divided responsibilities. Because issues such as energy-saving policy, the energy price, fiscal and tax policy and environmental protection cut across several government departments, an appropriate authority should be introduced to promote coherence.

Mandatory policies for energy saving will also need to be reformed, both in terms of the actual policies and their implementation and enforcement. Existing requirements for energy efficiency are inadequate. For example, there is no requirement for large public buildings to have energy management policies; these buildings can consume significant amounts of energy, and offer great potential for energy conservation. Even where mandatory building energy-saving standards exist, surveys show that only a small proportion of new residential buildings in large Chinese cities adhere to the standards: 50% for northern areas, 14% for areas with hot summers and cold winters and only 11% or so for areas with a hot summer and a warm winter. A policy requirement for new construction projects to undergo energy-efficiency assessments has never been effectively implemented.

Also in need of development are services related to energy conservation. Energy-saving service companies' progress in the construction sector has been hindered by constraints such as financing, taxation, marketing and risk control owing to the lack of an enabling policy environment. Services for assessing and testing energy conservation measures are essential for the implementation of energy-saving policies for buildings.

Finally, measures towards rational energy pricing would be of important benefit to the low carbon economy. A market-based heat pricing mechanism has not been established, and a reasonable policy on heat price needs to be introduced. This is one of the factors accounting for the failure of the heat reform policy.

3.1.4. Meeting the challenges of energy-saving in the transport sector

Globally the transport sector is the largest and fastest-growing emitter of CO_2. In China, the sector's energy consumption and emissions are likely to increase significantly in the coming years. For this reason, priority should be given to policies that can slow down the rate of increase of emissions in the short term while developing alternative pathways for transport.

The introduction of stricter standards on vehicles grams of CO_2/km) has been shown to significantly increase average efficiency. Countries across the world are incrementally increasing efficiency standards, but not to the level of the most efficient models available. This in part reflects the political sensitivity of the automobile industry around the world. But the picture is changing as a result of the economic crisis. The existence of multinational companies and global supply chains should enable the introduction of international production and efficiency standards that cause the best available technologies to be deployed rapidly.

Technological changes are not the only mechanism to lead to efficiency improvements. Behavioural changes could also bring marked gains, such as altering driving habits, driving more slowly and evenly, car-pooling and a switch to public transport for those who can afford cars. Some of these measures require relatively simple measures, such as changing speed limits or greater public awareness. Others, however, require changing infrastructure, which can be expensive and takes longer to implement.

3.2. Opportunities for technological Innovation, transfer and deployment

Improving the scientific and technological capacity of developing countries is fundamental to addressing climate change within the framework of sustainable development.

Without a major and rapid technological revolution, developing countries risk the 'lock-in effect': equipping new infrastructure with conventional low-efficiency technology, which would then run for several decades. If this happens, high emissions in China and elsewhere would be locked in for decades.

Therefore, to help developing countries move towards a low carbon economy, a shift in their development pathways is needed, for which low carbon technology innovation, transfer and deployment will be essential.

3.2.1 Opportunities for scientific and technological innovation

China's efforts to transform its economy from 'high carbon' to 'low carbon' have been hindered in part by its basic technological status and limited R&D capacity. Many lower carbon technologies already exist and/or may be free from intellectual property rights and so are widely available.

However, in certain areas it is necessary to break the bottleneck of technological innovation that will hamper China's progress towards a low carbon economy. The weak innovation capacity of Chinese enterprises is mainly due to the fact that there is no pressure for them to innovate and no mechanism to encourage them to do so. China will need to develop technology and import it, reform its institutions, make sound policy and deliver human resources and funding. Each of these conditions is indispensable so that innovation can drive low carbon transition.

China has enjoyed a latecomer's advantage in the process of industrialization: it was largely able to copy what had already been done elsewhere. The success of its efforts to chart a new development pathway, by creating a low carbon economy, will depend largely on its ability to break out of this pattern and develop an independent innovation capacity.

China must attach great importance to research and development, focusing on medium- and long-term strategic technologies. It needs to support the rapid diffusion and use of existing commercial low carbon technologies, to rationalize venture investment and financing so as to encourage companies to develop new low carbon technologies and also to enhance international cooperation in order to promote technology transfer from developed countries to China.

The National Economic and Social Development Statistical Bulletin of the People's Republic of China in 2007 showed that China's R&D spending in 2007 grew by 22%, amounting to 366 billion RMB or 1.5% of GDP. In 2006, the Organization for Economic

Cooperation and Development (OECD) estimated that in purchasing power terms, total R&D investment in China would be over $136 billion by the end of that year.[97] China ranks third in overall R&D expenditure and accounts for half the total R&D expenditure from non-OECD countries.[98] Investment in scientific and technological R&D has been taking up an increasing share of China's GDP: 1.23% in 2004, 1.34% in 2005, 1.41% in 2006 and 1.49% in 2007. These very substantial increases show that the Chinese government and enterprises are striving to boost independent innovation.

Nevertheless, there is a wide gap between China's actual investment in R&D and the 2% of GDP target for it set out in 11th Five-Year Plan (similar to the percentage spent by developed countries) and the 5–10% of revenue spent on R&D by the world's top 500 companies. Greater efforts must be made in order to bring China's R&D expenditure into line with the 3% of GDP level of the world's leading countries. Japan's per capita R&D expenditure is $1,000 while China's per capita R&D expenditure is only $140. Judging from the quality and substance of current research and development, China still has a long way to go towards becoming an innovative country.

Looking at the existing structure for R&D investment in China, one clear trend is that foreign-funded enterprises have increased their investment. Multinationals have established almost 800 R&D centres in China, and many leading Japanese companies, including Sony and Toshiba, have launched R&D bases in China. Fully half the applications for invention patents with high-end technology (including core technology) submitted to the Chinese State Patent Office are filed by foreign-owned enterprises based in China. According to WBCSD research in 2008, China registered more patents than in the total of the previous 30 years. Although this increase in patent registration is led by foreign companies, there is a significant increase in local patent holder registration, 33% between 1998 and 2008. The challenge is to ensure that all R&D investments in China will enhance the innovation capabilities of homegrown Chinese enterprises.

Overall, R&D investment by enterprises accounts for over 70% of the total in China, almost the same proportion as in developed countries. However, only 25% of Chinese medium- and large-sized enterprises have their own R&D unit. Three quarters have no full-time staff engaged in research and development.

Of total R&D spending by the 1,000 enterprises in the Global Business Research and Development List published by the United Kingdom's Department of Trade and Industry in 2005, companies from the United States, Japan and Germany accounted for 72%. Only four companies from mainland China made the list, and their R&D costs did not reach the equivalent of ₤22 million each. Three Japanese companies ranked in the top 15, with R&D expenditure of more than the equivalent of ₤2.5 billion each.

Many enterprises spend much more on technology imports than on technology absorption and assimilation. On average, the proportion of investment on imports to that for absorption is 6.5:1. In Japan after the Second World War, it was 1:7, more than inverted, although this partly reflects the much greater level of globalization today, with imports and exports of goods and services typically being a much greater part of many international companies' business models.

Insufficient technological innovation capacity is a weakness of China's economy. The

[97] OECD, *2006 Science, Technology and Industry Outlook*.
[98] Battellle/R and Magazine, 2009 Global R and D funding forecast, p. 5.[Please clarify source and title.]

country is a large resource consumer, but its average economic output per unit of resource consumed is less than 10% of that of developed countries. China is the third-largest trader, but only a tenth of its exports are accounted for by homegrown brands and intellectual property. It is a big manufacturer, but it needs to import major technical equipment. China's exports of high-tech products are growing, but it relies heavily on importing key components for those products and has to pay foreign companies large fees for software technology standards. 'Strengthening capacities of independent innovation of information technology' is a major goal of China's State Informatization Development Strategy (2006–2020).

3.2.2. International technology transfer

In addition to innovation, the diffusion of technology will play a critical role in addressing climate change.

Studies by McKinsey and others show that 70% of emissions reductions necessary to stabilize GHG concentrations in the atmosphere at 550 ppm by 2050 can be achieved by employing available and near-commercialized technologies over the coming 20 years. Thus the diffusion of these technologies is at least as important as the development of new ones.

However, developing countries often lack many of the advanced technologies that can support GHG emissions reduction. Economic development has obvious high-emission characteristics. For developing countries in the industrialization process to overcome high-pollution phase, financial and technical support are required.

Low carbon practices developed by industrialized countries need to be replicated internationally. For the purpose of addressing long-term climate challenges, developed countries should cooperate to facilitate the spread of energy technology through 'technology push' and 'market pull'. This would have positive implications for China in terms of policy and technology.

There are a number of obstacles to international technology transfer, including low human capacity and a shortage of talent, expensive transfer fees, decentralized industrial structures and weak policy environments. If the international climate regime could help to address these market obstacles, China would benefit from increased technology flows and reduced GHG emissions.

The international community has recognized this fact, but too often failed to act accordingly. The UNFCCC has clearly set an obligation for developed countries to increase technology transfer to developing countries, but actual progress on this front has been limited.

In addition, the CDM has been focused on the transfer of funds, to help developing countries finance their own sustainable development. China has had to rely on commercial channels to import technology including the crucial technology for wind, solar and nuclear power.

It is essential for the future international climate regime to set up institutional instruments to handle properly the relationship between the protection of intellectual property rights (IPRs) and technology transfer. China will have to develop a low carbon economy within the post-Kyoto international climate regime. The international community should provide sufficient economic incentives to promote the widespread diffusion of technologies essential for a low carbon economy globally.

However, the importance of IPRs should also be placed in proper perspective. Although intellectual property protection has been seen to be a serious obstacle to access to some medicines, they are not so core an issue in the transfer of clean technologies for climate change.

Intellectual property rights should not be an excuse for a failure to transfer technology. International technical cooperation has entered a new era to gradually form a number of mutual benefits and win-win outcomes. Future technology transfer mechanisms must enable developing countries to access to affordable advanced technology, thereby enhancing the capacity to address climate change. From an objective point of view, the suppliers of advanced technology can also benefit significantly from a broad market in developing countries. Internationally, the most serious challenge facing the creation of a low-carbon economy is: how to create an attractive, fair market, favorable policies and more investment; and how to make the world more consciously to reduce carbon emissions and assume a responsibility to protect the Earth.

The introduction and absorption of technology have a high priority. China has focused on the introduction of technology, but ignored the absorption for a long time. Many enterprises fell into the trap of technological dependence through the introduction of technology over and over again. The introduction of technology can have two kinds of mode: only for the current implementation and for enhancing the capability of independent innovation. Because China is now in the reform process and the enterprise mechanism is imperfect, firms are often willing to spend money on technology imports because of the immediate benefits. The input for the digestion and absorption is in shortage because it seems difficult to improve the performance in a short run. As a result, many enterprises repeatedly purchase the same technology. This simply results in an increasing total cost rather than a process of technological learning and the building of innovative skills.

3.2.3. Achieving the deployment of low carbon technology

Many (but not all) of the technologies that will enable a rapid, transformative change in the way energy is produced are already available but not adequately deployed. The World Business Council on Sustainable Development has identified 10 barriers to the deployment of energy-efficient technologies, along with specific policy responses to overcome them (see Table 3.1).

Energy efficiency gains will be achieved only by a concerted effort in all sectors of society. The general public and other energy consumers will have to be engaged in order to ensure prudent purchasing and investment decisions on the entire operational life of appliances, not just on upfront costs.

Lower and zero carbon supply options require market stability. As in most cases fossil fuel-based energy sources are currently cheaper than the low carbon alternatives, investors need both short-term incentives and confidence in a longer-term policy framework. Onshore wind energy, for example, is close to being competitive with traditional electricity generators, especially if environmental externalities are included in the price. However, barriers, such as access to the grid and planning regulations, often inhibit new investment. Relatively simple measures could be introduced to prioritize these technologies, enabling their wider diffusion in existing markets.

Other technologies, such as concentrated solar power and offshore wind energy, are further from commercialization. They will require an investment framework that addresses the lack of funding for research, development and deployment while their long-term feasibility is being assessed. This process should cover a wide range of technologies so as not to be picking winners at an early stage of development. The removal of other barriers, such as prohibitive financing, overly burdensome regulations and difficult access to energy networks, will also have to be addressed if rapid diffusion is to be achieved.

Table 3.1: Barriers to the deployment of energy-efficient technologies and practices

Barrier	Causes	How to overcome the barriers?
Low energy prices	Subsidies Prices do not include environmental costs	Eliminate perverse subsidies Put a price on carbon
High upfront costs and long payback periods	Most consumers value the present cost of consumption	Economic incentives (e.g. tax reductions) to decrease first cost White certificates schemes
Slow diffusion of technologies	Lack of skills, knowledge and support for the use of technologies Fragmented and un-integrated industry structures (e.g. the building sector)	Technology standards
Entrenched business models	Lack of incentives for energy companies to reduce customer demand	Internalize carbon prices in energy services Financially reward end-user Energy Efficiency measures Promote Energy Saving Companies
Diversity of consumers and energy needs	No single solution fits all	Promote voluntary sectoral initiatives and negotiated agreements
Information failures	Lack of information or imperfect information regarding future energy prices and EE alternatives	More effective technology standards (e.g. building codes) Product energy labelling Advice on energy-smart metering
Split incentives (the principal agent problem)	Those making decisions on EE do not benefit (e.g.	Provide clear information and incentives (e.g. tax

	building owners and tenants)	rebates, mortgage discounts, rebates and preferential loans)
Uncertainties about investment and risks	Uncertainties add a premium to investments	Economic incentives that cover those risks Develop robust energy and carbon markets
Consumer behaviour	Low priority of EE investments Lack of awareness and information on energy consumption and costs	Develop carbon markets Incentives to remove and replace old equipment Raise education and awareness on EE
Investment costs higher than expected	Do not include all transaction costs	Boost best practice sharing and EE education

Source: Developed by WBCSD and its member companies in 2009.

3.2.4 Supply chain bottlenecks

Changing engineering standards and the materials used in the manufacture and use of goods can have widespread implications for supply chains. In particular, higher efficiency standards for buildings have been known to result in bottlenecks owing to shortages of specific energy-efficient materials, e.g. high-spec windows. On paper, overcoming these potential blockages in the supply chain is simple: increase production.

In practice it is more complicated, and may require a number of measures, including clear medium- and long-term targets that facilitate R&D and investment; financial incentives for new production investment; increased co-operation and patent sharing to enable leapfrogging to the best available technology; and stricter penalties and regulation so as to avoid production based on redundant or soon-to-be redundant technologies.

3.3 Establishing a long-term effective mechanism and institutions

The advancement of low-carbon economy needs government guide, which includes formulating the long-term development strategy, issuing the policies to encourage technological innovation, energy-saving emission reduction, renewable energy use, cutting tax rate, enhancing financial subsidies, implementing government procurement, green credits and other measures.
Far-sighted enterprises should also recognize the direction and consciously follow up, with objective of promoting the “collective action” of low-carbon economic development. As stated previously, China's priority areas for change and reform is the energy pricing mechanism. The conventional practices, with the break-down of the energy-saving targets led by the central government and dominated by administrative means, should be transformed into that, with the use of market mechanisms for the energy-saving and the development of low-carbon economy.

3.3.1 Legislation for a low carbon economy

Building a low carbon economy requires corresponding laws, regulations and systems. China already has forward-looking laws and regulations on developing the circular economy and renewable energy. For the low carbon economy, however, there are no regulatory government documents, much less low carbon economic legislation.

The Chinese government could follow up on its existing legislation pertaining to sustainable development and set out legal norms underpinning the development of a low carbon economy. Forward-looking businesses will be able to see where the future lies, which will help to facilitate collective action for a low carbon economy.

3.3.2 Energy-pricing policy reform

China, like many developing countries, has found it rational and sometimes even necessary to subsidize energy consumption. Energy consumption takes a significant share of average disposable income, so the government has attempted to provide each citizen affordable access to energy in order to guarantee social equity.

In recent years, coal and oil prices have fluctuated greatly. High oil prices had a tremendous negative impact on the economy. When oil prices were high, the government regulated electricity and domestic oil prices in order to maintain price stability. Necessarily, this involved large subsidies. The state-controlled China National Petroleum Corporation (CNPC) and the China Petrochemical Corporation (Sinopec) were directed by the government to engage in loss-making business, and in turn received subsidies from the finance ministry. The interaction between market-based coal prices and the regulated electricity price was disconnected, causing coal-generated power plants to make losses. Sinopec was subsidized by 5 billion RMB in 2006, 4.9 billion RMB in 2007 and 7.4 billion RMB in the first quarter of 2008. This figure continued to rise as international oil prices soared. In April 2008, Sinopec received 7.1 billion RMB of financial subsidies, but believed that this did not even cover half its losses.

These subsidies and price controls come with problems. First of all, price controls imply production-side subsidies that decouple end users' consumption behaviour from the actual costs to the economy. While oil and coal prices rose in the international market, domestic oil and electricity consumption were unaffected. The subsidies encouraged increased and inefficient oil and electricity consumption, leading to pollution and contributing to future energy scarcity and price pressures.

The large-scale energy price subsidies run directly counter to the requirements of China's national economic development. They impede industrial restructuring and discourage investment in energy conservation. China cannot follow the path of developed countries, which relied on heavy consumption of energy and raw materials to achieve industrialization.

The problems of energy price subsidies are underlined by their prime beneficiaries. About 76% of electricity in China is consumed by industry, of which over 40% is used by high-energy-consuming industries. Only 11% is consumed by residents and less than 3% by agriculture. Thus electricity price subsidies benefit manufacturing industry first and foremost. The price signal is in effect promoting the development of energy-intensive industries.

Energy price reform could start from electricity and oil prices. Price subsidies should be abolished as soon as possible. Rationalizing the price of resource products to account for scarcity and environmental damage would play an important role in the development of market mechanisms for energy-saving.

There are already signs of progress in this regard. Eleven ministries, including the National Development and Reform Commission, have jointly issued the Notice on Implementing the 'Energy Conservation Law of the People's Republic of China' (FGHZ [2008] No. 2306), through which the resource tax will be perfected, an environmental tax introduced and a fuel tax imposed at the proper time.

3.3.3 Giving full play to the potential of market-based mechanisms

As noted previously, Chinese policies on energy-saving are still in transition from administrative to market-based approaches. Administrative measures are not without advantages. They promote the realization of short-term goals by breaking down energy-saving targets into small components for implementation by local governments and companies. They have been used to good effect in the power industry through energy conservation, the efficient despatching of power plant, the replacement of thermal power with hydropower and the closing down of small power companies and power plants in favour of large ones, to give some examples.

However, from a medium- and long-term perspective, energy-saving in the power sector needs to be based on market mechanisms, with the government playing a supplementary role rather than a central one.

China's regulators already have the ability to set efficiency standards for new plant and to close down the most inefficient existing plant, thereby determining conditions for market access and withdrawal. But there is currently much less flexibility for introducing mechanisms such as a carbon price that would affect the operation of the market.

In May 2002, a demonstration of sulphur dioxide emissions trading in the power industry was launched in four provinces (Shandong, Shanxi, Jiangsu and Henan), three municipalities/cities (Shanghai, Tianjin and Liuzhou) and one company (the China Huaneng Group). However, only a few 'forced transactions' with very low prices were implemented by government departments. These prices could not reflect the true cost of emission reduction and were indicative of insufficient market liquidity. Meanwhile, the underlying conditions for a market in trading sulphur dioxide allowances are extremely promising. With economic growth, the sulphur dioxide emission rights competitively pursued by many stakeholders have become extremely rare. Many power companies want to create new thermal power plants and are actively seeking sulphur dioxide emission rights. Some power companies are not willing to sell the sulphur dioxide emission rights they are not using: they would like to leave room for development and they do not want to sell them to the competition. Thus sulphur dioxide emission rights are badly needed, but the supply is illiquid, affecting the normal establishment of a market in trading emission rights.

China can learn from the practice of the EU Emissions Trading Scheme (EUETS) in allocating total control targets (quotas) and leaving a certain quantity of emission allowances to be allocated to newly established enterprises through auctions or to be used to adjust market prices.

At present, some developed countries and international organizations have great expectations for using market mechanisms to promote the development of low carbon economies in developing countries. But assuming that China would not take on a mandatory GHG emissions target before 2020, the potential for transactions in carbon dioxide emissions allowances would be highly limited. Experts believe that sulphur dioxide emissions trading should be carried out first in the power industry and integrated into the 12th Five-Year Plan. The experiences of this work could then serve as a reference for setting up a trade in carbon dioxide emissions allowances in future.

3.3.4 Monitoring and enforcement

China can improve its attempts to monitor GHG emissions, decrease energy intensity the deployment of low carbon technologies and changes in the manufacturing mix and public behaviour. Better monitoring would make it easier to adjust policies for achieving further increases in energy efficiency. It is difficult to enforce what has not been adequately measured.

The SO_2 trading scheme has already given China experience of measuring and controlling emissions. Furthermore, pilot programmes are being developed for CO_2 monitoring, measuring and trading schemes. Although a comprehensive national CO_2 monitoring scheme will not be accomplished in the short term, larger and larger pilot projects may contribute to the development of a national scheme. Robust monitoring, reporting and verification systems are an essential precursor to any future implementation of a carbon trading scheme. Experience in Europe suggests that such systems can take several years to set up and become reliable, even when robust financial accounting procedures are already in place to measure energy consumption. Adjustments to the measured emissions by participating companies caused a significant shift in the carbon price in the early part of the EU trading scheme. Robust monitoring and enforcement will be the cornerstone of any engagement between China and the international community on energy saving and emissions reduction efforts.

3.3.5 Public procurement of low carbon products

Green and low carbon public procurement is the process by which public authorities seek to reduce the environmental impact of the goods and services that they buy. In Europe, public authorities spend 16% of GDP, almost €2,000 billion, on goods and services each year. Much of this is spent in sectors with high environmental impacts, such as transport, buildings and furnishings. As purchasers, public authorities have huge buying power, and there is enormous scope for them to influence suppliers to innovate and produce more environmentally friendly goods and services. They also have the potential to persuade private sector companies and the general public to change their consumption habits.

In China, the percentage of GDP under the control of the public sector is higher. Using this spending to push the economy in a low carbon direction would reduce emissions in the long term and reduce the risk that expensive investments would become redundant in the short term.

3.3.6 Overcoming regulatory obstacles to energy-saving and avoided emissions

Chinese enterprises are facing a lack of incentives to implement low carbon strategies. Judicious policy interventions could do much to help. The first problem is cost, especially in the field of renewable energy investment. If the government does not provide policy support(such as financial subsidies and price, taxation and other measures), the market alone will not create incentives for the development of new energy sectors.

There are signs of progress towards that support. The Renewable Energy Law (2005) has established a framework for China's renewable energy policy. It includes a series of supporting measures such as special funds, power generation policies, price and cost-sharing and price subsidies. A relatively small number of renewable energy investment projects have been subsidized in China, although both the amount and proportion of subsidies are small, normally less than 10% of total investment (in developed countries, the figure is generally higher than 40%).

A policy has been implemented under which electricity generated from renewable sources shall be merged into the power network and fully purchased at a price generally higher than that for ordinary power, with the price difference to be shared among the whole power network. Market competition is encouraged in tender pricing, but if the price is kept low, investors' enthusiasm for further investments will be reduced. At the same time, it is not possible to give full play to market competition if the pricing is approved by the government.

The second problem is financing. Investments in energy-saving are characterized by a large one-off investment and a long recovery cycle. Poor near-term profitability and high debt ratios make project financing difficult. For example, bodies charged with promoting energy-saving will often advance money for the implementation of contracts for energy management; in the absence of such policy support, efficiency investments might simply not be made. The main problems here include an inadequate understanding of the contract energy management model and the fact that potential energy conservation service companies lack adequate capability and financing.

Standards pose another challenge. China established its energy conservation product certification system through the Energy Conservation Law of the People's Republic of China in 1998. This set up the China Committee for Certification of Energy Conservation Products and the China Certification Center for Energy Conservation Products (now the China Standard Certification Center), which promulgated the Certification Management Approaches of China's Energy Conservation Products and created certification marks for energy-efficient products.

In terms of current implementation efforts, there are still defects such as inconsistent certification standards and a lack of economic incentives. The domestic energy conservation market has not been standardized, and all kinds of products of different quality intermingle in the market for what are supposed to be energy conserving goods, causing customer confusion. Also, advanced energy conservation technologies are often expensive, making the final market price for such products much higher than those of less efficient competitors. As no incentive measures are available to bridge this gap, sophisticated energy-saving products do not enjoy a high level of market penetration.

The Chinese government needs to continuously evaluate and improve policies and regulations so as to make them more effective. Policies can both facilitate good behaviour and inhibit bad behaviour.

4. Scenario Analysis of a Low Carbon Economy

Several business-as-usual scenarios and emissions reduction scenarios were developed for this study. By making different assumptions for GDP, population, consumption, technology improvement and emissions reduction paths (following global GHG stabilisation targets up to 2050), different emissions reduction scenarios for China were produced. The quantitative analysis, based on that modelling, is presented at the end of the report.

Four scenarios are presented in detail: a business-as-usual scenario; two low carbon scenarios, differentiated by the level of GDP growth (high or low); and one enhanced low carbon scenario. In the low carbon scenario and the enhanced low carbon scenarios, the objective of low carbon development for China is achieved. These scenarios assume that economic growth and social development are achieved with lower energy consumption than in the BAU scenario. This is attained in the model by limiting the role of the energy-intensive sectors in the economy, thereby reducing domestic energy demand and imports. With support from national planning and fiscal policies, renewable energy and nuclear energy develop rapidly. By 2030, the main energy-intensive sectors in China will reach international efficiency standards or even more advanced levels of efficiency, so that the industrial sector realises high standards on emissions and efficiency.

In these low carbon scenarios, newly built buildings will meet high energy savings standards and household consumption will be based mainly on low- energy goods. Therefore, in these scenarios the overall level of CO_2 emissions will be very low. Policy options for achieving these emissions levels are also considered in this chapter.

4. 1 Methodology

4.1.1. Research framework

Substantial international and domestic research has been carried out focused on long-term emissions scenarios, such as the IPCC emissions scenarios issued in 2001 and the 2050 energy and GHG emissions multi-scenario research in China completed in 2002 by the IPAC modelling group of the Energy Research Institute (ERI). All these studies have benefited from advanced research and modelling methodologies.

Both at the international level and the domestic level, integrated assessment models are widely used to carry out modelling work. Many factors, for example social and economic development, energy resources, energy-consuming technologies, environmental constraints and consumption behaviour are taken into account in the models in order to arrive at a comprehensive analysis of China's future energy and GHG emissions scenarios.

In this analysis we use a methodology similar to that applied to previous research, China's emission scenarios in 2050, namely:

1) Describe qualitatively the scenario development framework of China's social and economic development, energy development, technology development, consumption style and emissions demand in the future;
2) Input a set of main development indicators according to the scenario development framework;
3) Build the extended model and carry out quantitative analysis of the scenario; and
4) Obtain, as an output, a set of emissions scenarios.

The timeline of the research is up to 2050. The base year is 2005, and the results are reported for 2010, 2020, 2030, 2040 and 2050.

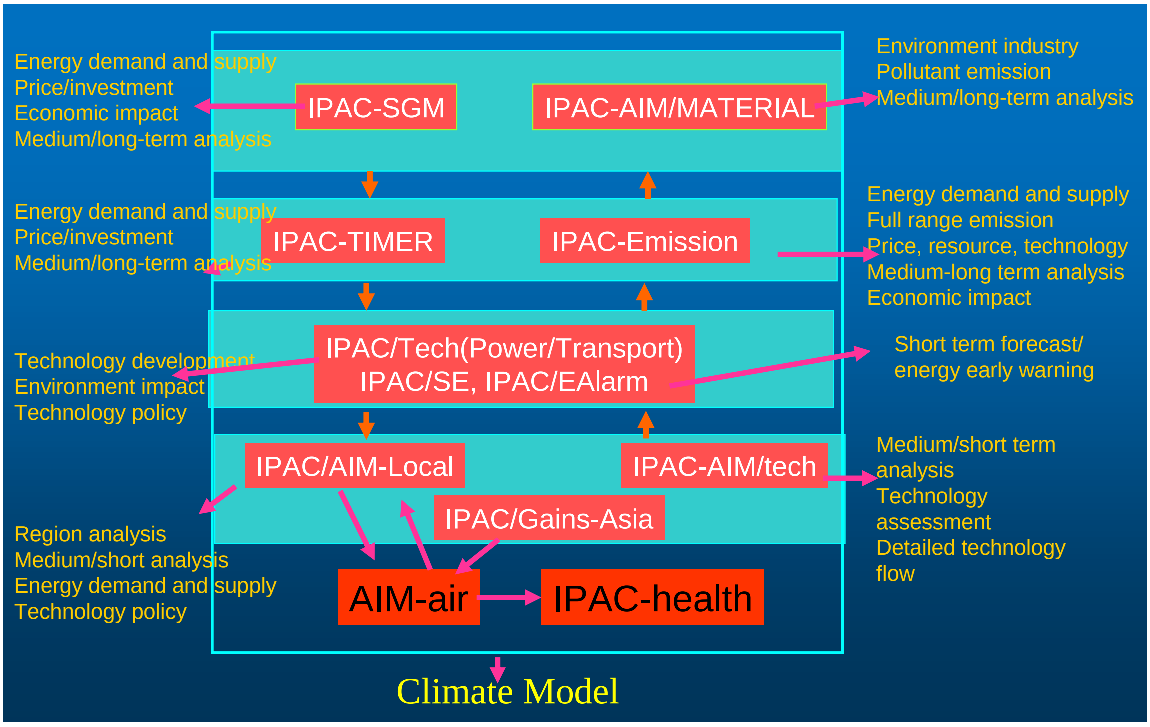
In this study, only the influence of CO_2 was considered. Given the scope of the analysis, other GHGs are not reported, but some are taken into consideration in the model.

4.1.2 Models

In this study, we use the Integrated Policy Assessment Model of China (IPAC) to provide quantitative analysis of the emissions scenarios. IPAC is an integrated model which was developed by ERI in order to analyse China's energy and environment policies. ERI has been doing long-term research on developing and utilising energy models since 1992. Since 2000, ERI has developed the China energy-environment integrated assessment model. This has benefited from several improvements over the past few years, which resulted in the IPAC model used for this analysis.

The structure of IPAC is shown in Figure 4.1. Except for the IPAC-emissions model, all modules in IPAC are currently soft-linked, which means that the output of one module is used as the input of another module.

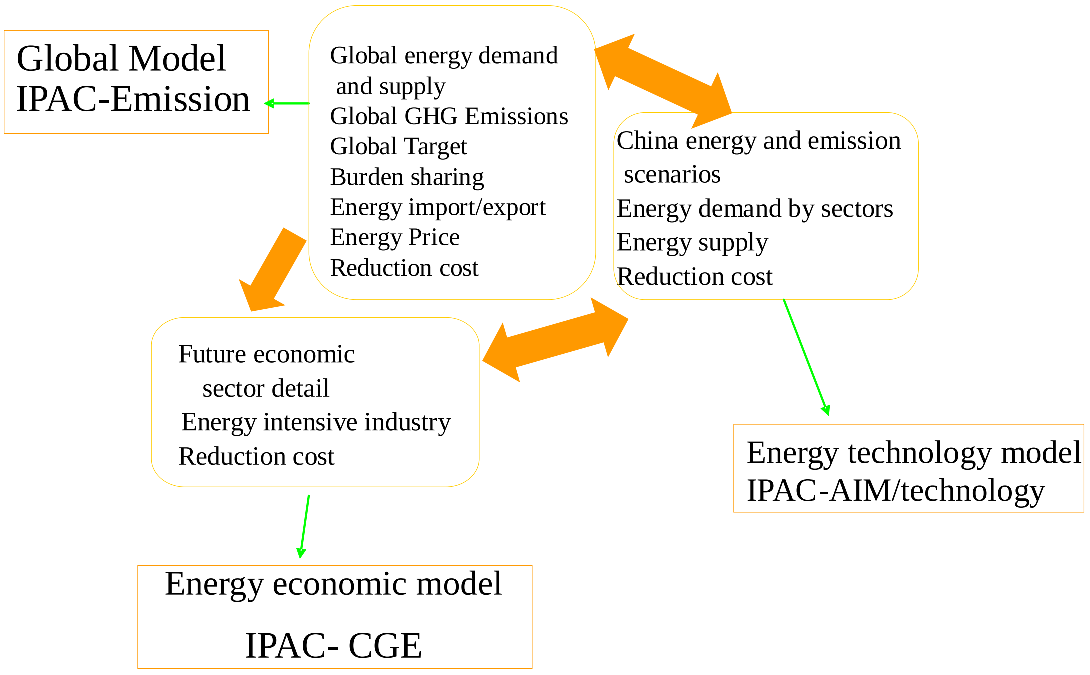
Figure 4.1: The integrated policy model for China: a framework



Source: ERI, China.

In this study we use three models in IPAC: the IPAC-CGE model, the IPAC-Emission global model and the IPAC-AIM/technology model. The links among them are shown in Figure 4.2.

Figure 4.2: Links among models in this research: the methodological framework


Global Model
IPAC-Emission
Global energy demand
and supply
Global GHG Emissions
Global Target
Burden sharing
Energy import/export
Energy Price
Reduction cost
China energy and emission
scenarios
Energy demand by sectors
Energy supply
Reduction cost
Future economic
sector detail
Energy intensive industry
Reduction cost
Energy technology model
IPAC-AIM/technology
Energy economic model
IPAC- CGE

The IPAC-Emission model is an extended version of the AIM-Linkage model used in the IPCC Special Report on Emission Scenarios. This model links social and economic development, energy activities and land use activities, which generate the overall emissions analysis. The temporal scope of the IPAC model is up to 100 years. The first 50 years have a more detailed analysis, with a time interval of 5 years; the latter 50 years have a time interval of 25 years.

IPAC-AIM/technology is the main component of the IPAC model. Its function is to give a detailed description of the current status and future development of the energy sector and its technologies and to simulate the energy consumption process sequentially. Under different scenarios, the model can calculate future demand for different types of energy from all energy end-use sectors and also calculate their CO_2 emissions. One of its most important functions is to evaluate the effect of different technology policies on technology diffusion and GHG reduction. The current version of the IPAC-AIM/technology model includes 42 sectors and their products and nearly 600 technologies, including existing and potential technologies.

IPAC-SGM is a general equilibrium model (CGE model); it models the impacts and interactions among various economic activities. Its main purpose is to analyse the economic outcome of different energy and environmental policies, and thus it can evaluate the impact of mid- and long-term energy and environment scenarios. IPAC-SGM divides the whole economic system into the following sectors: household, government, agriculture, energy and other production sectors; these can all be divided further, if necessary. Economic behaviour can be modelled for households, government and producers. The primary factors in the production sectors include capital, labour and land. The production sectors produce goods according to the combinations of these factors. The temporal scope of this study is from 2005 to 2050.

4.2 Scenario settings

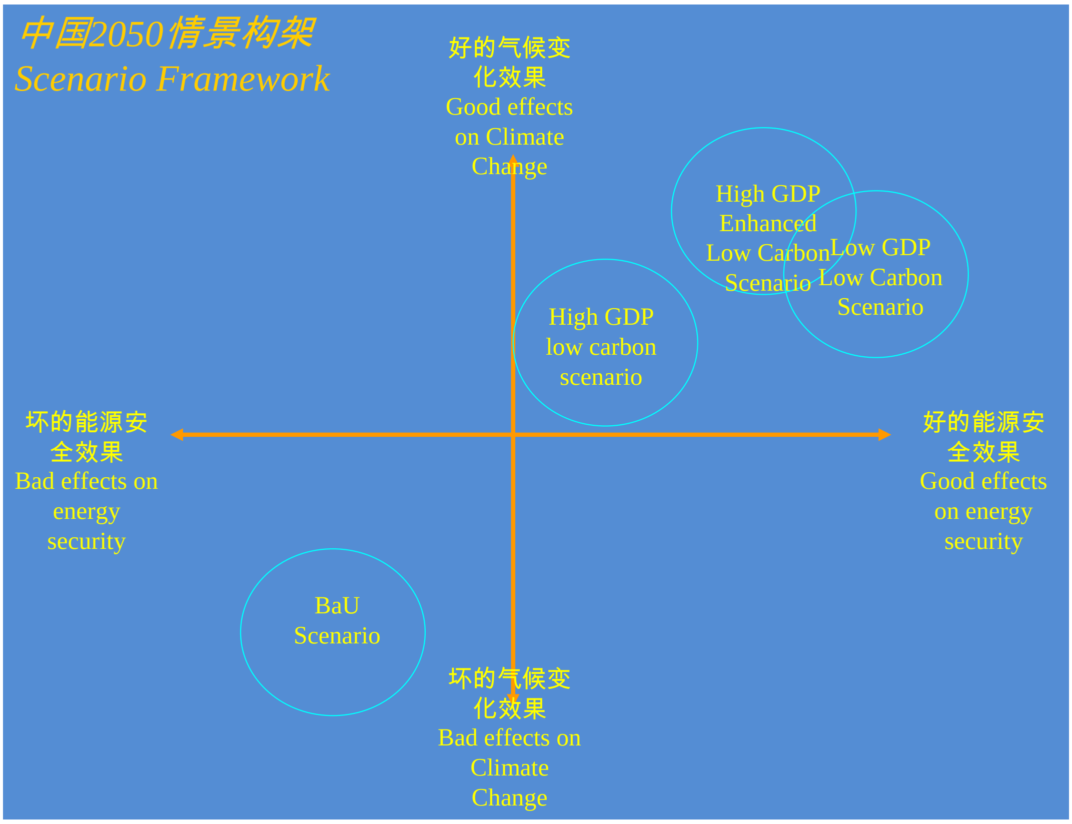
4.2.1 Scenario definition

In order to comprehensively reflect the possible GHG emissions paths in China and in view of previous scenario analyses to 2050 made by the IPAC modelling team, we design here four emissions scenarios based on several key factors closely related to future emissions (see Table 4.1).

Considering the uncertainty of economic development, we employ two GDP growth rate assumptions in the scenarios, corresponding to two kinds of economic structure.

We analyse mainly the low carbon scenario under the assumption of high GDP growth rates, but another low-carbon scenario, which assumes low GDP growth rates, is also explored. Figure 4.3 illustrates the main scenarios.

Figure 4.3: The low carbon scenarios: a framework



A key characteristic of all modelling carried out for these scenarios is the exogenous assumptions about growth rates. In other words, these scenarios do not explore what level of economic growth China can attain in a low carbon world. They describe the characteristics that the Chinese economy would need to have in order to meet current economic growth expectations in a low carbon world and an enhanced low carbon world. They focus mostly on how the supply side of the economy will need to change so as to be able to generate the same amount of economic growth with considerably less carbon.

The first scenario is the Business-As-Usual Scenario, which means implementing no climate change policies under the high GDP growth rate assumption. The key driver in this scenario is economic development. According to the results of previous scenario analyses, the scenario reflects a continuation of the economic development path for the next 50 years. Population will grow according to the national population plan, i.e. reach a peak of 1.47 billion between 2040 and 2050.

The second scenario is the Low Carbon Scenario (LC) under a high GDP growth rate assumption. This is the energy and emissions scenario that can be realised by unilateral domestic effort. It takes into account factors of national energy security, domestic environment and low carbon development strategy. This scenario mainly takes into account domestic social and economic development requirements and domestic environment development demands. Factors such as enhanced technology improvement, changes in modes of economic development, shifts in consumption behaviour and the realising of low-energy and low GHG emissions have been considered. This is the low carbon emission scenario which can be realised by domestic policies.

The third scenario is the Enhanced Low Carbon Scenario (ELC) under a high growth rate assumption. This scenario takes into account a shared vision of concurrent global efforts to mitigate climate change and assumes that China can make further GHG emissions reduction contributions than in the LC scenario. In this global efforts scenario, technology development is faster and deeper; the cost of key technologies decreases more sharply; and policies in the developed countries expand to developing countries. Also under the assumptions used for this scenario, China increases its investment in a low carbon economy, taking advantage of low carbon opportunities to contribute to its economic growth and development after 2030 as it becomes the largest economy in the world. Meanwhile, China will become a global leader in developing some of these technologies, such as clean coal and CCS, with large-scale deployment of CCS technologies in China. The enhanced low carbon scenario focuses on the supply side rather than on drastically changing consumption levels or patterns.

The fourth scenario is the Low Carbon Scenario under a low growth rate assumption (LLC). Assumptions for this scenario are similar to the other low carbon scenarios, with the exception of lower growth rates. For a more detailed view of these scenarios, see Table A-1 in the Appendix.

Table 4.1: The four scenarios: a description

Scenario	Abbreviation	Description
BAU under high growth rate	BAU	Average annual growth rate between 2005 and 2050 is set to be 7.5%, representing the high economic growth obtained in previous analyses. Characterised by high consumption and global investment, local pollution control, huge investment in technology and rapid technology improvement.
Low carbon scenario under high growth rate	LC	Considers factors such as sustainable development, energy security and economic competitiveness. High energy saving standards, renewable energy and nuclear power generation developments and CCS technology. Medium investment in low carbon economy under full development of the Chinese economy.
Enhanced low carbon scenario under high growth rate	ELC	Global mitigation of GHG emissions, realising a low GHG stabilisation target. Main mitigation technologies are further developed and have a faster decline in cost. High investment in low carbon technologies. CCS used on a much larger scale.
Low carbon scenario under low growth rate	LLC	The low carbon emissions path that China can achieve, considering the requirements for low carbon development from China and the demand for global emissions reduction.

4.2.2 The Setting of the Specific Scenarios

Growth of GDP

a) High GDP growth assumption

The assumption in three of the four scenarios is that the structure of development of the Chinese economy and population are very close to the national development target. After years of research and evaluation, this development structure is a widely accepted as the most beneficial economic development mode.

In this study, we take the three-step target in the national development plan as both a mid- and a long-term development target, which is to reach the developed countries' current level by 2050. In this scenario, China's industrial structure needs to be adjusted and reformed owing to the change of the domestic and international market environment. Especially after China's admission to the World Trade Organization, its industries will become increasingly globalised. In the coming decades, China will therefore be at the centre of global manufacturing; exports will be an important factor driving economic growth. But in view of the rapid development of the Chinese economy, after 2030 domestic demand will become the main driver of economic growth. The competitiveness of the international manufacturing sector will decrease because of the rapid increase in labour costs in China. To counterbalance this loss of competitiveness, China will take a series of effective measures to change its economic structure, upgrade the industrial structure and enhance the international competitiveness of its advanced industry.

These measures will allow China to maintain a high growth rate during this period of continuous adjustment. It is estimated that between 2005 and 2050, China will have an annual average growth rate of 6.4%. The economic growth for each period is shown in tables 4.2.

Table 4.2: GDP growth rate, 2005–2050 (%)

	2005–2010	2010–2020	2020–2030	2030–2040	2040–2050	2005–2050
GDP	9.73	8.55	6.44	4.56	3.38	6.15
Primary industry	5.15	4.28	2.65	1.91	1.34	2.83
Secondary industry	10.32	7.99	5.56	3.19	2.16	5.31
Tertiary industry	10.33	9.99	7.68	5.77	4.20	7.26

Table 4.3: Structure of GDP, 2005–2050 (%)

	2005	2010	2020	2030	2040	2050
Primary industry	12.4	10.0	6.7	4.7	3.6	3.0
Secondary industry	47.8	49.0	46.6	42.9	37.6	33.4
Tertiary industry	39.8	40.9	46.7	52.5	58.8	63.7

Source: ERI, 2009

As is clear from the tables, the engine of growth in this scenario is increasingly the tertiary sector. The industrial sector retains an important position in terms of its contribution to growth; but by the end of the scenario period in 2050, it accounts for only one third of total GDP, down from over half in 2005. We use the IPAC-SGM model to analyse this in a more detailed and sector-by-sector assessment in order to evaluate its contribution to changing the structure of the Chinese economy. This is a new task for the IPAC modelling team, and it was carried out taking into consideration existing research in this field. The detailed results are shown in Table 4.3. The main results confirm the overall trend in terms of the role of the tertiary sector in creating value added in the economy and accounting for the greatest level of GDP growth over the next decades. This analysis highlights that some secondary sectors, namely the high value-added high technology sectors and the energy sector, continue to have a strong impact in terms of the value added to the Chinese economy.

b) Low GDP growth rate assumption

China’s economic development, as indicated by a number of studies, could also take a lower GDP growth path. This would still be comparatively high compared to many other national economies. This lower growth rate is close to China’s national economic development plan targets. In the low carbon low growth rate scenario, the economic structure is further adjusted and sustainable development capacity is strengthened. Energy-saving goals continue to be implemented; renewable energy also develops significantly. Great attention is paid to domestic environmental problems and climate change issues. The detailed assumptions are shown in tables 4.4 and 4.5.

Similar to the high-growth scenario, the structure of the economy changes significantly in this scenario. The tertiary sector assumes increasing importance in terms of its value added while the primary and secondary sectors become less important (see Table A-2 in the Appendix).

Table 4.4: China’s GDP growth rate (%) by industry, 2005–2050

	2005–2010	2010–2020	2020–2030	2030–2040	2040–2050	2005–2050
GDP	9.73	7.71	5.81	4.14	3.07	5.66
Primary industry	5.15	4.12	2.56	1.84	1.29	2.74
Secondary industry	10.32	7.00	4.86	2.75	1.85	4.77
Tertiary industry	10.33	6.96	4.88	2.78	1.89	6.78

Table 4.5: Economic structure in the low growth rate scenario (%), 2005–2050

	2005	2010	2020	2030	2040	2050
Added value of primary industry	12.4	10.0	7.1	5.2	4.2	3.5
Added value of secondary industry	47.8	49.0	45.9	41.9	36.7	32.6
Added value of tertiary industry	39.8	40.9	47.0	52.9	59.1	63.9

Source: ERI, 2009

Population and Urbanisation

Population forecasts, which are common to all scenarios, are based on recent plans and research results. The government will keep regulating and controlling population growth in China. Birth conditions in rural areas will be improved and unplanned births will be reduced. The population in China will move forward according to the current trend.

In the latter years of the scenarios, along with the gradual natural reduction in population after the projected peak the government will loosen control of population growth. In this study we use population growth projections from the National Family Planning Commission and use the IPAC-population model to analyse trends. According to these projections, China's population will peak between 2030 and 2040. The peak level will be about 1.47 billion. By 2050, the population will decrease to 1.46 billion. The population in different periods is shown in Table 4.6.

The rate of urbanisation reported in the table is the result of current and future urbanisation trends and the effect of the migration of the labour force from rural areas. In the long term, employment and living standards in rural areas will reach the level of developed countries. Agricultural production standards will be modern enough that the labour demand for agriculture will be close to the level in developed countries. All the above factors will accelerate the urbanisation rate of China. Taking all those factors into account, the urbanisation rate assumptions are therefore higher than in comparable studies.

Table 4.6: Population and urbanisation, 2005–2050

	2005	2010	2020	2030	2040	2050
Population (mn)	1,308	1,360	1,440	1,470	1,470	1,460
Urbanisation rate (%)	43	49	63	70	74	79
Urban population (mn)	562	666	907	1,029	1,088	1,138
Average number of persons per urban household	2.96	2.88	2.80	2.75	2.70	2.65
Number of urban families (mn)	190	222	288	337	365	380
Rural population (mn)	745	694	533	441	382	302
Average number of persons per rural household	4.08	3.80	3.50	3.40	3.20	3.00
Number of rural families (mn)	183	190	181	160	152	144

We also use the IPAC-population model to analyse age distribution, mainly with reference to the labour supply and consumption behaviour. Birth rates in the future are projected to decrease proportionally with increasing income levels. We use the current birth rate in Japan to simulate China's birth rate in 2030.

Industrial Development

From the high- and low-growth scenarios analysis above, it is clear that by 2030 industry will still have a major role in generating GDP growth. Industry is also the main energy consumer. Therefore, in the mid-term and long-term it is useful to have a detailed analysis of this sector. We focus on the energy-intensive industries, describing the sectoral scenarios 30 to 50 years in the future. A lack of detailed analysis of industrial sectors has been a shortcoming of past energy scenario analyses. Generally, studies would generate assumptions on industry sectors by discussing with sectoral experts the future development of energy-intensive sectors. However, as there are few in-depth studies addressing this matter, there are usually large differences between different studies, which may cause much uncertainty and reduce the reliability of energy demand forecasts. In order to further understand the future development of industrial sectors and better predict trends in energy-intensive sectors and other sectors, we have used a combination of analytical methods. This will not only supply input parameters for the model but also provide a basis to compare our methodology, data and results with other studies.

We adopt the following three analytical approaches:

1) The first method uses the IPAC-CGE model to predict the future economic development of the industrial sectors. This forecasts sectoral growth and analyses the sector-level output from the general economic development perspective, which is a novel research methodology. However, as no similar research has been done domestically before, there are still some uncertainties in this method. Nonetheless, we are convinced that this will become an important methodology, which may interest other research groups.
2) The second approach is based on the detailed applications of means to predict the future development of the industrial sectors. This is similar to the input-output analysis method, which can also be regarded as an extension of the first method. For example, we can forecast the demand for iron and steel by analysing the development of downstream sectors.
3) The third method is to refer to sectoral analysis and sectoral experts, which is a commonly used approach.

We report the output of major industrial sectors from the IPAC-CGE model in the Appendix (tables A-3 and A-4). The main conclusions from this analysis are that for the low carbon and enhanced low carbon scenarios (which share the assumptions about industrial structure), the production levels of most large energy-intensive sectors (such as iron and steel, aluminium, cement etc) peak in about 2030 and then, by 2050, decrease to levels similar to 2005. In the low-growth scenarios, the decrease in production levels is even steeper, owing to lower demand associated with more moderate economic growth.

4.3 Settings of technology parameters in the model

4.3.1. Energy consumption per unit of energy-intensive products

Although assumptions about the structure of the industrial sectors are common in all high-growth and low-growth scenarios, an important differentiation of the scenarios comes from different assumptions on energy consumption per unit of product in the BAU, low carbon and enhanced low carbon scenarios. Using different assumptions on the adoption of new energy technologies (more efficient and with less emissions), we obtain assumptions of energy consumption per unit of energy-intensive products in each sector, as shown in Table 4.7. The energy-intensity data already take into consideration the efforts made by China in energy saving. Therefore, this data will also be suitable for the low growth rate low carbon scenario. Generally, the effect of energy-saving technologies in the low growth rate scenario will be not as good as in the high growth rate scenario as a result of the lower level of investment. However, these advanced energy-saving technologies in China will experience rapid development, and their incremental cost would not be obvious. So the indicators in Table 4.7 are still appropriate in the scenario of a low growth rate.

Table 4.7: Energy consumption per unit of energy-intensive products in a high growth rate, low carbon scenario, 2005–2050

	Unit	2005	2020	2030	2050
Iron and steel	Kgce/t	760	650	564	525
Cement	Kgce/t	132	101	86	81
Glass	Kgce/weight cases	24	18	14.5	14
Tile	Kgce/10^4 bricks	685	466	423	410
Ammonia	Kgce/t	1,645	1,328	1,189	1,170
Ethylene	Kgce/t	1,092	796	713	705
Sodium carbonate	Kgce/t	340	310	290	280
Caustic soda	Kgce/t	1,410	990	890	860
Calcium carbide	Kgce/t	1,482	1,304	1,215	1,130
Cooper	Kgce/t	1,273	1,063	931	920
Aluminum	kWh/t	15,000	12,870	12,170	12,000
Pulp and paper	Kgce/t	1,047	840	761	740
Thermal power generation	Gce/kWh	350	305	290	271

4.3.2. Urban households

Along with increasing income, demand for better standards of living will gradually increase. For northern households, the requirements of extending heating hours in winter and increasing air conditioning use in summer will become essential. For households in transition areas and southern areas, having space heating in winter and extending air conditioning use in summer will become common. Meanwhile, there will be more energy-saving electric appliances and more renewable energy available to households. A detailed description of the assumptions about household technology choices is available in the Appendix (see Table A-5).

4.3.3. Rural households

Considering the rise in rural household income, there will be a substantial increase in energy demand in rural areas. After 2030, the income level of rural households will be much higher: households will own electric appliances and there will be no obvious differences between rural and urban energy service intensity. Detailed assumptions are listed in the Appendix in Table A-6.

4.3.4. Service industry (excluding transportation)

The main drivers for energy demand in the construction sector, which is the largest component of the service sector, are the building sector and the energy services it supplies. The purposes of buildings can be divided into the following categories: commercial, education, government, hospital, financial services etc. Our analysis looks at all these types of building. All of our assumptions indicate a substantial increase, over the time span of the scenarios, in both the average areas of public and residential buildings and in the demand of energy they generate. These assumptions are common to all scenarios. More details are available in the Appendix (see tables A-7 and A-8)

4.3.5. Assumptions about the transportation sector

The drivers of the future development of transportation are economic growth and an increase in disposable income. Economic growth is the main driver for freight volume increase while an increase in disposable income is the main driver for passenger volume.

There is a strong relationship between freight volume and economic growth, as has been proven by several studies (World Bank, 2000; Zhu Songli, 2004; and others). Even in highly developed countries such as the US, Japan and the EU, the elasticity between freight volume and GDP is still about 1. However, considering the current freight transportation structure in China, we need a more detailed analysis of the future development of freight volume.
As a result of increasing disposable income, travel demand is likely to increase substantially together with changes in the means of transportation. These two factors are essential for forecasting passenger volumes.

To forecast the future transportation regime accurately, we divide cities into different categories according to their population. Different categories of city will have different urban transportation modes. One of the main objectives of categorising cities is to analyse public transportation, in particular the development of rail transportation, as well as the possible strategies to control road transportation for different cities.

Cities with a population of more than 5 million are suitable for developing rail transport. Rail transport should take up the dominant share of commuting. If the population is around 1 million, a city should develop mainly non-rail public transportation. Smaller cities can depend mainly on small vehicles, bicycles and walking.

Despite this, the number of vehicles is projected to increase substantially between now and 2050, with demand going from today's 30 million vehicles to approximately 600 million by 2050, the great majority of which will be passenger cars. The estimations under the low carbon scenarios are lower, with the total number of vehicles reaching approximately 550 million by 2050. A stronger difference between the scenarios emerges in terms of miles driven by car, suggesting a much stronger role for public transport in the low carbon scenario (see tables A-9 to A-14 in the Appendix).

4.4 Energy Consumption, Emissions and Cost in Different Scenarios

4.4.1. Energy consumption and the total amount of emissions

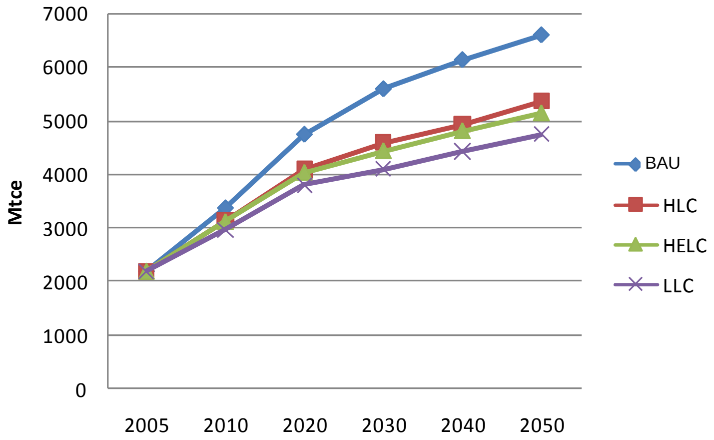
Based on the assumptions described above and using the IPAC-AIM/technology model, energy and emission scenarios for China were produced. The main outcomes in terms of energy demand and emissions can be seen in figures 4.4 to 4.6, and details can be found in the appendix (see tables A-15 to A-30 in the Appendix).

In all the scenarios, energy demand in China will continue to increase: primary energy demand is projected to increase steadily up to 2050, reaching 4.7 to 6.6 billion tonnes standard coal by 2050 in the scenarios. The difference between total primary energy demand in BAU and the low carbon scenario is significant: under the BAU, demand triples by 2050; under the most stringent enhanced low carbon scenario, it doubles. In terms of the energy mix, under the BAU, coal accounts for the largest share of produced energy (44%), followed by oil (27.6%), natural gas (10%), nuclear power (9%), hydro power (6%) and renewable energy such as wind and biomass power (3.4%). Under the low carbon scenario, in 2050 coal also remains the main energy source, with a lower share of 37% of total primary energy demand, followed by oil with 20.2%. Natural gas (14.4%), nuclear power (14.2%), hydro power (8.4%) and renewable energy (5.4%) have larger shares of primary energy.

Under the enhanced low carbon scenario, CO_2 emissions will decrease after 2030. Emissions in 2050 in the enhanced low carbon scenario are significantly lower (48%) than even the low carbon scenarios, reflecting the strong emissions reductions technologies adopted in this scenario. Based on the further strengthened energy-saving measures assumed for the enhanced low carbon scenario, total primary energy demand is 4.5% lower in this scenario than in the low carbon scenario.

Renewable energy and nuclear power account 58% of total, up by 7 percentage points when compared with low-carbon scenario. Also contributing to the lower emissions levels are assumptions about CCS: coal-fired power plants in the enhanced scenario are equipped with integrated gasification combined cycle (IGCC) and CCS after 2020, and high energy-consumption industries such as steel and iron, cement, electrolytic aluminium, synthetic ammonia, refining and ethylene also adopt CCS extensively. Assumptions about buildings also play a significant role in contributing to lower emissions: new buildings widely adopt renewable energy technologies, such as solar water heating and solar heating while wind power for households and solar photovoltaic will be installed in appropriate buildings and areas.

Figure 4.4: Primary energy demand, 2005–2050



The assumptions of the different scenarios have a significant impact on the estimated overall and per capita emissions in China by 2050. Emissions in 2050 range from 9t CO_2 per capita in the BAU scenario, a threefold increase from current levels, to the 3.5t CO_2 per capita in the lowest emission scenarios, a common result for the enhanced low carbon/high-growth scenario and the low carbon/low growth scenario. The low carbon/high-growth scenario comes in the middle, with per capita emissions of just above 6t CO_2.

Figure 4.5: CO2 emissions, 2005–2050

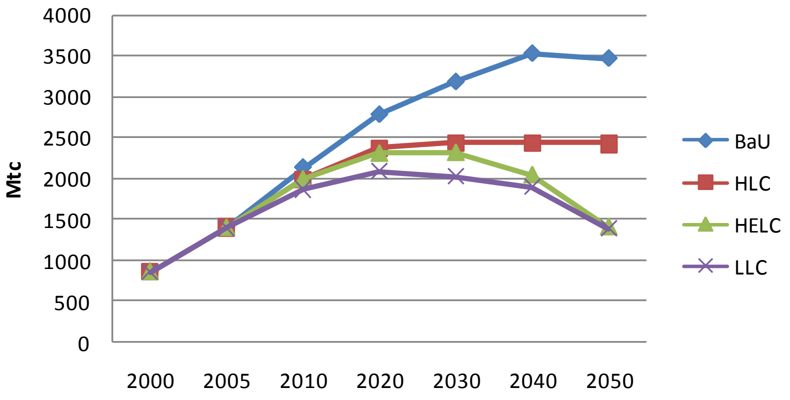
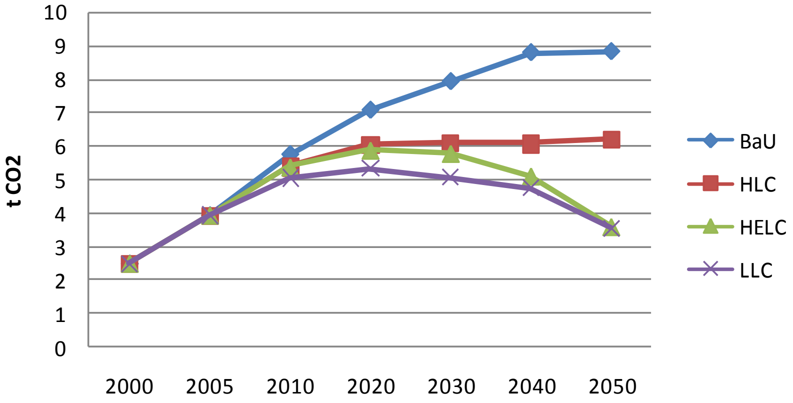


Figure 4.6: CO2 emissions per capita, 2005–2050



Source: ERI, 2009

Improving energy efficiency is the main driver of emissions reductions in the low carbon scenario. The annual decrease rate of energy intensity (energy per unit of GDP) is considerably stronger in the low carbon scenario compared to the BAU scenario (see Table 4.8). In particular, the industry sector has the greatest potential for improving energy efficiency; and under the low carbon scenarios' assumptions, the industry energy consumption per unit of output decreases by almost 5% annually.

Table 4.8: Rates of decrease of energy intensity of GDP (%), 2005–2050

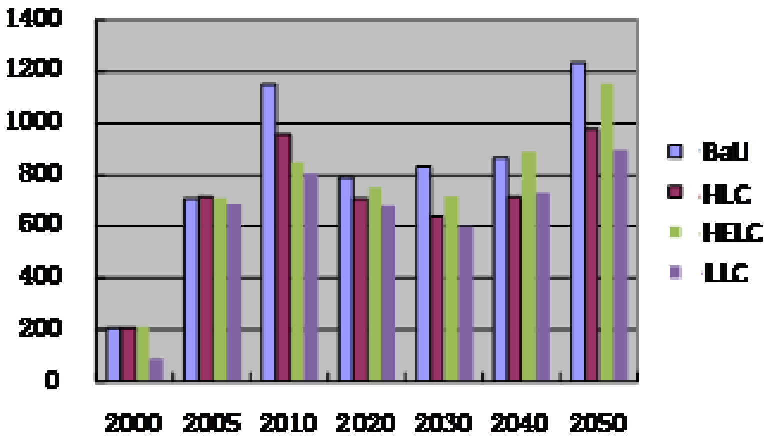
	2005–2020	2020–2030	2030–2040	2040–2050
Reference scenario	3.5	4.7	3.2	2.6
Low carbon scenario with high GDP growth rate	4.2	5.0	3.6	2.5
Enhanced Low carbon scenario with high GDP growth rate	4.4	5.2	3.5	2.5
Low carbon scenario with low GDP growth rate	4.3	4.8	3.2	2.3

4.4.2. Investment and cost in a low carbon economy

Another important characteristic of the low carbon scenario is the significantly higher levels of investment in low carbon technologies compared to the BAU scenario. The investment levels and cost analysis are illustrated in figures 4.7 to 4.9.

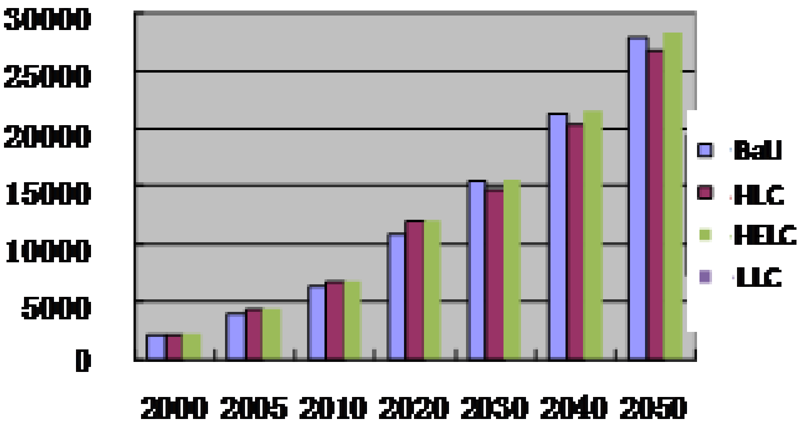
Under the low carbon scenario, energy demand is lower and therefore so is the investment required in the energy sector. But on the other side, the cost of technology under the low carbon scenarios is higher, as new low carbon technologies need to be developed, which calls for greater investment. The balance of these two trends is that energy investment under low carbon scenarios is marginally less that in the reference scenario.

Figure 4.7: Investment needed by the energy industry, 2000–2050 (billion yuan)



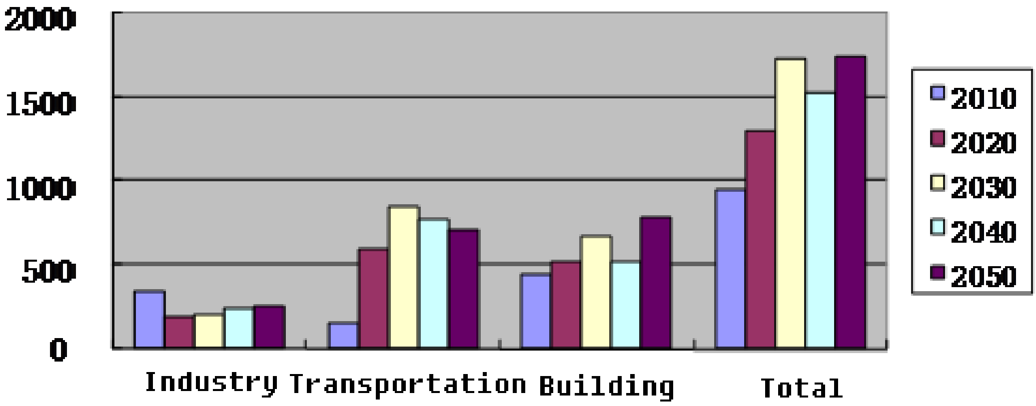
Total energy expenditure is another important index for measuring the input a country has made in energy sectors. Energy expenditure is the product of final energy demand and the energy price. As we pointed out earlier, final energy demand is lower under the low carbon scenario because of energy saving efforts, resulting in lower energy expenditure. On the other side, the price of energy is higher in this scenario, as both an energy tax and a carbon tax are assumed to be introduced, leading to an increase of energy expenditure. Again, the balance of these two effects is lower expenditure under the low carbon scenario compared to the BAU scenario. Furthermore, if the energy tax and the carbon tax are not taken into account, energy prices under the low carbon scenario will be lower than that of the BAU scenario.

Figure 4.8: Energy expenditure in the four scenarios, 2000–2050 (billion yuan)



Incremental investment is needed under the low carbon scenario in order to support the necessary infrastructure for delivering a low carbon economy. The transport and building sectors are the ones in which most of the extra investment will be required.

Figure 4.9: Extra investment needed under the low carbon scenario, 2010–2050 (billion yuan)



In this scenario we also use the IPAC-Emission model in order to evaluate the macroeconomic impact of emissions reductions in the context of global action on climate change. Three global emissions objectives are studied in this analysis - realising a concentration of 650ppmv (parts per million by volume), 550ppmv and 450ppmv in terms of CO_2. The convergence of emissions per capita and carbon emissions intensity reduction objectives are also analysed, as they are quite frequently mentioned in recent research.

Table 4. 9: Economic loss and emissions reduction rates in all scenarios,* 2010–2100

	2010	2020	2030	2050	2075	2100
Rate of GDP Net Loss (%)						
650	-0.1	-0.1	1.2	1.1	0.9	0.9
550	-0.2	-0.2	1.9	2.0	2.0	2.4
450	1.4	2.3	2.9	3.7	3.9	4.8
Emissions reduction per capita	-0.2	-0.2	-0.1	-0.1	0.7	1.5
Carbon emissions intensity	-0.2	-0.2	-0.1	-0.1	-0.2	-0.2
Rate of CO_2 reduction (%)						
650	-1.5	-1.7	18.8	22.6	27.7	30.5
550	-2.6	-2.4	29.1	40.6	51.6	58.0
450	14.7	30.0	41.6	62.4	69.0	75.0
Emissions reduction per capita	-2.6	-2.4	-1.9	-1.8	27.3	48.5
Carbon emissions intensity	-2.6	-2.4	-1.9	-1.8	-4.0	-3.1

* Percentage changes in total GDP. Positive signifies net loss; negative indicates net benefits.

One of the key assumptions in this simulation is that developed countries begin to reduce emissions before developing countries. This implies that energy prices in developed countries rise quickly, so that products from developing countries become more competitive, bringing benefits to the developing countries' economies. This is a controversial effect, as developed countries may put in place policies to protect their loss of competitiveness owing to a carbon price.

Under the 450 ppmv stabilisation scenario, developing countries start reducing their emissions in 2010. This implies a loss to the economy of developing countries which is projected to be 4.8% of GDP by 2100. However, the analysis does not take into account technological progress and the benefits this creates for the economy at large: once this effect is taken into consideration, overall GDP loss will decrease.

Under the scenario of carbon emissions intensity reduction, China will experience an increase in GDP because of the 'leakage' effect as well as an increase in its CO_2 emissions because there is no further request to China for emissions reduction (while developed countries need to reduce their emissions substantially).

By analysis of the effect of reduction strategies on China's GDP, the following basic conclusions can be drawn:

- Large-scale emissions reductions could harm the Chinese economy.
- The earlier the country starts to plan for reducing emissions, the lower the cost. If a country can prepare for emissions reduction 10 or 20 years earlier and adapt to the need for investment and capital for technological change, this can relieve the negative impact on the economy.
- Technology is the key element for achieving emissions reduction objectives. The cost of emissions reduction depends on emerging technologies. Thus technological innovation will be important for implementing emissions reductions all over the world. In particular, the research and development of key technologies will be of great importance. China should focus on the introduction of new technologies and strengthen its capability in advanced technology, with a particular focus on energy-efficiency innovation. At the same time, more investment should be dedicated to research and development of advanced technologies such as clean coal technology, which is likely to be attractive to coal-intensive economies (including China, the US, Australia, South Africa and Japan) and will have a large effect on China.
- Under the 450 ppmv stabilisation scenario, the loss to the economy is projected to be 4.8% of GDP by 2100. Correspondingly, the GDP growth rate per annum during the period from 2000 to 2100 will decrease to 4.19% from 4.23%.

4.4.3. Preconditions and steps for undertaking low carbon development in China

From now to 2050, the energy demand of China will increase together with a continuous and steady improvement in living standards and the economy. In this context, it is necessary to increase efforts to reduce energy consumption to meet energy demand reduction targets such as those described in the low carbon policy scenario. Measures that can be adopted include optimising the structure of the economy and energy production, establishing and perfecting energy markets and meeting annual energy-saving targets (2.59%) to 2050 by adopting advanced technologies. Analysis indicates that the ratio between energy and economic growth in China under the low carbon scenario would be 40–65%, which implies that energy elasticity will be 0.40–0.65, much lower than that of developed countries in their economic takeoff period. In the next 40 years, greenhouse gas emissions will also rise given the projected increase in energy consumption. As we observed earlier, under the BAU scenario CO_2 emissions in 2050 will be almost 3.4 billion tonnes of carbon; that of the low carbon policy scenario may be 35% lower.

The development of technologies for energy conversion, utilisation and supply will have a great impact on the trends for energy demand and greenhouse gas emissions. Furthermore, it determines the quantity, quality and sources of energy supply and is therefore the cornerstone of low carbon development. For this reason, it is crucial to combine policies on technology development with policies addressing climate change, in particular to make use of the natural resources of China to develop the exploration, conversion and utilisation of clean energy. This will enable China to simultaneously promote the development of energy, the environment and the economy.

The feasible approaches for China to create a low carbon economy include:

- optimising the industrial structure, controlling the development of energy-intensive industries and reducing consumption of energy-intensive products;
- ensuring that the energy efficiency of Chinese industry reaches the highest or best available international level by 2025;
- developing renewable energy technologies, diffusing wind power and hydropower and building demonstrations of solar thermal and photovoltaic technologies;
- comprehensively developing nuclear power, especially the third and fourth generation of nuclear power technology;
- improving public awareness and ensuring that a low carbon lifestyle is widely accepted; and
- developing low carbon agriculture and strengthening forest cover and forest management.

The current trend in energy-saving and emissions reduction in China is in line with the low carbon development objective. Thus the objective of developing a low carbon economy in China is not a new approach but a deepening and extension of present national energy, environment and sustainable development policies.

A comprehensive approach to policy is needed in China, and should be integrated in the near future. Currently there are a number of policy elements which need to be coordinated. The current energy-saving policy of China is perceived from the global point of view as an emissions reduction policy. But there are several other policy elements which will contribute to emissions reductions. For instance, in 2006 China identified renewable energy development as a key objective, which means that the proportion of renewable energy in energy consumption may double. The hybrid electric vehicle, the hydrogen fuel vehicle and the pure electric vehicle will be launched in the Chinese market soon. The price will be appropriate to local demand – much lower than the Toyota hybrid vehicle. The lower price for hybrid electric vehicles will attract more vehicle manufacturers to the Chinese market. The government is likely to encourage public transportation and to issue laws and regulations to control exhaust emissions. Meanwhile, biofuels are developing rapidly in China, with second-generation technologies emerging quickly.

The opportunity for China to develop a low carbon economy will constitute a substantial comparative advantage. Compared with Japan, the US and European countries, China can develop a low carbon economy at lower cost. For instance, taking into account the cost of fuel, the overall cost of coal power supercritical units is lower than that of conventional thermal power generation. Although the initial investment for supercritical units is relatively high, the development of low carbon technology is made easier by the abundance of capital in China. There is little time left for China to develop supercritical units, as it is necessary to start the next generation of power generation technology-IGCC and to lay the foundation for CCS. Chinese power station equipment manufacturers have paid much attention to IGCC technology. They have put a large amount of private investment into the development of the technology; this is the result of cooperation between multiple stakeholders.

As for the design of a carbon tax, different studies have arrived at different conclusions. According to our analysis, it is better to implement a fuel tax at first, then an energy tax and finally a carbon tax. The essential point is that China has to make the most of the present opportunity in order to support the carbon reduction of related industries.

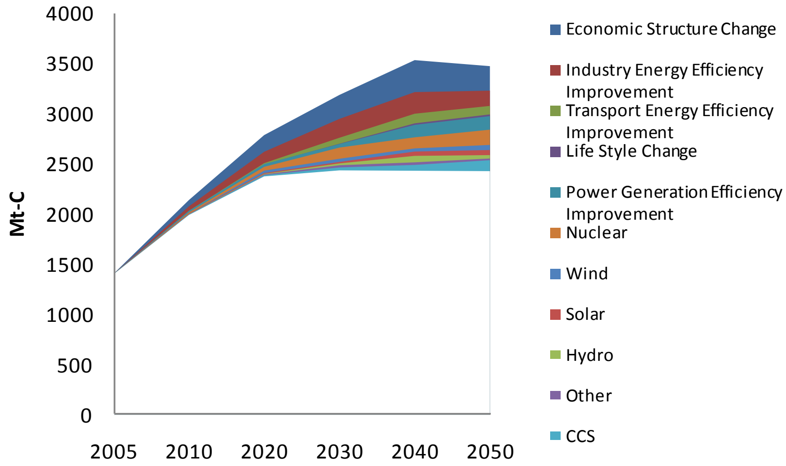
As climate change has become a threat for the whole of humankind, we have no choice but to develop a low carbon economy. It is possible, however, that the low carbon economy will become a new trend in international economic development and lead to a change in the terms of trade, in international markets and in patterns of international technology competition. The EU has already decided that a low carbon economy will be at the heart of Europe's development strategy. In 2007 it was pointed out at the United Nations Conference on Climate Change held in Bali that we are all supposed to change to a low carbon economy mode, prompting a low carbon lifestyle. According to the basic consensus in the Kyoto Protocol, all countries have a responsibility to address climate change and greenhouse gas emissions, with developed countries having the heavier responsibility. Many of those countries are indicating their willingness to support and help developing countries to develop a low carbon economy. Thus implementing a low carbon economy is imperative, and will provide huge opportunities to society as well as for economic development.

In the short term, the present energy-saving policies and renewable energy development policies in China are compatible with the objective of moving to a low carbon economy. Energy-saving technology development in China aims at reaching the highest energy efficiency standards in the world between 2020 and 2030 through a comprehensive effort across the economy. After 20 years of strong development in this direction, new infrastructure will mostly be equipped with advanced energy-efficiency technologies. For example, the NDRC has already issued a regulation to request all the newly built thermal power plants to adopt supercritical and ultra-supercritical units.

4.4.4. The emissions contribution of major factors

The key factors contributing to emissions reduction in the low carbon scenarios can be seen in Figure 4.10. The change in the structure of the economy, with a move from energy-intensive industry to the service sector, is a key contributor to emissions reductions. But it is energy efficiency, across industry and transport and in lifestyle changes, that plays the most important role in containing emissions: by 2050 it will contribute 66% to emissions reduction. Other important factors include nuclear power, which will contribute 13.4%), renewable energy (9%) and CCS (9%).

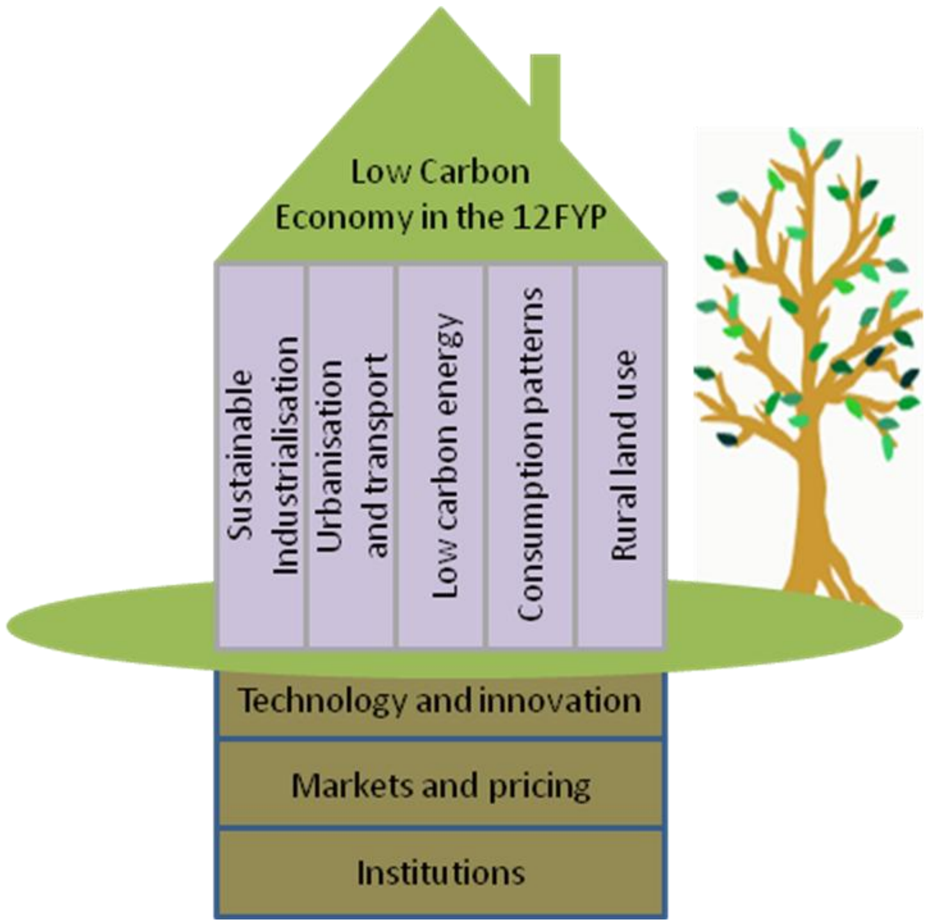
Figure 4.10: Key factors contributing to CO2 emissions reduction under the high-GDP, low carbon scenario, 2005–2050


4000
3500
3000
2500
2000
1500
1000
500
0
Mt-C
2005
2010
2020
2030
2040
2050
Economic Structure Change
Industry Energy Efficiency Improvement
Transport Energy Efficiency Improvement
Life Style Change
Power Generation Efficiency Improvement
Nuclear
Wind
Solar
Hydro
Other
CCS

5. A roadmap for China's low carbon development

This chapter and Chapter 6, based on the scenario analysis in Chapter 4, describe the road map for China's low carbon development from the prospective of development goals and the main approaches and policy choices. Figure 5.1 shows the framework of the road map. In general terms, the five pillars and three bases for low carbon development constitute the low carbon road map. The five pillars include new and low carbon industrialisation and urbanisation, sustainable consumption patterns, low carbon energy resources, the optimisation of the energy structure, the optimisation of land use and increasing carbon sinks. The bases of low carbon development are technological innovation, market mechanisms and institutional systems. This chapter will discuss low carbon economic development objectives, the five pillars and their technological basis. Market mechanisms and institutional systems will be addressed in Chapter 6.

Figure 5.1: Five pillars for China's low carbon development



5.1. A major strategic choice for China

Scenario analysis shows that if China does not change its economic growth pattern, by the year 2030 it will be consuming annually 5.5 billion tonnes of coal equivalent of energy, comprising 6 billion tonnes of coal and 1.2 billion tonnes of petroleum. Its CO_2 emissions would therefore reach 12 billion tonnes, equivalent to 8 tonnes per capita . By this time China will be the world's leading consumer of coal and oil. Its per capita CO_2 emissions will get close to that of the OECD countries while more than 80% of its petroleum will be imported from foreign countries. The growth trend will continue to 2050, when China's energy consumption and CO_2 emissions will reach 6.7 billion tonnes coal equivalent and 13 billion tonnes of CO_2 respectively. In short, under this scenario China would retake the road of developed countries in the process of industrialisation and urbanisation.

But by taking a low carbon development pathway, China can achieve a significant reduction in energy consumption and GHG emissions without hindering its economic growth. This will not only contribute to global reduction of GHG emissions but also enhance China's environmental protection, energy security and economic competitiveness, thereby achieving prosperous and sustainable development.

China can reduce annual energy consumption in 2030 to 4.5 billion tonnes, petroleum consumption to no more than 700 million tonnes, CO_2 emissions to 8.6 billion tonnes and CO_2 per capita to 5.9 tonnes. This estimate is based on domestic efforts to enhance technological progress, by changing the mode of economic development, changing consumption patterns and developing a low carbon economy. After 2030 China's energy consumption will continue to grow, but low carbon energy will become the main source of energy, so that the growth of GHG emissions will slow down and remain generally stable.

A globally shared desire to slow down climate change could have the effect of further strengthening technological advances and reducing the cost of key low carbon technologies more rapidly. In addition, China will have become the largest economy in the world after 2030 and will be able to further increase its investment in a low carbon economy. Under these conditions, China could even further reduce energy consumption and GHG emissions. Such a scenario could mean that by 2030 it is able to reduce annual energy demand to 4.3 billion tonnes coal equivalent, CO_2 emissions to 8.2 billion tonnes and per capita emissions to 5.5 tonnes. Advances in technology would mean that carbon capture and storage is gradually put into large-scale application after 2030 and that China's CO_2 emissions begin to decrease in absolute terms. By 2050 those emissions could decrease to 5.1 billion tonnes, lower than emissions in 2005.

In this low carbon scenario, the peak value of China's CO_2 emissions per capita will be not only lower than the historical peak value of industrialised countries' emissions but also lower than the United States' emissions in 2030 (predicting from its current commitment to reduce emissions, its CO_2 emissions per capita in 2030 will be 10–12 tonnes), and it will become close to the emissions of the United Kingdom in 2030.

If China achieves such a low carbon development in the process of industrialisation and urbanisation, its economic and social development would have the following characteristics compared to the present:

- Industrial production is highly efficient resulting in means lower emissions per unit of output;
- Energy conversion is highly efficient resulting in lower emissions per unit of electricity and distance travelled;
- Renewable energy sources and clean energy take a larger proportion of the energy supply;
- High energy efficiency and lower emissions from transportation;
- Domestic and commercial buildings are more energy-efficient;
- Reduced export of products with high energy consumption and/or emissions;
- Public transport replaces private transport and people use bicycles and walk more frequently;
- Industrial structure is optimised, with a greater role for the service sector. Low carbon industry has become a new focus of economic growth; and
- Agriculture, forestry and other land uses are managed in order to encourage carbon sequestration.

5.2. Strategic objectives for a low carbon economy

To realise the vision set out above, four dimensions should be considered. First, energy saving and energy efficiency enhancement needs to be vigorously promoted in order to significantly reduce energy consumption per unit of GDP. Second, the energy structure needs to be optimised so that the carbon emissions per unit of energy consumption drop considerably. Third, carbon productivity needs to be substantially improved. In addition to energy efficiency and adjustments to the energy structure, optimising land use management and increasing rural carbon sinks will make an important contribution. Finally, China can lead the R&D and the commercial applications of the world's low carbon technology, making the low carbon industry a new source of economic growth and a new edge for international competitiveness.

According to the analysis undertaken by the Task Force, the above-mentioned targets can be quantified as follows:

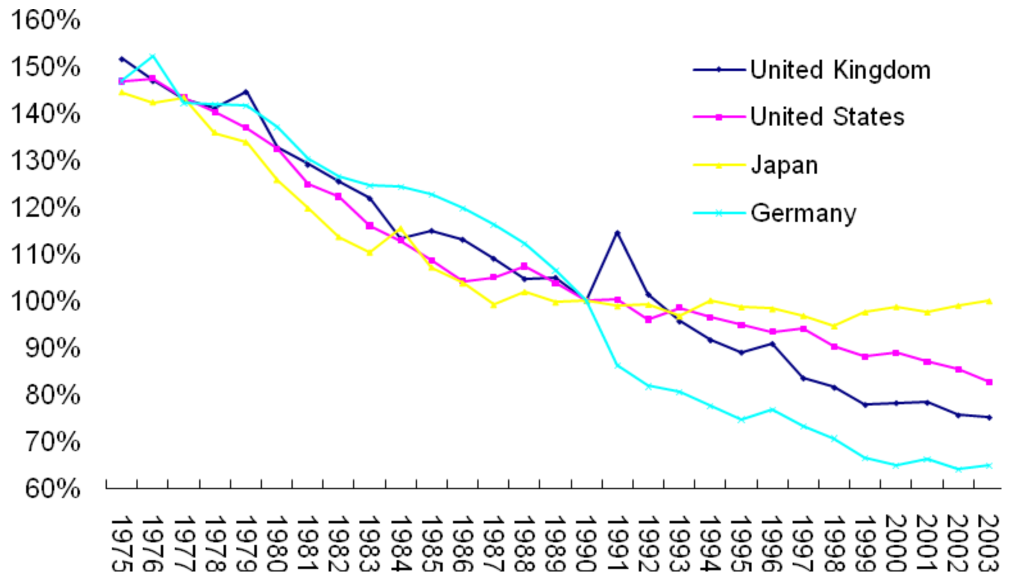
- On energy intensity, the goal is to reduce energy consumption per unit of GDP by 75–85% by the year 2050, which means an annual drop of 3–4%. There are three key drivers.
    - First is industrial restructuring and modernisation. The proportion of secondary industry should decline from the current nearly 50% to about 30% in 2050. Process-intensive and knowledge-intensive industry will replace heavy chemicals as the leading secondary industry. It's contribution to industrial added value should increase from the current 25% to about 35–40%.
    - Second is technological progress, including the promotion of proven technology and the development and application of new technology.

China will strive to reach an internationally advanced level of physical energy efficiency by 2015 and to reach an internationally leading level by 2030. For China's overall energy efficiency level, the aim is to meet internationally advanced levels by 2030 and to achieve internationally leading levels by 2050.
    - Third, low carbon cities can be developed through a new model for urbanisation and by establishing low carbon consumption patterns.

- Regarding energy structure optimisation, China will strive to reduce the carbon emissions factor per unit of energy consumption by 35–50% by 2050. By 2030, more than half the increased energy demand will be met by low carbon energies; by 2050, the main increased energy demand will be met by clean energy. CCS will be gradually promoted and used from 2030.
- On energy intensity, the goal is to reduce carbon emissions per unit of GDP by 85–90%. In other words, China's carbon productivity should rise by 10 times while carbon emissions per unit of GDP should decrease by 4–5% per annum. In addition to lowering energy consumption per unit of GDP and the carbon emissions factor per unit of energy consumption, carbon sequestration will also play an important role as China will add 500–600 million tonnes of CO_2 to carbon sinks each year via afforestation, land management and other measures.
- Regarding the R&D of low carbon technology and its commercial applications, China will promote existing proven low carbon technologies with great force and deploy R&D and trials of immature technology by 2015. Between 2015 and 2030, the goal is to leap into the top ranks of the world in the commercial application of third-generation nuclear power, electric automobiles, Integrated Gasification Combined Cycle (IGCC) and other new technologies that are currently in the demonstration phase. Between 2030 and 2050, China will strive to lead the world in the large-scale application of fourth-generation nuclear power and the application of solar energy as well as research, development and commercialisation of third-generation bio-energy, CCS and other cutting-edge technology.

In order to demonstrate the significance of the strategic objectives described above, they can be compared to the historical performance of developed countries; see Figure 5.2 and 5.3 and Table 5.1

Figure 5.2: Percentage changes of carbon dioxide emissions per unit of GDP in major developed countries, 1975–2003 (1990=100%)



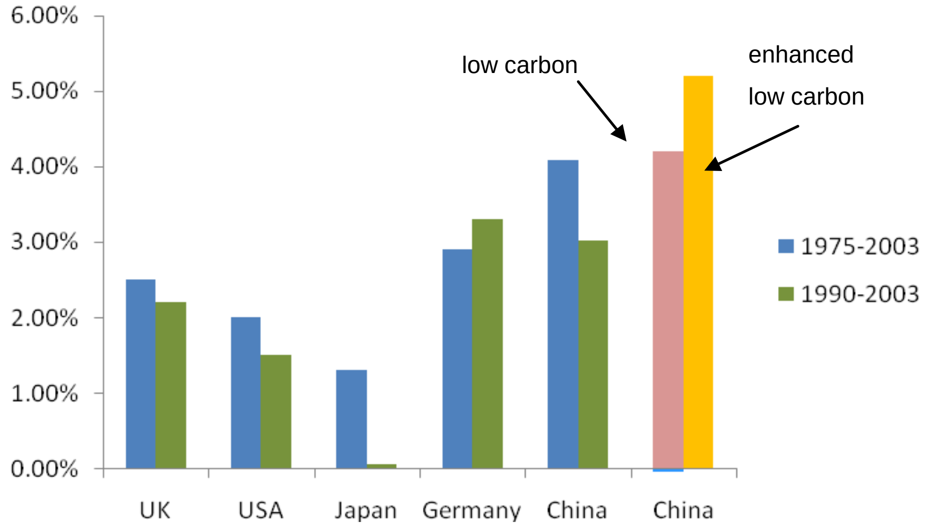
Source: Raw data from WDI in 2007; edited by the author.

Table 5.1: Average percentage decline in CO_2 emissions per unit of PPP GDP in major developed countries, 1975–2003

	UK	US	Japan	Germany
1975–2003	2.5	2.0	1.3	2.9
1990–2003	2.2	1.5	0.05	3.3

Source: World Development Indicators

Figure 5.3: China's low carbon situation versus the historical decline of CO2 per unit of GDP in developed countries



Source: World Development Indicators

From the above figures, we can see that China's CO_2 emissions per unit of GDP decline by 4–5% annually. This improvement of emissions intensity is significantly larger than that of developed countries after the 1970s oil crisis and also larger than that after the signing of the Kyoto Protocol, reflecting the efforts China has already made to develop an LCE.

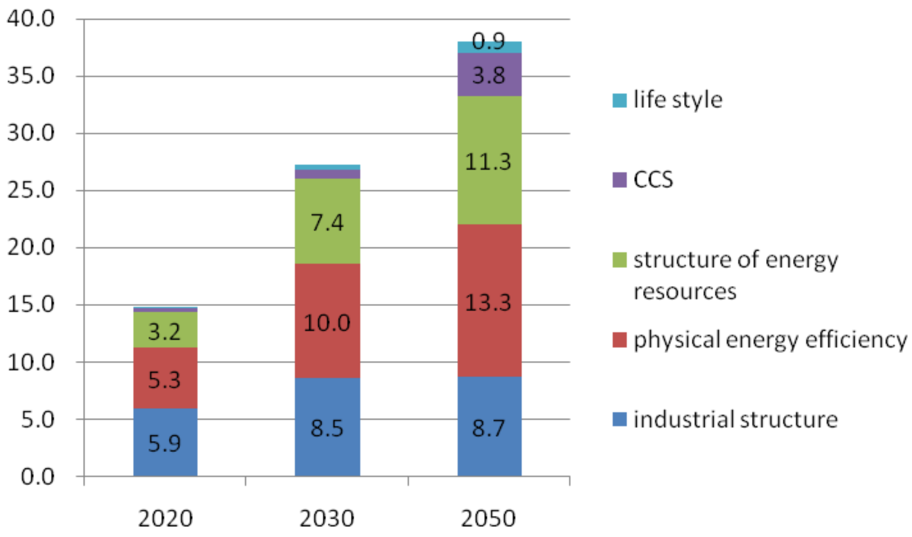
5.3. Five pillars for low carbon development

Compared with the baseline scenario, low-carbon scenarios can significantly reduce carbon dioxide emissions - by 1.89 billion tons up to 2020, 3.06 billion tons up to 2030 and 38.8 million tons up to 2050 respectively. These emission reductions come from several areas: Industrial restructuring; improvement of physical energy efficiency in the fields of industrial end-use, transportation, building and thermal power generation; changes in lifestyle, including the mode of travel; optimisation of the energy structure, including the structural optimisation of fossil fuels and the development of low-carbon energy; and the implementation of CCS.

As shown in Figure 5.4, energy-saving (including industrial structure adjustment, the enhancement of physical energy efficiency as well as changes in lifestyle) makes a great contribution – it is responsible for 60% of emissions savings by 2020, 62% by 2030 and 57% by 2050 respectively. The contribution of the energy structure optimisation is also significant, increasing gradually from 16% in 2020 to 24% in 2030, then to 30% in 2050. Moreover, the contribution of CCS won't be revealed until after 2030.

Based on the above analysis, it is clear that China should take the road of low carbon development. Following the structure set out at the start of this chapter, five major policy areas have been identified. These are low carbon industrialisation; urbanisation and transportation; low carbon energy; consumption patterns; and rural land use. The rest of this section describes each of these areas in turn.

Figure 5.4: Contributions to emissions reduction of major factors in the low carbon scenario （Unit：100million ton CO2）



5.3.1. Pillar 1 – Low carbon industrialisation

Building a vibrant, high energy-efficiency and low carbon productivity industry base is essential for China's trade competitiveness, for implementing the circular economy and for enhancing technological innovation.

Step 1: Optimise and upgrade China's industrial structure

China is still, as noted above, in the process of rapid industrialisation and urbanisation. The proportion of industry as a contribution to GDP, as well as the proportion of the heavy chemical industry in the industrial sector, remains relatively high. China could:

- Eliminate backward production methods and technology;
- Consolidate industrial sectors by promoting mergers and company reorganisation, and in so doing accelerate industrial upgrading as well as increase the industrial added-value ratio;
- Achieve further energy savings and emissions reductions through the greater use of benchmarking for energy and carbon standards; and
- Accelerate the introduction and funding of energy efficiency programmes.

From the medium- and long-term perspective, there is much to be achieved through industrial restructuring and the internal adjustment of industrial sectors. On one hand, the development of the service industry will speed up, and its proportion of GDP will increase, thereby reducing the energy consumption per unit GDP. China will strive to increase the proportion of tertiary industry from the current approximately 40% to around 50% by 2030 and to two thirds by 2050. The modern service industry of knowledge, technology and the service sector will become a major driver of economic growth.

At the same time, China should develop in its industrial restructuring:

- Strategic and emerging industries
- High-tech industries
- An energy-saving environmental industry
- An electronic information industry
- A technology-intensive manufacturing industry and other high-processed industries.

It should make these a major force in driving economic growth.

Table 5.2: Percentage analysis and forecast of China's industrial structure, 2005–2050

	2005	2010	2020	2030	2040	2050
Primary industry	12.4	10.0	6.7	4.7	3.6	3.0
Secondary industry	47.8	49.0	46.6	42.9	37.6	33.4
Tertiary industry	39.8	40.9	46.7	52.5	58.8	63.7

At present, the energy consumption efficiency of China's industrial sectors is still lower than those of the advanced countries by 20–40%. China needs to increase the efficiency of energy utilisation in all industrial sectors and to speed up technological progress.

Table 5.3 The energy consumption per unit of major products: China vs. best practice

	2000		2005		2007	
	China	Best Practice	China	Best Practice	China	Best Practice
net coal consumption rate gce/kWh	392	316	370	314	356	312
comparable energy consumption per ton of steel /kgce/t	784	646	714	610	668	610
alternating current. Consumption per ton of electrolytic aluminum /kWh	15480	14600	14680	14100	14488	14100
comprehensive energy consumption of cement /kgce/t	181	126	167	127	158	127
comprehensive energy consumption in ethylene /kgce/t	1125	714	1073	629	984	629

Source: Wang Qingyi, 2008, China's Energy Data

There is still much potential to be tapped in energy saving and emissions reduction, by accelerating the technological transformation of the main energy-consuming industries and the improvement of technological capabilities so as to narrow the gap with the best international levels. From the medium- and long-term perspective, the development and application of new technologies becomes the main focus of energy-saving and emissions reduction.

To achieve the above goals, China should greatly enhance its capacity for technological innovation and tackle any challenges in certain major scientific and technological projects, innovation projects and key industrial technologies. The aim is to realise the localisation and independent innovation of core technology in key low carbon industries, techniques and products.

China should also promote technology standardisation, for example by establishing compulsory energy efficiency standards for related industrial energy-consuming products, home appliances and office equipment; improving energy-saving design standards in major energy-consuming industries; adopting benchmarking in key energy-consuming industrial sectors; and also by supervising the implementation and improvement of these standards.

In addition, the efficient integration of information technology and traditional techniques should be vigorously promoted and the resource utilisation efficiency of industrial sectors should also be improved. For details of the path to technological upgrading in key energy-consuming industries, see Box 5.1 below.

Step 2: Develop a circular economy with a high level of resource utilisation and low energy consumption and emissions. The development of a circular economy can help to reduce energy consumption, environmental pollution and GHG emissions.

In the near term, China should vigorously conduct resource-saving actions, in particular for construction materials and especially the efficient use of steel and cement. China should also energetically promote clean production approaches and reduce emissions of NO_x and other greenhouse gases.

In the medium and long term, China can build a circular economic development mechanism that includes the whole process from raw material procurement, transportation, storage and production to packaging, distribution processing, distribution and sales.

In the case of resource exploitation, China should:

- Promote advanced and applicable technologies;
- Process engineering and equipment so as to improve the recycling rate of mining, ore dressing and smelting;
- Vigorously promote the comprehensive utilisation of tailings and waste rock in order to improve the comprehensive recycling rate of resources;
- Enhance the management of energy, raw materials, water and other resources in key industries; and
- Make great efforts to reduce consumption and to improve the resource utilisation rate.

In the case of waste generation, China should:

- Strengthen pollution prevention and control of the whole process;
- Promote enterprises to extend the industrial chain in different industries reasonably, strengthen the recycling of various types of waste and encourage enterprises to realise zero emission of waste;
- Accelerate the construction of facilities to reclaim water, reclaim and reduce the quantity of urban waste and sewage sludge; and
- Ultimately reduce the amount of final waste.

In the case of renewable resource generation, China should:

- Energetically reclaim and recycle various waste resources so as to support the remanufacture of obsolete machinery and electronic products;
- Establish rubbish collection and sorting systems; and
- Introduce systems and approaches towards a comprehensive, integrated product policy.

In view of the preceding paragraphs, there is no doubt that the range and strength of actions in both the short and medium term will be of great advantage in developing a low carbon technology and service industries in China and creating new growth areas and a competitive edge in these important global industries.

Box 5.1: Technological upgrading path of key energy-consuming industries

1) Iron and steel industry: develop technologies and equipment, equipping coke oven with coke dry quenching device; building new blast furnace equipped with top pressure recovery turbine (TRT); adopting concentrating materials into furnace, oxygen-rich coal injection, molten iron pretreatment, large-scale blast furnace, converter and ultra-high power electric furnace, refining outside furnace, continuous casting, rolling control, cooling control and other advanced technologies and equipment. Besides, develop technologies of recycling coal gas emit from coke oven, blast furnace and converter and also develop circular power generation using coal gas combined with steam, residual pressure of blast furnace, evaporative cooling and the reclaiming and recycling of smoke, dust, waste residue and other energy and resources.

2) Non-ferrous metal industry: mines will be exploited mainly in large-scale, highly efficient energy-saving equipments; copper smelting will adopt advanced oxygen-rich flash and oxygen-enriched bath smelting process; aluminum smelting will be equipped with large pre-baking electrolytic bath; lead smelting will adopt a new technology with oxygen blowing in bottom and other lead smelting technology with oxygen blowing directly; and new wet processing will be developed in zinc smelting.

3) Petrochemical industry: oil and gas extraction will adopt technologies such as extraction system optimisation, heavy oil thermal recovery supporting energy saving, water injection system optimisation, carbon dioxide re-injection, airtight gathering and transportation of oil and gas supporting comprehensive energy-saving and venting natural gas recycling technology. The raw material structure for ethylene production will be optimised and advanced technology will be used to transform ethylene cracking furnaces. Large-scale ammonia plant will adopt advanced energy-saving technology, new catalysts and efficient energy-saving equipment. A furnace flue gas waste heat recovery technology will be promoted for plants using natural gas as the raw material of synthetic ammonia. Synthetic ammonia will speed up its transformation of using natural gas instead of fuel oil as the raw material. Small- and medium-sized ammonia manufacturing plants will use energy-saving equipment and pressure swing adsorption recovery technology. The traditional fixed-bed gas technology will be replaced by technology using coal-water slurry or advanced pulverised coal gasification technology. Gradually the producing method of graphite anode diaphragm will be eliminated, and the extent of the application of the membrane method will be increased.

4) Building materials industry: in the cement industry, China should develop the new dry method of off-kiln decomposition technique, actively promote energy saving grinding equipment and cement kiln waste heat generation technology, reconstruct large- and medium-sized rotary kilns, grinders and driers to save energy and phase out mechanical upright kilns, wet kilns, dry hollow kilns and other backward cement production processes. We should use combustible waste to replace mineral fuels and make comprehensive use of industrial solid waste and tailings. In the glass industry, we should develop the advanced float process, eliminate the backward vertical drawing and horizontal drawing processes and promote furnace and kiln whole thermo-insulated technique, oxygen-enriched and pure oxygen combustion technology etc. In the building ceramics industry, China should eliminate backward kilns such as the down draught kiln, pushed slab kiln and beehive kiln and promote roller kiln technology. In the production of sanitary ceramics, China should change the fuel structure and adopt the clean gas fuel open sintering process. China shall actively promote and apply new walling material and acoustic insulation material with high quality, environment- and energy-saving waterproof material and sealing material, to improve application proportion of high-performance concrete and prolong the lifespan of buildings.

5.3.2. Pillar 2 – Building low carbon cities: a new approach to urbanisation in China

According to the experience of the OECD and EU countries, the energy utilised in urban buildings and transport is two thirds of final energy consumption. That proportion in China has grown rapidly, from 35.9% in 2000 to 41.9% in 2007.

As the lifetime of basic infrastructure construction is long, it is difficult to change urban morphology in view of the pace of urbanisation. Avoiding lock-in in this sector is therefore critical for China's low carbon development.

The current urbanisation model leads to a multiplicity of problems: an uncontrollable thirst for non-renewable resources, the absence of a waste management system, a collapse of the transport system, a deteriorating living environment and resultant social problems.

This calls for a rethink, about a more low carbon urbanisation model with an integrated and circular perspective that would avoid the mistakes of the past.

This 'doing more with less' innovation could make a significant impact on energy pathways, as urban buildings and transport account for two thirds of final energy consumption.

To be specific it should:

Step 1: Advocate the compact approach to urbanisation and improve urban morphology and spatial arrangements

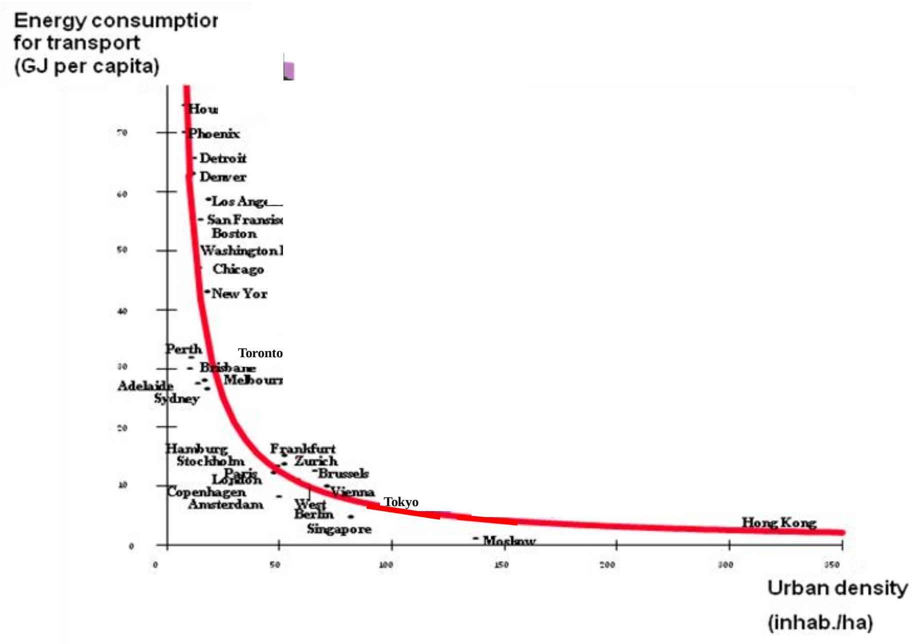
(a) Take a compact approach to urbanisation. Research shows that there is an obvious negative correlation between urban population density and urban energy consumption per capita (see Figure 5.5). China should keep a certain urban density during urban construction, thereby avoiding the phenomenon of suburbanisation. Compact cities use 30% less energy. North American cities are of a low density and extend over large areas. They require large amounts of energy to run the transportation and distribution systems.

(b) Focus on urban functional design in order to improve the space structure in metropolises and mega-cities. Adopt the 'organic evacuation' development model in cities with a population of over 2 million, appropriately mixing the functions of land utilisation. The distance between residence and workplace should be as short as possible.

(c) Develop urban agglomerations and city belts and speed up the construction of a large array of compact satellite towns and deputy city centres forming a radial spatial framework and strengthening the carrying capacity of the environment so as to reduce the pressure on the urban population, resources and environment and to improve the allocation efficiency of urban resources.

Figure 5.5: The relationship between urban population density and urban energy

consumption



Source: UN-Habitat, State of the World's Cities 2008/2009.

Step 2: Prevent carbon lock-in

Strengthen the promotion of energy-saving building technology and standards and develop urban low carbon buildings. Buildings currently account for 20–30% of total energy consumption in China, but the country is seriously short of energy-saving buildings. Among the finished buildings of almost 2 billion m^2 per annum, only about 3% are energy-saving buildings; about 97% are high energy-consuming buildings. According to the most optimistic estimation, only 5% of existing buildings satisfy the energy-saving building standard.

According to present trends, building energy consumption in China will reach 1.089 billion tonnes of standard coal by 2020, which is twice of that of 2004. Thus the strengthening of building energy conservation is of great significance. Three measures are necessary. First, strictly implement the existing building energy saving standard, appropriately improve the standard in developed areas and vigorously advance the energy-saving retrofitting of existing buildings. Second, increase the application of low energy-consuming construction technology and advance the application and promotion of energy-saving building materials, new building envelopes and systematic energy saving technology. Third, promote the use of electricity-saving lighting and energy-saving household appliances and encourage efficient and energy-saving kitchen systems.

Improve urban energy supply modes and increase the utilisation of new forms of energy

- Encourage the development of distributed energy sources such as combined heat and power generation, which has an integrated energy efficiency of 70–80% and is an important measure in improving energy efficiency in north European countries. However, the rate of concentrated heating supply in northern cities in China is not high, and the combined heat and power generation is only about 20%. Distributed energy supply modes such as combined heat and power generation and combined heat, power and cold generation should be vigorously promoted in northern cities in China, increasing urban energy supply efficiency.

- Advance the reform of the heat supply system, implement household heat metering and establish an incentive mechanism for personal users' energy saving.
- Improve the rate of electrification and the rate of urban gas utilisation and increase the applicable proportion of high-quality clean energies. Solar lighting can be used in places such as urban non-trunk roads, squares and the public space around office buildings, courtyards and parks. Vigorously develop ground source heat pumps and the utilisation of power generation from waste.
- Redesign layout and use of basic utilities, such as water, communications and waste.

Strengthen urban energy management and carry out energy-saving product certification. The strengthening of urban energy management can also provide huge opportunities for energy-saving and emissions reduction. The electric power consumption of large-scale public buildings is equal to the total electric power consumption of urban residential buildings but is only 5% of the total building area. If the refrigerating appliances, electric machines and electric equipment in those public buildings are revamped, 30–50% of their energy consumption can be saved.

A supervisory system should be constructed for the energy consumption of large commercial buildings, for energy auditing and for energy saving operation demonstration. At the same time, based on implementing the energy-saving product certification of household appliances and lighting fixtures, China should enlarge the range of certified energy-saving products, explore the establishment of an internationally recognised system for certified products and improve consumer awareness of certified products.

Step 3: Rethink urban mobility, vigorously develop the public transport system and optimise the urban transportation structure

Vigorously develop urban public transportation, urban light rail and a high-speed intercity railway. The development of public transport not only reduces energy consumption directly but also supports the framework of spatial arrangement optimisation (see Box 5.2).

1. Improve the transport mode control the immoderate growth of private cars, vigorously develop the zero carbon emission transport system for walking and riding bicycles and realising a seamless connection with rapid public transport systems.
2. Improve the efficiency of energy utilisation of motor vehicles and energetically develop means of transport with low carbon emissions such as mixed-fuel and electric vehicles.

Box 5.2: Comparison of characteristics of urban passenger transportation modes

	Volume people/h)	Speed (km/hr)	Occupation of road area (m^2/people)	Application range	Characteristics

Bicycle	2000	10–15	6–10	Short range	Low cost, no pollution, flexible and convenient
Compact car	3000	20–50	10–20	Wide	High cost, big investment, high energy consumption, serious pollution
General public traffic	6000–9000	20–50	1–2	Medium range	Low cost, low investment, small energy consumption per capita and light environment pollution
Light rail	1000–30000	40–60	Elevated track: 0.25 Exclusive lane: 0.5	Long range	High cost of construction and operation, low transportation cost, small energy consumption and light environment pollution, high transport efficiency
Underground	Above 30,000	40–60	Does not occupy ground surface area	Long range	High cost of construction and operation, low transportation cost, small energy consumption and light environment pollution, high transport efficiency

In addition, the per capita energy consumption per 100 km of public buses is 8.4% of that of compact cars. If 1% of people who travel with private cars change to buses, 0.08 billion litres of fuel would be saved nationwide every year. The average usage rate of Chinese urban public transportation is less than 10%, and the rate is only about 20% in mega-cities, far below the level of 40–60% in Japan, Western Europe and South American countries. The running speed of public transportation is also very slow: the average is only 10 km/h, which is below the 12 km/h of bicycles and the 20 km/h of compact cars. The construction of public traffic systems with large volumes is very slow, and also the road space allocation is not reasonable. According to estimates, if priority is given to the development of urban public transportation, the energy demand of the Chinese transportation sector would be 9.4% less than that of the base case in 2020 (according to the current development trend); if the development of efficient and clean transportation is accelerated, the energy demand would be 29.9% less than that of the base case.

5.3.3. Pillar 3 – Optimising China's energy structure and developing more low carbon energy

About 90% of CO_2 emissions in China come from the burning of fossil fuels. Therefore, optimising the energy structure and developing more low carbon energy are highly important: they would help to reduce the greenhouse gas emissions per unit of energy consumption. The overall target of energy structure optimisation is:

- To gradually reduce the share of coal in total primary energy demand;
- To speed up the development of natural gas and guarantee the security of oil supplies; and
- To actively develop the advance utilisation of hydropower, nuclear power and renewable energy sources.

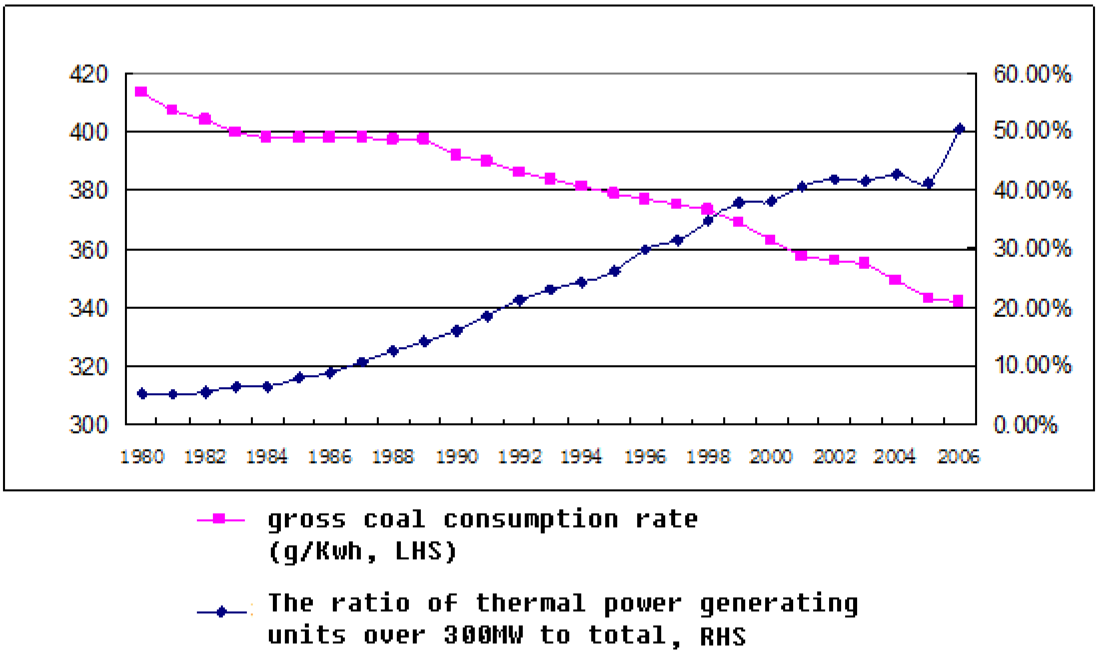
By 2020, the energy supply and demand systems will have been changed. By 2030, clean energy will be able to meet more than half the requirements of new added energy. In 2050, clean energy will be able to meet most of the requirements of new added energy. At the same time, an infrastructure system suited to the development of renewable energy sources such as a smart electric grid will have been built. The specific approaches are as follows:

Step 1: Using coal more efficiently

The excessive growth of coal must be controlled so that by 2020 coal growth will have reached its peak and the share of coal in energy consumption will have been reduced from about 70% at present to about 55%, then to below 50% in 2030 and to about 33% in 2050.

- Advanced coal-fired power generation technology will be promoted so as to increase the efficiency of converting coal into electricity. In 2020, the aim should be to reduce coal consumption in power generation to 320 g/kWh; new thermal power units will adopt mainly ultra-supercritical generating technology and IGCC. By 2030, with a reduction of coal consumption of power generation to 290 g/kWh, the proportion of IGCC plant in additional plant will increase to 50%. By 2050, the coal consumption of power generation will be reduced to 270 g/kWh. In 2020 and after 2030, the goal is to increase the efficiency of coal fired power stations from the current level of 55% to 65% and 80% respectively .
- Poly-generation technology such as combined heat and power and combined cooling and power will be energetically promoted in order to increase comprehensive utility efficiency.

Figure 5.6: Trends in coal consumption of power generation for thermal power (total and units over 300 MW), 1980–2006



Source: State Electricity Regulatory Commission

Step 2: Controlling oil consumption and switching to lower carbon fuels

Great efforts should be made to develop energy-saving and low carbon transport such as electric vehicles and also sustainable biofuels and to develop public transport. China should strive to limit the amount of petroleum consumption to no more than 550 million tonnes in 2020 and no more than 700 million tonnes in 2030. By expanding the development and use of domestic natural resources and by importing natural gas and liquefied natural gas from surrounding countries, natural gas can replace a significant amount of coal and petroleum in China. By 2020, 2030 and 2050, the goal is for the proportion of natural gas consumption in primary energy consumption to reach about 8%, 12% and 14% respectively.

Step 3: Developing more low carbon energy

To speed up the construction of hydropower, nuclear power and wind power construction and to promote the commercialisation of solar power, China will strive to realize low carbon development through the standardisation, industrialisation and commercialisation of low carbon energy sources by 2020. The power generation capacity of low carbon energy will reach about 550 million KW, accounting for 35% of total installed capacity. The amount of low carbon energy utilisation will reach 800–900 million tonnes standard coal equivalent, accounting for 20% of energy consumption.

China's targets for low carbon commercial utilisation will put it high up in the world ranking (see Box 5.3). By 2030, low carbon energy will account for 50% of new added energy. Low carbon development will account for 50% of total installed capacity. By 2050, low carbon energy will meet all the requirements for new added energy. The proportion of low carbon in the fuel mix will exceed 33%. At that time, the structure of Chinese energy will be divided into three parts: coal, 33%; oil and gas, 33%; and low carbon, 33%.

Box 5.3: Development targets and an international comparison with China's low carbon energy in 2020

1. The overall target of development utilisation of low carbon energy. By 2020, China will realize the low carbon development of standardisation, industrialisation and commercialisation. The power generation capacity of low carbon energy will reach about 550 million KW, accounting for about 35% of installed capacity. The amount of low carbon energy utilisation will reach 800–900 million tonnes standard coal equivalent, accounting for 20% of the energy consumption structure.

2. The specific field of low carbon energy development and utilisation. By 2020, installed hydropower capacity will be up to 300 million KW, installed wind power capacity 100–150 million KW, installed nuclear power capacity 86 million KW and installed solar power capacity 20 million KW. In 2020, the amount of biomass energy utilisation will reach 45 million tonnes standard coal equivalent, of which biomass energy installed capacity will be 25 million KW.

3. International comparison of low carbon energy development and utilisation. By 2020, China will not only have the largest amount of low carbon energy utilisation in the world but also enjoy the largest proportion of low carbon as a share of consumption and in terms of installed capacity. This is set out in Table 5.4.

Table 5.4: Development expectation and international comparison of China's low carbon energy[99]

	Proportion of low carbon energy accounting for energy consumption 2020	Proportion of low carbon power generation accounting for total installed capacity in 2020
China	20%	35%
America	20% renewable energy and approximately 15% nuclear	N/A
United Kingdom	15% renewable energy and approximately 5–10% nuclear electricity	30–50 GW of renewables and 1–5 GW of nuclear power from a total installed capacity of 100–120 GW
EU	20% renewable energy and approximately 30% nuclear electricity	Approximately 350–400 GW of renewables and 100 GW of nuclear from a total installed capacity of 1,000 GW

[99] In North America and Europe, there are no targets for the use of energy. Therefore the figures are appoximations based on current commercial expectations

Step 4: Building a strong, smart grid

As the proportion of low carbon energy grows, additional demands will be placed on infrastructure and grid management. In response, China should construct a strong grid framework. Then the output of new energy sources such as wind power and nuclear power can be more effectively transmitted. Also, the ability of the distribution network to manage variability of supply and demand should be improved, and it should be supported with demand side management, including in future from electric vehicles. Local renewable energy should be promoted.

Step 5: Implementing CCS in stages and in a focused manner

Before 2020, China should focus on R&D and experiment and demonstration, and it can also undertake some low-cost carbon capture and storage by integrating CCS with petroleum exploitation. Later China's IGCC plant and some industrial processes are expected to employ CCS.

5.3.4. Pillar 4 – Low carbon consumption patterns

A low carbon pathway affects both the production and the consumption sides of the economy, and therefore attention needs to be paid to low carbon consumption. With a similar level of economic development and industrial structure, per capita energy consumption is 4 tonnes standard oil in Japan and 10 tonnes standard oil in America. Analysis shows that 70% of the Japan–US energy consumption gap lies in different patterns of consumption.

Step 1: The '6R' principles

Low carbon consumption, an extension of sustainable consumption concept, is described by the '6R' principles:

1) Reduce: save resources, reduce pollution;
2) Re-evaluate: green consumption, environmental protection;
3) Reuse: reuse, multiple use;
4) Recycle: rubbish classification, recycling;
5) Rescue: rescue species, protect nature; and
6)Recalculate: recalculating means that during the process of choosing a commodity or service, consumers consider not only the direct economic cost of their behaviour but also the amount of carbon emissions involved in producing the product or the whole process of providing the service, the 'carbon footprint' .

Consumers should be encouraged to choose products and lifestyles with small 'carbon footprints'. To build a low carbon consumption pattern, several aspects should be promoted, including culture, policy, concept, principle, habit, behaviour and evaluation. The details are as follows:

A sustainable consumption law, a green procurement law and a rubbish disposal law should be produced and published in the near term. Research into carbon emission standards for consumer goods should be accelerated and their implementation in the medium term should be prepared for.

Step 2: Increasing taxation and financial stimulus:

- Financial support for customers purchasing green products will be increased in the short term.
- Subsidies will be provided for products that use electricity efficiently, new-energy automobiles etc.
- A green consumption credit will be studied;
- A carbon emission tax and other types of environment tax will be implemented in the medium and long term.
- In the long term, a combination of the above measures with wider tax reform is necessary to realise the transition to a nationwide green tax system.

Step 3: Intensifying publicity and education:

A national publicity plan and education activities will be studied in the near term. Their inclusion in community and company publicity and in school education will be advocated. Household education will be encouraged. Citizens' awareness of green consumption will be improved, and will be complemented by carbon labelling on products. In the medium and long term, a merit award scheme will be implemented (awards such as Green Enterprise, Green Community, Green Household and Green School). The publicity should cover both urban and rural areas, reaching all citizens. China will develop a consumption guide in a low carbon economy.

Step 4: Establishing a system for sharing green information

- In the near term, China will establish a publicity information system related to law, standards, administrative proceedings, technology and products. In the medium and long term, it should promote a 'carbon footprint' calculating formula for the whole of society, designed and suited to China's conditions.
- In the long term, using information technology, China should build real-time information and monitoring mechanisms so as to reveal carbon emissions.

5.3.5. Pillar 5 – Land use management and carbon emissions

In recent years, the amount of carbon stored in China's terrestrial ecosystems has increased by 190–260 million tonnes per annum. . Carbon sequestration is therefore an important dimension of the low carbon economy. Three key land use types are forests, arable land and grassland. In each case, three measures should be considered: increasing the amount of carbon stored, protecting existing carbon storage and Substitution

Step 1: Storing more carbon in forests

Forests act as important stores of carbon in China. In recent years the amount stored has grown by 150 million tonnes annually. At present, artificial conservation areas in the country amount to 54 million hectares, ranking first in the world. The amount of growing stock is 1.5 billion cubic metres. Forest coverage has increased from 13.9% since the early 1990s to 18.2% in 2005. Between 1980 and 2005, the accumulated net absorption of China's afforestation activities was about 3.06 billion tones of CO_2, and forest management absorbed 1.62 billion tonnes of CO_2. At the same time, 430 million tonnes of CO_2 emissions were avoided by reducing deforestation.

In order to increase sequestration in forests, China should take the following measures:

- restore degraded ecosystems, by establishing an agroforestry–forestry system, strengthening forest management in order to improve the production of forest and to prolong rotation time;
- reduce deforestation, by improving logging regulations, utilising woods more efficiently and effectively controlling forest disasters (forest fires, plant diseases and insect pests); and
- use marsh gas instead of fuel wood and durable lignin products instead of energy intensive materials, recycle logging residue and further process wood products via recycling.

Step 2: Storing more carbon on arable land

Arable soil makes an important contribution to the total carbon stored in terrestrial ecosystems. The organic carbon content of China's arable land is relatively low, about 0.8–1.2% in the south, 0.5–0.8% in northern China, 1–1.5% in the north-east and below 0.5% in most areas of the north-west. The organic carbon content of most European arable lands exceeds 1.5%, and in the US it reaches 2.5% to 4%. Therefore, China has great potential for increasing the carbon storage of arable land.

The first step is to return straw to arable land. This can improve land fertility and increase production and also increase the amount of carbon stored. In 2007, straw was returned to only 40% of arable land in China; Japan reached 68% and the US above 50%. There is significant room to increase sequestration by returning straw to arable land.

The second step is to encourage practices that use fertilisers and pesticides more efficiently and to make further use of organic fertiliser. The fertilizer use efficiency is generally low in China. For example, the use efficiency of nitrogenous fertiliser is 9–62%, phosphate fertilizer 3.7–32.4% and potash fertilizer 13.8–50%. Producing one tonne of synthetic ammonia requires about 1.7 tonnes standard coal equivalent in China at present. Strengthening fertilizer management and utilizing fertiliser use more efficiently can reduce grain production costs and also reduce energy consumption and emissions of carbon dioxide.

The third step is zero tillage or minimum plough methods designed to reduce the turbulence of arable soil, which reduces its ability to fix carbon. The amount of organic carbon can be increased by the transformation of terrestrial biota and fallen leaves.

Step 3: Storing more carbon in grassland

The key to maintaining and increasing the sequestration of carbon in grassland lies in preventing degeneration and in encouraging the recovery of deteriorated grassland. Specific measures include reducing grazing density, enclosing grassland and planting artificial grass (see Table 5.5). In addition, grassland sequestration can be improved by animal husbandry management approaches such as fence breeding, rotational grazing and introducing different grass varieties.

Table 5.5: Main measures for increasing carbon sequestration

Land type	Carbon sequestration	Retaining carbon stocks	Substitution
Forest	• Forestation and reforestation • Forest fertiliser • Prolong rotation time	• Reduce cutting • Prevent intensive agriculture and grazing and disforestation • Fire management • Plant diseases and insect pest management	• Other biological energy sources instead of fuel wood • further processing of wood products • Prolong useful time of wood products • Recycling of wood products and paper • Develop replacement industry
Arable land	• Returning strew to arable land • Fertiliser management • Zero tillage • Returning land for farming to forestry and grassland • Recovery of degenerated soil • Using organic fertilizer	• Prevention of soil degradation • Fertilising management • Water management • Vegetation conservation	• Develop biofuel • Develop replacement industry
Grassland	• Artificial forest, planting grass • Recovery of grassland • Fertilising and irrigating grassland	• Prevention of overgrazing • Closing grassland	• Taking reasonable animal husbandry management measures • Develop replacement industry

5.4. Promote innovation and application of low carbon technology, and improve the international competitiveness of key industries

Realising the five pillars depends to a great extent on the innovation and application of low carbon technology. In the medium and long term, low carbon technology innovation and application on a large scale is fundamental to managing greenhouse gas emissions. The innovation and application of low carbon technology can also foster new growth points in the national economy and a new competitive advantage.

According to the IEA, to realise the target of carbon emission reduction by 2050, power generation efficiency and fuel switching and end use fuel switching will have to contribute 7% and 11% respectively of global emissions savings. The remaining 82% will have to be achieved through improving energy efficiency, developing renewable energy and nuclear energy and adopting CCS technology.

As for China, in the low-carbon scenarios increasing in the physical energy efficiency , the development of low carbon energy and the deployment of CCS depend to a large extent on technology innovation . By 2050, the emissions reduction related to technical innovation possibly accounts for about 70% of total (as shown in Figure 5.4).

In order to promote the technology innovation and application we should:

Step 1: Promote more application of advanced and proven technology, and improving energy efficiency

A significant difference between China's low carbon development and that of developed countries is that energy savings are more important in China, accounting for about two thirds of potential reductions up to 2050. The first reason for this is that China's industrial structure is unbalanced, with the emphasis on heavy industry; the second reason is that its technical efficiency lags far behind that of developed countries.

By accelerating current technology innovation, China has great potential for saving energy. The promotion and application of mature technology should be speeded up – including energy efficiency technology and energy efficiency in buildings, solar energy, combined heat and power generation and heat pumps.

From a policy point of view China should:

1. Strengthen the monitoring of new projects and products, to strictly implement and gradually improve energy efficiency standards;
2. Close down backward production facilities and encourage people to trade in old low-efficiency products for new ones; and
3. Introduce advanced, efficient technology from foreign countries.

Step 2: Promote R&D and the demonstration of a new generation of low carbon technology

Globally, we are entering a period of accelerating innovation for low carbon technologies. Many countries' governments have devoted tremendous attention to low carbon technology development. China should arrange R&D and demonstration of a new generation of low carbon technology as soon as possible. It should aim to achieve a higher level both in the use of technology and in R&D, making these an important part of the green industrial revolution. First, we shall accelerate the extensive, large scale commercial application of ultra-supercritical boilers, second-generation nuclear power, hybrid electric vehicles, wind power and other technologies. Second, China should support the demonstration and initial commercialisation of technologies such as third-generation nuclear power, electric vehicles, IGCC and solar photovoltaic. In the commercialisation of low carbon technology, China's goal should be to take its place in the front ranks of the world, to occupy the commanding heights of the green industrial revolution and to foster its new competitive advantage. Third, China will promote the basic research and R&D of fourth-generation nuclear power, CCS, solar energy power generating, second-generation biofuel, nucleosynthesis, advanced materials, advanced manufacturing etc. Table 5.6 provides more details of the timing of these measures.

Table 5.6: Blueprint of low carbon technology innovation and application

	Phase I (12th FYP)	Phase II (2015–2030)	Phase III (2030–2050)
Large-scale application	Current, proven and advanced energy efficiency technology, energy saving buildings, solar thermal applications, combined heat and power generation, heat pumps, ultra-supercritical boilers, wind power, second- generation nuclear power, hybrid electric vehicles	Third nuclear power, wind power, next-generation solar PV and concentrated solar power, electric vehicles, IGCC	Fourth nuclear power, CCS, solar electrical energy generation, second- generation biofuels
R&D and promote commerci-alisation	Third-generation nuclear power, wind power advanced components, electric vehicle, IGCC, solar photovoltaic	Fourth-generation nuclear power, CCS, second biofuel	Nucleosynthesis, third biofuel, advanced materials

Basic research	Fourth-generation nuclear power, CCS, solar thermal generating, second-generation biofuel, advanced materials	Nucleosynthesis, third biofuel, advanced materials	

Step 3: Sow the seeds for a knowledge-based and highly innovative low carbon economy

Building a low carbon technology innovation system requires two problems to be solved:

1) How to share the huge investments and the high costs of R&D by encouraging a wide range of cooperation among commercial operations
2) The relatively small size of its domestic companies.

For this reason, the ability of those companies to innovate is limited. They need the government to guide and integrate social resources. Specific measures by the government would include:

- Setting up a special institute for promoting low carbon technology innovation in governmental departments and strengthening the organisation and guidance of low carbon innovation technology;
- Building a common platform of technology innovation or establishing a new alliance for technology innovation;
- Promoting group development of universities, R&D institutes and enterprise R&D, stimulating information exchange; and
- Accelerating policy development for technology innovation by:
  - Increased financial support for basic R&D;
  - Stimulating the application of policies such as patent protection, incentives, self-determination and preferential tax rates;
  - Supporting demonstration by providing government protection, tax reduction, preferential loans and temporary prices;
  - promoting the application and spread of new technology at the beginning of the commercialisation stage by setting a price for carbon, solving the imbalance of new technology information, giving franchise rights, establishing government procurement and improving regulatory standards and implementation.

Step 4: Speed up the process of establishing a standards, certification and monitoring system guiding and standardise the new industry -wide development of low carbon energy

The standards, certification and monitoring system is an important measure for guaranteeing product quality, promoting technological development and reducing costs. It is also critical for standardising the development of new industry. Leading countries in wind power such as Denmark, Germany, America and India have generally implemented a certificate system of wind power. Specifically:

1) China should establish the certificate standard of wind power, solar power and the design of key spare parts. The standard should comply with its natural environment, resources, conditions and industrial basis.
2) China should improve the ability of checking and certification, which can be combined with the construction of public test facilities such as wind power experimental areas.
3) China will gradually adopt the unified certificate system of wind power and solar energy, starting with a voluntary certificate system but implementing compulsory product certification rules when manufacturing capacity and certification ability are improved. In addition, it will make the cutting-in technology standard for wind power and photoelectric power as soon as possible.
4) When establishing the system, China should refer to international standards, which can guide equipment manufacturing enterprises to develop technology friendly to the electric grid, guarantee the safety of the electric grid and create opportunities for exports. On the other hand, the situation of China's industry should be considered and buffer time allowed for domestic manufacturing enterprises and relevant construction.

6. Policy recommendations

The transition to low-carbon economy is not only one of the world trend of economic and social development, but also the urgent task for China to achieve sustainable development. China should construct its own comparative advantage in the low carbon development by seizing the historical opportunity to build low carbon economy and the strategic opportunity to promote technology innovation significantly. It will not only help to solve the current problems in the fields of energy, resource and environment, but also enhance the capability for technological innovation and form the new competitiveness finally. All of these embody the scientific development concept as China always advances. Therefore, China should establish low-carbon economic development strategies, make a road map for the development of low-carbon economy, focus on the low-carbon industrialisation, urbanisation, consumption patterns, energy development and technology innovation as well as the optimisation of land use, rigorously improve the institutions and policy environment through the reform in the areas of energy pricing mechanism, green taxation system, market mechanism, the regulation and others. Specific recommendations are as follows:

6.1. Start the development of a low carbon economy as soon as possible

The transition to a low carbon economy is a necessary and urgent task, and presents important strategic opportunities for China. The first recommendation of the Task Force is the inclusion of the low carbon economy as a key principal in the 12th Five-Year Plan.

1. **In the 12**th **Five-Year Plan, set targets for reduction of carbon emissions per GDP unit.** According to preliminary calculations, during the 12th Five Year-Plan period energy consumption per unit of GDP could be reduced by about 15–17% through energy-saving measures while the development of new energy sources could reduce carbon emissions per unit of energy by 5–6%. Thus energy-saving measures and new energy sources combined could reduce carbon emissions per unit of GDP by 20–23% or more. Therefore we suggest that a 20% reduction in carbon emissions per unit of GDP is set as one of the binding targets of the 12th Five-Year Plan.

2. **In the 12**th **Five-Year Plan or its programmes for implementation, identify the main methods and sectors through which the low carbon economy will be developed.** At the same time, disaggregate low carbon economy targets and tasks to regional and sectoral level and increase enthusiasm for the development of new energy.

3. Include low carbon industrial development and technological innovation as important parts of the **12**th **Five-Year Plan's programme for structural**

adjustment and technological innovation. Promote low carbon innovation and industrial innovation via project construction, industrial development, technological innovation and systems and mechanisms.

6.2. Reform energy pricing

The reform of energy pricing is a key lever in meeting low carbon objectives. Three areas have been identified for reform. First, gradually realise competitive price setting in the energy sector, with clear supervision of natural monopolies. Second, reflect the external costs and resource consumption of energy development, processing and use in the price of energy products. Third, cross-subsidies should be made transparent and later eliminated, with any subsidies for energy consumption being provided from public finances. Specifically:

Coal: The cost calculation policy should be reformed. Fees for the use of coal reserves, safe production, environmental restoration, the transfer of coal mines and employee health costs should be fed into the cost of coal, thus internalising external costs and gradually realising coal pricing that reflects total costs.

Electricity: The price of conventionally generated electricity (such as from coal) at the point of supply to the grid should gradually be allowed to be set by the market. The cost of distributed electricity should gradually become independent. The issue of cross-subsidy of retail electricity costs should be gradually resolved in order to provide a foundation for bilateral electricity trading. In the near future the extra costs associated with renewable and clean energy will need to be promptly apportioned as these sources expand.

Oil and natural gas: Reform further the pricing of oil products. Recently the government has set retail costs in accordance with international prices. In the middle to long term, entry to wholesale markets should be liberalised in order to create a competitively priced market. The factory-gate cost of natural gas should gradually shift from government-set to market-set while achieving a more rational price via an adjustment of resource taxes.

Urban heating: Centralised heating provision and more efficient combined heating–cooling projects should be promoted and encouraged. Heating and cooling use should be measured by household, and pricing should be reformed. The reform of heating subsidies should take place as soon as possible, with hidden subsidies becoming visible and a 'pay-for-what-you-use' system implemented. Heating should become a monetised commodity with a rational price setting mechanism.

6.3. Build a green tax system and increase public funding for the development of a low carbon economy

1) Use resource taxes to reflect costs of environmental damage and use of resources in energy prices.

This measure includes raising taxes or fees made for the release of pollution, increasing the scope of collection of fees, gradually replacing pollution fees with pollution taxes and ensuring that the ‘polluter pays’. Resource taxes should be collected as a percentage of the market price – not as a fixed amount for a given quantity of the resource. Export tax rebates for energy-intensive products should be reduced, or extra tariffs could even be imposed, in order to reduce the export of energy in this form.

2) Guide consumption and behaviour through an energy tax in order to increase costs.

In China, petrol and diesel already incur taxes of 1 yuan and 0.8 yuan per litre respectively. We suggest that at an appropriate time this is increased and that other energy taxes are introduced.

3) Preparations for a carbon tax should start soon in order to send a stable price signal for low carbon innovation and large-scale commercialisation.

The carbon tax rate should not be too high at the very start. After that, the tax rate should be adjusted gradually with consideration of the economic and social affordability.

4) Strengthen funding for energy saving, renewable energy and low carbon technological innovation.

Initiatives on behalf of this measure include:

1) Energy-saving: Regular budgets should include an outlay for energy-saving; energy-saving products and companies should receive tax breaks and direct subsidies; and energy-saving should be given greater weight in government procurement.

2) Promotion of renewable energy: Further reduce value-added tax for renewable energy; implement business tax reductions for the sector; reduce import tariffs and value-added taxes on renewable energy equipment; and offer subsidies for households purchasing solar roofing or small wind power generators.

3) Promote technological innovation: Increase investment in low carbon R&D and provide tax breaks for enterprises carrying out low carbon R&D and technological innovation.

4) Increase funding channels: In the near future, existing government funds should be reorganised and standardised, with the orientation shifting from construction funds to funds for sustainable development of energy. They should focus on energy-saving, renewable energy development and technological innovation. In the middle to long term, part of the revenue from additional fuel, energy and carbon taxes should be allocated to sustainable development funds.

6.4. Using the market mechanism to promote the development of low carbon economy

Besides setting up a carbon tax, a carbon trading system also can realise the carbon price and accelerate emission reductions In the long term, China should establish a carbon trading scheme. In the near term, a voluntary carbon trading scheme would help to build capacity and accounting systems. Appropriate subsidies or loan support should be used to encourage firms to carry out voluntary emissions reductions, with participating firms proposing emissions reduction against their baseline emissions and the government organising emissions trading among the companies. Companies could register at the existing environmental asset exchanges, allowing the trading, settlement and auditing platforms there to be used and establishing emissions auditing, reporting and operating methods. Meanwhile, third-party certification agencies would confirm emissions baselines and reductions, and confirmed surplus emissions rights and those already confirmed by international authorities would be traded at the exchange. In the mid term, energy-intensive firms would be allowed to choose voluntary agreements to reduce emissions at the same time as collecting a carbon tax. Those unable to complete those agreements could purchase emissions through the trading system.

In the current framework of global emission reductions, China should make full use of the CDM mechanism, with the aim to get international emission reduction funds and achieve the technology transfer. In addition, China can gradually introduce carbon banking system, establish the carbon account for major and regional enterprises, and realise the forward price of carbon through carbon trading.

6.5. Aggressively support technological innovation, diffusion and international cooperation

1. **Strengthen the construction of public R&D institutions and testing platforms.** These will have a hugely important role in systems supporting technological innovation. They will be particularly crucial in the research and development of framework and common technology, in promoting commercialisation and in carrying out major government research programmes. We propose establishing an open national new energy research institution. This will have the ability and facilities to carry out research and will also be able to carry out pilot projects, thus covering basic research, development, trials and testing and certification. The institution will be open to businesses, universities and other research institutions and will carry out research and development of basic and common technology, experiments, testing and certification. This will resolve the lack of adequate common technology in the new energy sector.

2. **Further improve policies encouraging technological innovation.** First, continue to implement the extremely important policies on self-reliance programmes and the requirements for equipment in major projects to be sourced domestically so as to

promote localisation. Second, as soon as possible implement detailed rules for implementation of the plans for the adjustment and reinvigoration of the equipment manufacturing industry, establish and use risk compensation mechanisms for new domestically produced equipment and encourage insurance companies to insure these projects. Implement preferential tax policies for technological innovation. Also, fund and encourage firms to form alliances to research common technologies and the domestic production of key components.

3. **Speeding up the commercialisation of the innovation outcome.** Support the demonstration of low carbon technology and provide the tax cutting and financial subsidies for purchasing low carbon products.

6.6. Improve legislation and regulations, and strengthen the enforcement of laws and standards

1) Improve legislation for the energy production and transfer, energy-saving, solid waste and forestry sectors in order to help reduce carbon emissions. Specifically, produce and implement as quickly as possible the Energy Law and make revisions to the Coal Law, the Electricity Law, the Energy Saving Law and the Renewable Energy Law that will further encourage the development and use of clean, low carbon energy sources. Produce and improve regulations on implementation of the Law on Promotion of the Circular Economy. Establish systems of regulations based on the Agriculture Law, the Forestry Law, the Grasslands Law and the Land Management Law that will improve agricultural and forestry production and increase the carbon storage of their ecosystems. Revise regulations on the protection of forests, farmland and grasslands and strictly control development in environmentally vulnerable regions. Strengthen policies to prevent the destruction of natural forests, grasslands and farmland.

2) Draft and improve energy standards. Improve design norms for energy-saving in the main energy-consuming industries and for building energy saving standards and improve standards for controlling the heating and cooling of buildings. Draft energy-efficiency standards for energy-consuming industrial equipment such as fans, pumps, transformers and engines and also for domestic appliances, lighting, office equipment and vehicles.

3) Strengthen the enforcement of energy-efficiency standards. Energy-efficiency standards should be included in the evaluation and auditing of industrial projects. New or expanded fixed-asset projects should be subject to carbon-emission reduction evaluations and auditing, with approval refused for those that do not carry out, or fail, evaluations, thus reducing emissions at source. Energy efficiency tests should be carried out on all major public buildings and commercial residential housing, with completion procedures denied to those failing to pass.

Also, improve ‘carbon footprint’ labelling and certification. Gradually implement a ‘carbon footprint’ labelling system and steadily expand the scope of the scheme. Increase public awareness in order to shift consumption to low carbon products and thereby encourage firms to develop those products.

6.7. Improve the quality of energy and carbon statistics and measurement

First, improve energy statistics and systems. Improve energy survey and auditing methods so as to increase the scientific nature of statistics gathered. Strengthen and standardise energy statistics activity at the grassroots level, to increase accuracy. Also, establish statistics agencies below the city level in order to strengthen the foundation of statistics gathering.

Second, establish a 'carbon footprint' measuring system for enterprise. The first step in the foundation of energy-saving and emissions-reduction work is to verify the emissions of energy and emission-intensive products and equipment in key industries. Encourage other businesses to calculate their GHG emissions according to international standards – either doing so themselves or employing a third party to do so. This information will inform clear carbon emissions standards and carbon emissions reduction targets for both industries and products. At the same time, the authorities should organise experts to research methods of calculating 'carbon footprints' and labelling standards. A supervision and certification authority should be formed, with funding and equipment provided, for training and certifying staff. The measuring of 'carbon footprints' should be included in the Statistics Law.

Third, in future the Statistics Bureau should begin to collect carbon emissions data and to make it available to the public on a regular basis.

Fourth, encourage industrial associations to monitor the rate of technology innovation and the use of lower carbon technologies.

6.8. Include the requirements of the low carbon economy in urban planning and run demonstration projects

Include requirements for 'low emissions, high efficiency' in urban planning and rural development planning and run demonstration projects. Propose and improve low carbon urban planning strategy that explores low carbon urban planning in terms of urban zoning, industrial structure, public transport and land use.

Start a batch of low carbon urban development projects in suitable cities in the near future. Survey and analyse the energy use of aspects such as transport and buildings and then use economic incentives, policy and systems, technological innovation and application, and public funding to achieve energy-savings, ultimately reducing urban carbon emissions. In the near term, new cities should include low or zero carbon communities, industrial zones or ecological cities. Common standards for measuring low carbon development should be developed and agreed that reflect the diversity of development characteristics.

Also, low carbon development should be taken into consideration when choosing winners of national ecological, environmental and liveable city competitions. Change the current situation in which environmental cities are environmentally friendly in some aspects but still have high carbon emissions.

The rural dimensions of China’s future low carbon economy should not be overlooked. Land-use management and change has a significant effect on the amount of carbon stored in terrestrial ecosystems. Sustainable approaches to agriculture, forestry and bioenergy can make a significant impact on greenhouse gas emissions and create important opportunities for carbon finance in rural areas. Urban–rural economic and transport linkages affect the pattern of energy and greenhouse gas emissions, and many industries are located in rural areas. China is already seeking to achieve balanced urban–rural development. A low carbon economy can make a major contribution to this objective.

7. References

Xiaolu Zhang (2004), Research on Ultra-supercritical Power Generation, China Scientific Institution 2004 Annual Meeting Electric power sub-meeting place Symposium

Liqiang Duan, Rumou Lin, Hongguang Jin, Ruixian Cai (2000), Progress of IGCC Technology, Gas Turbine Technology, 2000,1

Shisen Xu (2006), Current Situation and Development of IGCC in China, speech on the workshop

Dongxu Zhao (2007), The Status quo and Policy Implication of IGCC technology in China, Power Technical and economic, 2007,6

China new energy (2003), Solar Photovoltaic Industry, http://www.newenergy.org.cn/energy/solar/index.htm

Xinhua net (2006), Australia will build the biggest solar power plant, Oct, 26,2006. http://news.xinhuanet.com/photo/2006-10/25/content_5248716.htm

Hongbo Gai (2005), Photovoltaic Prospect, Global Technology Economic Outlook, 2005, 9

People Daily (2007), High cost of Solar Power Generation is hopeful to be broken, Dec, 19, 2007

People Net (2007), Photovoltaic Technology has breakthrough, Sep, 19, 2007 http://www.in-en.com/newenergy/tech/pv/index.htm

Yang Zi Night News (2007), the cost of solar electricity is 0.6 Yuan/kw, Jun, 4, 2007

China Chemical News (2007), Recent status of Coalbed Methane Development in China, http://www.ccin.com.cn/news1/ShowArticle.asp?ArticleID=20964

IEA(2007) World Energy, Technology and climate policy Outlook 2030, IEA, Paris.

Zhaoning Zheng, Shuwei Zhang, Deshun Liu (2004), The cost and policy recommendations of the Commercialization of China's nuclear power, China Soft Science, 2004,10

Huixin Yang (2005), natural gas power generation market analysis, gas turbine power generation technology, Vol 7, No. 3 / 4, October 2005

NDRC (2007), long-term development of renewable energy planning, NDRC

Junfeng Li et al, China wind power report 2007, China Environmental Science Press, Beijing

Xiulian HU, Kejun JIANG, China's greenhouse gas emission reduction technology options and countermeasures evaluation, China Environmental Science Press, Beijing, 2001

Songli Zhu, Kejun Jiang, Energy demand and pollutant emissions of Beijing urban traffic, China's energy, 2006,6

Kejun JIANG, Xiulian HU (2002), China's greenhouse gas emissions scenarios and technique evaluation, 2002, China's Climate Change Science Conference Proceedings

Xiulian HU, Kejun JIANG (2002), ERI-AIM/ China energy emission model and application, 2002, China's Climate Change Science Conference Proceedings

Kejun JIANG (2005), IPCC Working Group III, the second seminar of new emission scenarios, climate change research progress, 2005,7

Kejun JIANG, Xiulian HU (2003), Chinese and global greenhouse gas emissions scenario analysis model, "China Energy Research 2002", 2003

Schipper L., Marie-Lilliu C., Fulton L., Diesels in Europe – analysis of Characteristics, usage patterns, energy savings and CO2 emission implications, Journal of Transport Economics and Policies, Vol.36, part 2, May 2002, pp. 305-340

Oil price, International Energy Agency, www.iea.org, July 2005

Gordon D., Summary of international experience on fiscal and taxation policy to promote the development of transportation, launched by Energy Foundation, 2005

Edmonds J,H.M Pitcher, D. Barns, R.Baron, M.A. Wise"MODELING FUTURE GREENHOUSE GAS EMISSION: The Second Generation Model Description", Pacific Northwest Laboratory, 901 D St. SW, Washington, DC 20024, August 8, 1994.

John Beghin, Sebastein Dessus, David Roland-Holst, Dominique van der Mensbrugghe: "Chinese CGE Model for the Trade and Environment Program Technical Specification", OECD Development Center, 94 rue, Chardon-Lagache, 75016 Paris, France, August 9, 1995.

China Year Book 2007, China Statistic Publishing House, Beijing

China Power Industry Year Book 2001 (2002), China Power Industry Year Book Publishing House, Beijing.

Hu, X., Jiang, K., Liu, J. (1996) Application of AIM/Emission Model in P.R. China and Preliminary Analysis on Simulated Results, AIM Interim Paper, IP-96-02, Tsukuba, Japan.

Jiang, K., Hu, X., Matsuoka, Y., Morita, T. (1998) Energy Technology Changes and CO2 Emission Scenarios in China. Environment Economics and Policy Studies 1:141-160.

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

Kejun JIANG, Xiulian HU, Carbon Tax: An integrated analysis for China, Processding of International Workshop on Green Tax Reform, 2000, Seoul Korea.

Kejun Jiang, Tsuneyuki Morita, Toshihiko Masui, and Yuzuru Matsuoka， Long-Term Emission Scenarios for China，Environment Economics and Policy Studies Vol.2:267-287, 1999.

Zhu Songli, Jiang Kejun, Analysis of Technical Options for Mitigating CO2 Emission from Urban Transport System: A Case Study for Beijing, International Journal of Environment and Pollution(IJEP), 2003.

8. Appendix

Table A-1: The four scenarios in 2050: outcomes

	BAU	**LC**	**ELC**	**LLC**
GDP	Realising the national target of three-step development. Average annual growth rate is 9% between 2005 and 2020, 6% between 2021 and 2035 and 4.5% between 2036 and 2050. Annual average growth rate is 6.4% between 2005 and 2050.	Similar to BAU	Similar to BAU	Realising the national target of three-step development. Average annual growth rate is 8.6% between 2005 and 2020, 5.5% between 2021 and 2035 and 4% between 2036 and 2050. Average annual growth rate is 5.6% between 2005 and 2020.
Population	Reaching the maximum of 1.47 billion. In 2050, population decreases to 1.46 billion	Similar to BAU	Similar to BAU	Similar to BAU
Per capita GDP	About 270,000 yuan in 2050 ($38,000)	Similar to BAU	Similar to BAU	About 150,000 yuan in 2050 ($22,000)
Industry structure	Economic structure is optimised to a certain extent. Tertiary industry is the main component of economic growth. The development of secondary industry is accompanied by high domestic consumption; heavy industry still holds an important role.	Economic structure is further optimised, similar to the historical pattern of developed countries. Tertiary industry develops quickly. IT industry has an important role.	Similar to LC	Similar to LC
Urbanisation	70% by 2030, 79% by 2050	Similar to BAU	Similar to BAU	Similar to BAU
Configuration of exports and imports	Primary products begin to lose competitiveness by 2030. Energy consumption is driven mainly by domestic demand.	Primary products begin to lose competitiveness by 2020. Energy consumption is directed mostly to domestic demand rather than to exports, with high added-value and service industries playing an increasingly important role in the economy.	Similar to LC	Similar to BAU
Energy consumption by energy intensive industry	Peaking by 2030 and decreasing subsequently.	Peaking between 2020 and 2030. Subsequently decreasing. Demand at peaking is lower than in BAU.	Similar to LC	Similar to LC
Primary energy	About 6.5 billion tce	About 5.3 billion tce by	About 5.1 billion tce	

demand	by 2050	2050	by 2050	
CO_2 emissions	About 3.4 billion tonnes of carbon (12 billion tonnes of CO_2)	About 2.2 billion tonnes of carbon (8 billion tonnes of CO_2)	About 1.5 billion tonnes of carbon (5.5 billion tonnes of CO_2)	
Domestic pollution	Achieving goals. But treatment is still lags behind pollution as a result of environment KUZNETZ curve.	Similar to BAU	Achieving the treatment before 2020. But treatment still lags behind pollution as a result of environment KUZNETZ curve.	Achieving the treatment before 2020. But treatment still lags behind pollution as a result of environment KUZNETZ curve.
Energy technologies	Advanced technologies are widely available by 2040. China becomes the technology leader, and energy efficiency levels are 40% higher than at present.	By around 2030, advanced technologies are widely available. Industry and technology standards in China are among the highest in the world. China becomes a technology leader, and energy efficiency levels are 40% higher than at present.	Similar to LC	Similar to LC
Application of non-conventional energy resources	Exploitation of non-conventional oil and gas after 2040.	Similar to BAU	Almost no need to exploit non-conventional oil and gas.	Similar to ELC
Electricity generation from solar energy and wind energy	The cost of solar energy is 0.39 yuan/ kWh by 2050; on-shore wind widely applied.	The cost of solar energy is 0.27 yuan/ kWh by 2050. On-shore wind widely applied. Offshore wind plants start being constructed on large scale.	Similar to LC	Similar to LC
Nuclear power generation	Generating capacity is more than 200 million kW by 2050; unit cost decreases from 0.33 yuan/kWh (2005) to 0.24 yuan/kWh by 2050.	Generating capacity is more than 330 million kW by 2050; unit cost decreases from 0.33 yuan/kWh (2005) to 0.22 yuan/kWh by 2050. Forth-generation nuclear plants begin to develop on a large scale after 2030.	Generating capacity is more than 380 million kW by 2050; unit cost decreases from 0.33 yuan/kWh (2005) to 0.2 yuan/kWh by 2050. Forth-generation nuclear plants begin to develop on a large scale after 2030.	Similar to ELC
Coal power generation	Mainly super critical (SC) and ultra super critical (USC) technologies are used for new plants throughout the period.	Mainly super critical (SC) and ultra super critical (USC) technologies are used for new plants before 2030. Subsequently mostly integrated coal gasification combined cycle (IGCC) technologies are adopted for new plants.	Mainly IGCC after 2020	Similar to ELC
CCS	No consideration	CCS projects begin appearing by 2020, with some reductions in cost subsequently. CCS technologies are used for newly built IGCC generating plant from 2050.	CCS is applied in combination with all newly built IGCC generating plants. CCS is also used extensively after 2030 in the following industries: iron,	Similar to LC

			cement, electrolytic aluminium, synthesis ammonia, ethylene.	

Table A-2: Scenario settings of GDP,* 2005–2050

	2005	2010	2020	2030	2040	2050
GDP	183,132	291,361	612,343	1,077,002	1,615,282	2,185,183
Added value of primary industry	22,718	29,206	43,744	56,302	67,565	76,790
Added value of secondary industry	87,446	142,889	281,012	451,468	592,343	711,685
Added value of tertiary industry	77,428	126,578	248,106	399,613	525,579	633,932

*10^8 yuan, 2005 prices; low GDP growth rate scenario.

Table A-3: Production of main energy-intensive products, LC and ELC scenarios, 2005–2050

	Unit	2005	2020	2030	2040	2050
Iron and steel	10^8 tonnes	3.55	6.1	5.7	4.4	3.6
Cement	10^8 tonnes	10.6	16	16	12	9
Glass	10^8 weight cases	3.99	6.5	6.9	6.7	5.8
Copper	10^4 tonnes	260	700	700	650	460
Aluminium	10^4 tonnes	851	1,600	1,600	1,500	1,200
Lead and zinc	10^4 tonnes	510	720	700	650	550
Sodium carbonate	10^4 tonnes	1,467	2,300	2,450	2,350	2,200
Caustic soda	10^4 tonnes	1,264	2,400	2,500	2,500	2,400
Paper and paperboard	10^4 tonnes	6,205	11,000	11,500	12,000	12,000
Chemical fertiliser	10^4 tonnes	5,220	6,100	6,100	6,100	6,100
Ethylene	10^4 tonnes	756	3,400	3,600	3,600	3,300
Ammonia	10^4 tonnes	4,630	5,000	5,000	5,000	4,500
Calcium carbide	10^4 tonnes	850	1,000	800	700	400

Table A-4: Production of main energy-intensive products, LLC Scenario, 2005–2050

	Unit	2005	2020	2030	2040	2050
Iron and steel	10^8 tonnes	3.55	5.7	5.4	4.2	3.4
Cement	10^8 tonnes	10.6	15	15	11	8
Glass	10^8 weight cases	3.99	6.3	6.5	6.3	5.3
Copper	10^4 tonnes	260	650	650	600	440
Aluminium	10^4 tonnes	851	1,400	1,400	1,400	1,100
Lead and zinc	10^4 tonnes	510	700	670	620	510
Sodium carbonate	10^4 tonnes	1,467	2,000	2,150	205	1,900
Caustic soda	10^4 tonnes	1,264	2,200	2,300	2,200	2,100
Paper and paperboard	10^4 tonnes	6,205	10,000	10,500	11,000	11,000

Chemical fertiliser	10^4 tonnes	5,220	5,500	5,500	5,300	5,100
Ethylene	10^4 tonnes	756	3,000	3,200	3,200	2,900
Ammonia	10^4 tonnes	4,630	4,900	4,900	4,900	4,200
Calcium carbide	10^4 tonnes	850	900	700	600	350

Table A-5: Technology parameters in urban households, 2020–2050

Service	Unit	Service		
		2020	2030	2050
Household number, million units	Million households	288	336	380
Share of household having space heating	%	42	44	48
Index of heating intensity, 2000=1	2000=1	1.35	1.5	1.6
Index of heating hours, 2000=1	2000=1	1.33	1.36	1.4
Share of 50% energy saving buildings	%	20	45	65
Possession of air conditioning per 100 households	%	130	180	260
Index of air conditioning intensity,2000=1	2000=1	1.3	1.4	1.6
Index of air conditioning utilisation hour, 2000=1	2000=1	1.6	1.8	2.2
Ownership rate of fridges	Per 100 households	100	120	130
Average volume of fridges	liters	250	310	390
Fridge efficiency	kWh/day	0.8kWh/day	0.8kWh/ day	0.7kWh/ day
Ownership rate of washing machines	%	100	100	100
Number of utilisation of washing machines per week	time	5．4	8	8
Ownership rate of TVs	%	180	220	290
Average power of TV	W	320W	300W	280
Viewing time per TV per day	Hour/day	3.5	3.2	2.9
Penetration rate of energy saving light	%	100	100	100
Number of lightening bulb per household (standard illumination of 40W fluorescent)		14	21	27
Ownership rate of water heater	%	100	100	100
Ownership rate of solar water heater	%	18	25	33
Ownership rate of electric cooker per 100 households	%	130	140	260
Utilisation hour of electric cooker per day	Hour/day	12 minutes	30 minutes	50 minutes
Power of other household appliances	W	1500W	1800W	2300W
Utilisation hour of other appliances per day	Minute/day	50 minutes	80 minutes	100 minutes

Table A-6: Technology parameters in rural households, 2020–2050

Service	Unit indicator	Service		
		2020	2030	2050
Household number, million units	Million households	152	131	

Share of household having space heating	%	42	44	
Index of heating intensity, 2000=1	2000=1	2.1	2.6	
Index of heating hours, 2000=1	2000=1	1.5	1.7	
Share of 50% energy saving buildings	%	15	35	
Possession of air conditioning per 100 households	%	45	70	
Index of air conditioning intensity,2000=1	2000=1	2	2.6	
Index of air conditioning utilisation hour, 2000=1	2000=1	1.7	2	
Ownership rate of fridges	Per 100 households	70	95	
Average volume of fridges	liters	220	290	
Fridge efficiency	kWh/day	0.67kWh/day	0.65kWh/day	
Ownership rate of washing machines	%	78	94	
Number of utilisation of washing machines per week	time	4	6	
Ownership rate of TVs	%	130	180	
Average power of TV	W	270W	270W	
Viewing time per TV per day	Hour/day	3.5	3.2	
Penetration rate of energy saving light	%	70	100	
Number of lightening bulb per household (standard illumination of 40W fluorescent)		10	18	
Ownership rate of water heater	%	70	100	
Ownership rate of solar water heater	%	48	80	
Ownership rate of electric cooker per 100 households	%	55	70	
Utilisation hour of electric cooker per day	Hour/day	8 minutes	28 minutes	
Power of other household appliances	W	1000W	1300W	
Utilisation hour of other appliances per day	Minute/day	30 minutes	60 minutes	

Table A-7: Main factors influencing energy consumption in service sector

	Construction area	**Area of large public buildings**	**Average power of appliances in large public buildings**	**Energy saving rate of electric appliances**	**Area of other public buildings**	**Average power of appliances in other large public buildings**	**Energy saving rate of electric appliances**	**Energy saving rate of heating (50% and above energy saving buildings)**
Units	10^8 m^2	10^8 m^2	W/m^2	%	10^8 m^2	W/m^2	%	%
2000								
2005	41	5.6	36.9		35.4	11.4		
2010	69	9.8	45.4	3	59.2	12.1	3	5
2020	146	22	58.7	9	124	13.3	8	30
2030	245	39	72.1	19	206	14.9	17	65

2040	310	52	84.5	28	258	16.5	26	80
2050	340	63	95.1	41	277	18.0	40	95

Table A-8: Technology parameters in service sector

Technology	Indicator	Level of technology penetration		
		2020	2030	
Construction area of service sector, 10^8 m^2		270	370	
Ratio of heating (%)		34	38	
Index of heating intensity, 2000=1		1.4	1.6	
Index of heating hours, 2000=1		1.2	1.3	
Share of 65% energy saving building (%)		30	65	
Ownership rate of copier		12	14	
Ownership rate of computers		55	65	
Index of computer's utilisation hour intensity, 2000=1		1.3	1.6	
Ownership rate of elevator		16	18	

Table A-9: Vehicle population (10,000 units), BAU scenario, 2005–2050

	2005	2010	2020	2030	2040	2050
Total	3,160	6,836	19,538	39,672	56,372	60,524
Passenger cars	2,132	4,869	16,330	35,376	50,314	53,117
Trucks	1,027	1,967	3,208	4,296	6,058	7,407
Cars	1,919	4,589	15,970	34,866	49,594	52,217
Family cars	1,100	3,589	14,770	33,466	47,994	50,617
Other cars	819	1,000	1,200	1,400	1,600	1,600
Minibus	131	162	202	275	374	450
Large passenger coach	82	117	158	234.6	345.6	450
Small passenger coach	214	280	360	510	720	900
Motorcycles	6,582	9,947	10,942	12,036	12,036	11,434

Table A-10: Vehicle population (10,000 units), low carbon scenario, 2005–2050

	2005	2010	2020	2030	2040	2050
Total	3,160	6,227	18,583	36,318	51,717	55,810
Passenger cars	2,132	4,299	15,504	32,323	46,083	48,922
Trucks	1,027	1,928	3,079	3,995	5,634	6,888
Cars	1,919	3,921	14,982	31,558	45,075	47,662
Family cars	1,100	3,145	14,032	30,454	43,675	46,062
Other cars	819	776	950	1,104	1,400	1,600
Minibus	131	265	313	383	524	214
Large passenger coach	82	113	208	382	483	1,045
Small passenger coach	214	378	522	765	1,008	1,260
Motorcycles	6,582	9,848	10,613	11,193	11,193	10,634

Table A-11: Annual travelled distance of family cars (km), BAU, 2005–2050

	2005	2010	2020	2030	2040	2050
Urban	**9,500**	**9,500**	**9,300**	**9,000**	**8,700**	**8,500**
Rural	6,500	6,500	5,500	5,000	5,000	5,000

Table A-12: Annual travelled distance of family cars (km), low carbon scenario, 2005–2050

	2005	2010	2020	2030	2040	2050
Urban	**9,500**	**8,500**	**7,800**	**7,000**	**5,000**	**5,000**
Rural	6,500	6,000	5,300	5,000	4,800	4,600

Table A-13: Proportion of large passenger cars and public transportation in road transportation (%) in two scenarios, 2005–2050

	2005	2010	2020	2030	2040	2050
BAU	96	84	64	58	59	64
Low carbon scenario	96	89	78	76	79	88

Table A-14: Traffic turnover volume,* BAU scenario, 2005–2050

	2005	2010	2020	2030	2040	2050
Turnover volume of passengers	3,446	5,100	8,631	13,869	20,640	28,312
Turnover volume of traffic freight	9,394	14,429	23,832	36,035	57,379	79,970
Passenger traffic volume in road transport	2,628	3,980	6,699	10,634	14,866	17,405
Passenger traffic volume in rail transport	606	752	1,072	1,385	1,791	2,315
Passenger traffic volume in air transport	204	360	853	1,842	3,976.6	8,585
Passenger traffic volume in water transport	7	7	7	7	7	7
Freight traffic volume in road transport	2,251	3,565	6,853	10,713	19,345	22,637
Freight traffic volume in rail transport	2,073	2,692	4,003	5,576	7,769	10,824
Freight traffic volume in air transport	8	12	29	70	182	477
Freight traffic volume in air transport	4,954	7,949	12,296	18,136	26,758	39,490
Freight traffic volume in pipeline transport	109	209	651	1,540	3,325	6,541

* Billion passenger-kilometres/billion tonne-kilometres.

Table A-15: Primary energy demand,* BAU scenario, 2005–2050

	Coal	Oil	Natural gas	Hydro-power	Nuclear power	Wind power/ solar	Biomass energy	Alcohol gasoline	Biodiesel	Total
2000	944	278	30	85	6	0.4	1.0	0.0	0.0	1,346
2005	1,536	435	60	131	20	0.8	1.9	1.8	0.6	2,189
2010	2,424	628	109	217	28	7	16	10	0.6	3,438
2020	2,991	1,096	271	294	90	20	30	22	3.1	4,817
2030	2,932	1,708	460	358	181	54	44	33	7.9	5526
2040	3,001	1,710	532	380	380	84	71	36	8.5	6,202
2050	2,925	1,836	668	397	595	103	86	39	9.2	6,657

*Million tonnes of standard coal.

Table A-16: Generated energy,* reference scenario, 2005–2050

	Coal	Oil	Natural gas	Hydro power	Nuclear power	Wind power	Biomass energy	Total
2000	10,584	451	68	2,351	175	11	27	13,667
2005	19,546	636	125	3,960	599	25	50	24,940
2010	34,222	871	435	6,531	914	131	435	43,540
2020	49,773	1,175	1,632	9,465	2,024	359	849	65,276
2030	58,925	1,229	3,770	11,474	4,262	1,065	1,229	81,954
2040	54,512	1,437	8,143	13,412	13,412	2,970	1,916	95,803
2050	58,007	1,629	10,863	13,035	19,553	3,367	2,173	108,628

*100 million kWh.

Table A-17: Installed capacity,* reference scenario, 2005–2050

	Coal	Oil	Natural gas	Hydro power	Nuclear Power	Wind power	Biomass energy	Total
2000	21,823	930	152	7,672	220	52	55	30.904
2005	36,879	1,311	227	12,133	855	119	100	51,623
2010	68,445	1,742	968	19,791	1,306	622	871	93,744
2020	103,694	2,350	3,626	27,043	2,891	1,710	1,697	143,010
2030	128,098	2,459	8,378	30,194	6,088	5,073	2,459	182,748
2040	118,504	2,874	18,096	35,296	19,161	14,142	3,832	211,905
2050	126,103	3,259	24,140	34,304	27,933	16,036	4,345	236,118

*10,000 kW.

Table A-18: Final energy consumption, reference scenario,* 2000–2050

	Coal	Coke	Coal gas	Oil	Natural gas	Thermal	Electricity	Total
2000	429	81	13	265	22	59	155	1,024
2005	651	189	38	390	45	90	285	1,689
2010	917	321	50	597	78	157	449	2,569
2020	1,106	209	33	1,043	169	274	674	3,509
2030	1,133	164	23	1,505	279	398	847	4,292
2040	1,072	141	19	1,620	277	432	991	4,552
2050	1,037	123	15	1,731	313	474	1,177	4,870

*Million tonnes of standard coal.

Table A-19: Primary energy demand,* high economic growth and low carbon scenario, 2000–2050

	Coal	Oil	Natural Gas	Hydro power	Nuclear Power	Wind power	Solar Power	Biomass Energy	Alcohol Gasoline	Biodiesel	Total
2000	944	278	30	85	6	0	0	1	0	0	1,346
2005	1,536	435	60	131	20	1	0	2	2	1	2,189
2010	2,173	528	109	207	46	12	0	9	2	1	3,087
2020	2,195	843	349	375	136	51	1	32	8	6	3,996
2030	2,091	964	529	401	301	92	4	52	28	12	4,474
2040	2,063	1,010	628	424	471	118	9	61	36	13	4,833
2050	1,984	1,025	745	422	760	169	20	68	44	14	5,250

*Million tonnes of standard coal.

Table A-20: Generated energy,* high economic growth and low carbon scenario, 2000–2050

	Coal	Oil	Natural gas	Hydro power	Nuclear power	Wind power	Solar power	Biomass energy	Total
2000	1,042	45	14	233	17	1	0	3	1,354
2005	1,938	62	25	396	60	2	0	10	2,494
2010	3,193	59	84	645	142	38	0	29	4,191
2020	3,324	57	312	1,249	454	170	2	108	5,677
2030	3,438	54	630	1,431	1,073	329	14	186	7,156
2040	3,605	53	883	1,513	1,682	420	34	219	8,408
2050	3,657	50	1,206	1,507	2,713	603	70	241	10,047

*100 million kWh.

Table A-21: Installed capacity,* high economic growth and low carbon scenario, 2000–2050

	Coal	Oil	Natural gas	Hydro power	Nuclear power	Wind power	Solar power	Biomass energy	Total
2000	21,487	922	301	7,603	218	52	0	60	30,643
2005	37,276	1,286	453	12,133	855	119	0	222	52,344
2010	66,525	1,304	1,863	21,558	2,036	1796	23	652	95,757
2020	69,258	1,262	6,938	38,883	6,488	8,110	126	2,397	133,462
2030	74,749	1,193	12,595	45,192	15,334	15,675	795	4,135	169,667
2040	78,361	1,177	16,052	48,242	24,023	20,019	1,868	4,858	194,601
2050	79,499	1,116	21,920	48,057	38,751	28,704	3,907	5,358	227,312

*10,000 kW.

TableA-22: Final energy consumption,* high economic growth and low carbon scenario, 2000–2050

	Coal	Coke	Coal gas	Oil	Natural gas	Thermal	Electricity	Total
2000	394	83	13	271	22	54	153	990
2005	594	194	38	390	45	83	284	1,627

2010	700	314	49	493	65	111	457	2,189
2020	803	185	29	786	171	161	620	2,756
2030	770	127	19	872	274	188	775	3,025
2040	702	109	16	902	300	201	920	3,149
2050	641	91	13	889	326	215	1,099	3,273

Million tonnes of standard coal.

Table A-23: Primary energy demand,* intensified high economic growth and low carbon scenario, 2000–2050

	Coal	Oil	Natural gas	Hydro-power	Nuclear Power	Wind power	Solar power	Biomass Energy	Alcohol gasoline	Biodiesel	Total
2000	944	278	30	85	6	0	0	1	0	0	1,346
2005	1,536	448	60	131	20	1	0	3	1	0	2,203
2010	2,083	532	107	180	40	18	0	8	2	1	2,971
2020	2,144	838	330	354	145	66	1	31	8	6	3,921
2030	1,903	943	491	395	301	156	5	49	20	12	4,275
2040	1,814	993	604	429	497	214	16	59	22	13	4,660
2050	1,715	1,032	710	420	761	239	37	63	23	14	5,014

*Million tonnes of standard coal.

Table A-24: Installed capacity,* intensified high economic growth and low carbon scenario, 2000–2050

	Coal	Oil	Natural gas	Hydro power	Nuclear power	Wind power	Solar power	Biomass energy	Total
2000	21,487	922	301	7,603	218	52	0	54	30,637
2005	36,573	1,286	453	12,133	855	119	0	200	51,618
2010	57,437	1,218	1,623	19,045	1,774	2,609	43	568	84,317
2020	63,029	1,191	6,550	36,888	6,891	10,464	158	2,263	127,433
2030	62,530	1,193	11,009	44,576	15,343	26,531	987	3,878	166,048
2040	61,516	1,075	15,391	48,765	25,338	36,471	3,320	4,658	196,533
2050	60,321	1,042	20,453	47,853	38,836	40,621	7,720	5,000	221,845

*10 thousand kW.

Table A-25: Final energy consumption,* intensified high economic growth and low carbon scenario, 2000–2050

	Coal	Coke	Coal gas	Oil	Natural gas	Thermal	Electricity	Total
2000	394	83	13	271	22	54	153	990
2005	594	194	38	390	45	83	284	1,627
2010	692	269	38	496	67	111	414	2,087
2020	799	185	29	781	165	148	585	2,694
2030	743	127	19	817	257	184	734	2,881
2040	684	109	16	827	287	201	882	3,005
2050	621	90	13	795	313	216	1,025	3,072

Million tonnes of standard coal.

Table A-26: Primary energy demand,* low economic growth and low carbon scenario, 2000–

2050

	Coal	Oil	Natural gas	Hydro-power	Nuclear power	Wind power	Solar power	Biomass energy	Alcohol gasoline	Biodiesel	Total
2000	944.4	278.1	30.4	85.3	6.4	0.4	0.0	1.0	0.0	0.0	1,346.0
2005	1,536.5	435.2	60.4	131.5	19.9	0.8	0.0	1.9	1.8	0.6	2,188.6
2010	2,069.4	532.1	107.2	187.0	41.3	10.9	0.1	8.5	2.0	1.0	2,959.6
2020	2,099.1	817.3	322.9	344.0	125.1	46.9	0.6	29.7	8.3	5.8	3,799.8
2030	1,913.3	918.8	471.7	359.9	269.9	82.8	3.6	46.8	20.1	12.0	4,098.9
2040	1,887.0	967.8	569.9	381.1	423.4	105.8	8.5	55.0	21.7	13.0	4,433.3
2050	1,783.1	1,007.8	672.3	367.4	661.3	147.0	17.1	58.8	23.4	14.0	4,752.2

*Million tonnes of standard coal.

Table A-27: Generated energy,* low economic growth and low carbon scenario, 2005–2050

	Coal	Oil	Natural gas	Hydro power	Nuclear power	Wind power	Solar power	Biomass energy	Total
2000	10,421	447	135	2,330	173	11	0	27	13,545
2005	19,384	624	249	3,960	599	25	0	100	24,940
2010	28,918	531	759	5,845	1,290	342	4	266	37,956
2020	29,828	521	2,867	11,468	4,170	2,242	42	990	52,128
2030	29,597	482	5,656	12,854	9,641	4,049	321	1,671	64,272
2040	29,312	476	7,939	13,609	15,121	6,048	1,134	1,966	75,605
2050	27,641	437	10,497	13,121	23,617	7,872	2,187	2,099	87,471

*100 million kWh.

Table A-28: Installed capacity,* low economic growth and low carbon scenario, 2000–2050

	Coal	Oil	Natural gas	Hydro power	Nuclear power	Wind power	Solar power	Biomass energy	Total
2000	21,487	922	301	7603	218	52	0	60	30,643
2005	37,276	1,286	453	12,133	855	119	0	222	52,344
2010	60,247	1,181	1,687	19,713	1,844	1625	29	590	86,915
2020	62,141	1,158	6,371	35,966	5,958	10,633	321	2,201	124,749
2030	64,342	1,071	11,312	41,027	13,773	18,692	2,472	3,713	156,401
2040	63,722	1,058	14,434	43,883	21,602	26,710	8,724	4,368	184,500
2050	60,089	972	19,085	42,488	33,739	32,901	16,821	4,,665	210,759

*10,000 kW.

Table A-29: Final energy consumption,* low economic growth and low carbon scenario, 2000–2050

	Coal	Coke	Coal gas	Oil	Natural gas	Thermal	Electricity	Total
2000	395	83	13	271	22	54	153	991
2005	617	192	27	405	45	83	280	1,649
2010	691	269	38	496	66	111	414	2,085
2020	781	177	28	761	159	148	569	2,624
2030	718	123	19	793	242	170	696	2,761
2040	656	104	15	804	274	191	827	2,871

2050	596	88	12	775	303	210	957	2,941

*Million tonnes of standard coal.

Table A-30: CO_2 emissions from the fossil fuel combustion,* 2000–2050

	Reference scenario	**High economic growh and low carbon scenario**	**Intensified high economic growth and low carbon scenario**	**Low economic growth and low carbon scenario**
2000	867	867	867	861
2005	1,409	1,409	1,409	1,401
2010	2,134	1,943	1,943	1,869
2020	2,779	2,262	2,194	2,086
2030	3,179	2,345	2,228	2,033
2040	3,525	2,398	2,014	1,902
2050	3,465	2,406	1,395	1,387

* Million tonnes of carbon.