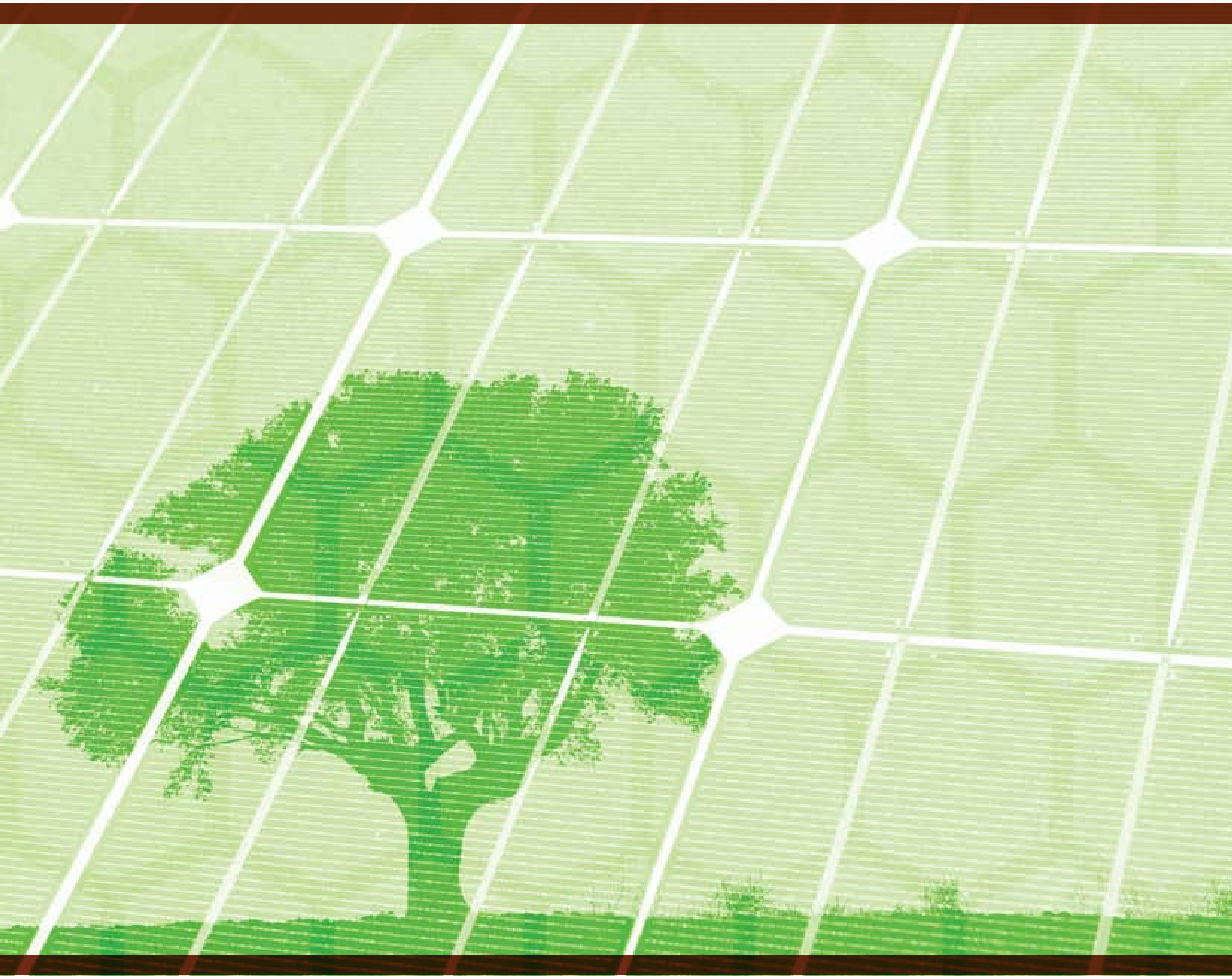
A CHATHAM HOUSE REPORT — NOVEMBER 2007

Changing Climates

Interdependencies on Energy and Climate Security for China and Europe



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The Royal Institute of International Affairs
Chatham House
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About *Changing Climates*

Changing Climates is written by the project team of the Interdependencies on Energy and Climate Security for China and Europe project. The analysis and findings from this report are drawn from over twenty separate studies prepared by researchers from Chatham House, CASS, ERI, E3G and IDDRI and other institutions. Contributors to the report include Bernice Lee, Antony Froggatt, Nick Mabey, Jason Switzer, Richard Tarasofsky, Beverley Darkin, Rebecca Jackson, Jun Li, Jennifer Morgan, and Yiping Zhu. Extensive comments were provided by Jiahua Pan, Kejun Jiang, John Mitchell, Jim Watson, Günter Heiduk, Karl Hallding and Trineesh Biswas on the first draft. The project team also benefited from discussions with a number of individuals in the past six months, including Asif Ahmad, Allan Amey, Philip Andrews-Speed, Thiru Balasubramaniam, John Barton, Christophe Bellmann, Yong Chen, Michel Colombier, John Drexhage, John Fox, Vera Franz, Sam Geall, Magnus Gislev, James Godber, Mark Halle, Isabel Hilton, Leo Horn, Fuqiang Li, Lailai Li, Feng Liu, James Love, Howard Mann, Ricardo Meléndez-Ortiz, Deborah Murphy, Lo Sze Ping, Bo Qian, David Runnalls, Cyril Sayag, Lynn Sheppard, Alexandra Sombsthay, Mahesh Sugathan, Derek Taylor, Can Wang, Leanne Wang, Tao Wang, John Warburton, Wenbiao Ye, Ji-Qiang Zhang, Xiangchen Zhang and Jimin Zhao. This report is edited by Margaret May and Trineesh Biswas.

Project Team

Team Leader:	Bernice Lee
Deputy Team Leaders:	Antony Froggatt and Beverley Darkin
Researchers:	Rebecca Jackson, Jun Li, Yiping Zhu
Project Coordinators:	Vanessa Curney and Iain MacKenzie
Research Interns:	Diarmuid Torney, Xiao Shu, Rob Foulkes

About the Project

The Interdependencies on Energy and Climate Security for China and Europe Project is an independent initiative of European and Chinese research institutions to facilitate further understanding of China–EU interdependence and the potential for collaboration on energy and climate security issues. The Steering Committee of this initiative comprises representatives from Chatham House (Royal Institute of International Affairs), E3G (Third Generation Environmentalism), the Chinese Academy of Social Sciences (CASS), the Energy Research Institute (ERI), the Potsdam Institute for Climate Impacts Research (PIK) and the Institute for Sustainable Development and International Relations (IDDRI). This project is supported by the UK Foreign and Commonwealth Office, the Open Society Foundation, the UK Department for International Development and the Swedish Ministry for Foreign Affairs.

Steering Committee

Rosemary Hollis and Richard Tarasofsky	Chatham House
Nick Mabey and Jennifer Morgan	E3G
Jiahua Pan	Chinese Academy of Social Science
Kejun Jiang	Energy Research Institute
Lawrence Tubiana and Michel Colombier	IDDRI
Antonella Battaglini	PIK

Executive Summary

We are on the cusp of a new industrial revolution, one driven by energy and climate security concerns. Policy-makers and business leaders are beginning to calibrate decisions on trade, financing and production planning against this new reality. Central to making this vision work is enlightened thinking around the potential economic and political benefits – rather than the costs – of the transition to a low-carbon future.

China and the European Union (EU) together account for around 30% of global energy consumption and 30% of global emissions. Their common interests provide a foundation for deepening collaborative efforts on energy and climate security over the next quarter-century. The combined economic might of the EU, the world's largest single market, and China, the fastest-growing economy, can provide unprecedented opportunities to generate benefits of scale that will lower the costs of climate-friendly goods and services globally. By working together, China and Europe could become the *de facto* engine of global low-carbon transformation.

Business as Usual (BAU) is not an option. The International Energy Agency (IEA) forecasts a global increase in energy consumption of more than 55% by 2030. There is no sign that energy demand and consumption will abate in the near future. Oil prices increased fivefold over the last eight years, in real terms hitting the 1979 high in October 2007. The era of cheap hydrocarbons may now be over. Waiting for world oil production to reach its maximum capacity could leave the world with a significant liquid fuel deficit for at least two decades. Supply concerns are driving investments towards unconventional fossil fuel sources, with large associated energy costs and significant CO_2 emissions.

The alarming projected impacts of climate change also point to the range of risks, vulnerabilities and choices confronting policy-makers and citizens. The Stern Review estimated the avoidable costs of inaction would be between 5% and 20% of GDP per year. BAU scenarios project extreme temperature rises of 4–7°C by the end of the century. A responsible risk management strategy for policy-makers would be to keep to the low probability range of 2°C rise, as climate sensitivities appear higher than previously estimated. Put another way, global CO_2 emissions will need to peak in the next two decades and reduce by over 50% by 2050. For developed countries, such as the member states of the EU, this implies moving to an essentially zero-carbon economy by around mid-century, with major developing countries such as China following well before the end of the century.

Choices made in China matter. China's immediate decisions about its infrastructure needs and patterns of consumption will have a decisive impact on global efforts to stabilize greenhouse gas emissions, and the feasible rate of reduction to sustainable levels. China currently emitted about 19% of global CO_2 emissions in 2005 and is expected to contribute about 27% by 2030. In preliminary estimates for 2006, China topped the list of CO_2-emitting countries, surpassing the US by an estimated 8%. However, China's per capita carbon emissions level is over three times less than the EU average and six times less than the US average.

China's strategic aspiration towards an innovation-based economy with science-based development – as enunciated at the 17th Party Congress in October 2007 – is in line with the vision for a low-carbon transition. A focus on developing and deploying advanced climate technologies is also consistent with China's aspiration to move up the global value chain. A recent study suggested that for every US$1,000 of Chinese exports to the United States in 2002, only US$386 was accrued in China. Ensuring that China gains a sizeable share of the low-carbon economy is critical to managing its domestic emission growth, and would provide incentives for China to play a larger role in the post-2012 global deal on climate change.

Why China and the EU?

China and the EU are economically entwined. China is the EU's largest trading partner. The EU is China's second largest. The EU is also China's largest supplier of technologies, foreign direct investment (FDI) and services. China is increasingly the main source of EU trade deficits. Bilateral trade deficits make news headlines, but obscure the fact that a significant part of the value addition of products 'made in China' accrues to European companies. Shoes imported from China return 50–80% of their value to the European companies that design and market them. As manufacturing supply chains integrate across borders, components are often made in one country and then shipped to others for final assembly. It means that it has never been harder to know who reaps the economic benefits from a product, and who should bear responsibility for the emissions produced in its manufacture.

Investments in China have helped EU firms stay competitive through access to lower-cost inputs. Cheap Chinese imports have meant lower prices for European consumers. The rate of return from FDI in China is increasing: in 2003 it was 8%, while the average return on EU capital from investments in other countries was 6%. In the longer term, as the European workforce shrinks, the economic relationship with China will become increasingly critical for the European economy. Estimates show that European wages in 30 years could be 16–40% lower if China fails to sustain its rapid economic growth.

China and the EU face common challenges in energy and climate security. Both are expected to be importing 80% of their oil supply by 2030. Resource needs have driven investments into politically unstable and fragile regions, changing the geopolitical landscapes in Central Asia, the Middle East and Africa. Ensuring security of supply – and stability in resource-rich regions – is thus a vital interest for both regions. They also need to manage the impacts of climate change, which will increasingly undermine food, water and human security, with implications far beyond national borders including in areas of high shared strategic interest such as Central Asia and East Africa. The two powers will both need to radically improve their adaptive capacity and work with other countries to reduce the risk of resource conflict over access to vital resources and distress migration. China and the EU also have remarkably similar and ambitious energy policies to enhance energy security through greater energy efficiency and use of renewable energy. It is estimated that the EU could be purchasing 77% of carbon credits generated in China by 2012 to help meet its compliance with the Kyoto Protocol.

It is imperative for China and the EU to take advantage of the opportunities offered by their interdependence to achieve win-win solutions that not only bring national economic benefits but also generate shared public goods of energy and climate security. This cooperation should be driven by mutual opportunities and recognition of the shared carbon responsibilities associated with bilateral trade. Estimates suggest that over 40% of China's CO_2 emissions are produced during the manufacture of goods made for export. For Europe to strengthen its relationship with China, it needs to avoid political rhetoric that feeds anxieties based on exaggerated fears of Chinese competition. Such populism will undermine support among European citizens for the cooperation needed to preserve their energy and climate security in the long term.

The scale of China's market – and its corresponding clean energy needs – offers one of the quickest routes to bringing new, clean energy technologies to maturity and widespread use. The combined strength of the Chinese and EU economies could help substantially bring down the cost of low-carbon technologies and adaptation tools and make them available to less industrialized countries. The maturity of the EU's aspirations to global leadership will perhaps be measured in part by its willingness to strengthen engagement with China on energy and climate security.

Avoiding lock-in of carbon-intensive investments

In the next quarter-century, $22 trillion will be needed for investment in energy supply infrastructure worldwide. China alone requires about $3.7 trillion. The shape of this investment will help determine the energy use patterns and CO_2 emissions for a generation. In the power sector China's reliance on coal is well known, as is the rate of expansion. Estimates suggest that 1,260 GW of new power stations will be built by 2030, 70% of which will be coal-fired. What is less well known is that over the same period Europe will build over 850 GW of new power stations needed to replace old ones and meet growing demand. Both regions share a responsibility in ensuring this planned capacity does not lock the world into a high-carbon future.

Constructing these facilities with conventional technology would both increase emissions immediately and reduce opportunities for switching to less polluting sources in the future. As an alternative, existing technologies, such as energy efficiency and renewables, can be introduced and implemented rapidly. Rapid expansion of renewable energy use is pushing up prices, but Europe and China could work to remove supply chain bottlenecks and create integrated supply chains that support aggressive supply expansion and cost reduction. Even with these programmes China will still increase its coal use. EU–China cooperation could be strengthened to reduce the sustainability impacts of the whole coal fuel cycle, from mining to efficiency of use for power and heat. Europe should also enhance its collaboration with China on carbon capture and storage technology, building a truly shared partnership to accelerate commercialization in both China and Europe.

The building sector in China is in the midst of a massive boom. New housing stock being built between now and 2020 will equal the total housing stock in the EU-15 countries today. China's existing building codes, if effectively enforced, would deliver significant energy efficiency gains. Far more could be saved through introducing EU best practice. Similarly in the EU, an immediate move towards implementing best practice will bring measurable improvements, with estimates of well over 20% savings already possible at low or negative costs. More ambitiously, Europe and China could work to mainstream and massively expand the use of existing close-to-zero-energy housing technology, and cooperate to develop better and cheaper technologies in this sector.

The growth in fuel use for transport in both China and the EU is accelerating and in the medium term will outstrip emissions growth from all other sources. Increased demand coupled with declining domestic resources add to the climate incentive for reduced oil use. With 80% of Chinese vehicles manufactured by joint venture companies, many with EU partners, there are opportunities for collaboration on joint roll-out of higher emissions standards across a huge combined market. Similarly, the search for low-carbon and sustainable liquid transport fuels presents opportunities for joint development and deployment – for example, around new-generation biofuels.

Leading the technology race

Both China and the EU have prioritized the development of new efficient and low-carbon technologies, ranging from incremental improvements to buildings and vehicles to potentially disruptive innovations harnessing biotechnology, nanotechnology and advanced materials. However, achieving these advances remains costly, difficult and uncertain. Embracing both aggressive technological innovation and diffusion as policy goals requires creatively balancing the incentives for the innovators or investors, while urgently maximizing access to climate technologies at affordable prices to avoid technology lock-in.

To create the necessary enabling framework, energy and climate policies need to contain incentives for innovation and diffusion. Existing subsidies that favour inefficient technologies to the detriment of low-carbon alternatives need to be reformed. Investments in research and development (R&D) need to be complemented by other policies to create or expand markets and to drive large-scale deployment of low-carbon technologies. Market pull from regulation, prices, and public procurement strategies will all be critical. There will be no 'one size fits all' solution. Different technologies have varying needs. They will be accelerated down the innovation chain in different ways, often helped by some concrete mechanisms.

There has been only slow progress on developing the practical and effective innovation incentives needed to drive a global low-carbon transition. Despite ongoing initiatives in China and the EU, the question of how best to utilize existing efforts to promote transformative impacts at scale remains. Too often the desire to support national champions or protect local markets stands in the way of productive initiatives to share risks, pool research efforts and combine market incentives for innovation. Many allocated resources for collaborative innovation by both regions remain under-utilized. Today, there are genuine opportunities to embrace new models of technological cooperation to lower costs and accelerate progress for China and Europe. This will require addressing the linkages between technical standards, intellectual property rights and legal enforcement capacity in a clear and balanced manner as part of the incentive framework for low-carbon innovation and diffusion. Europe could potentially implement stronger measures to share publicly supported low-carbon technologies with China, for example, especially if market reforms enabled rapid market expansion for its firms in the energy efficiency and services sectors.

Capturing gains through trade and investment

The Stern Review points to the need for a transformative increase in the scale of international finance flows for a low-carbon economy. China and the EU can explore win-win options to capture both carbon and economic gains through creating new market incentives for scaling up low-carbon trade and investment. The sheer size of the two markets means that an EU–China trade agenda will influence the global marketplace and further stimulate trading opportunities, both with each other and elsewhere. This could also help offset competitiveness concerns of EU and Chinese entrepreneurs about moving quickly towards low-carbon alternatives.

This vision, however, requires removing barriers to trade and investment in low-carbon trade in goods and services. Easier to implement and potentially more significant than tariff cuts, enhanced cooperation on defining common and improving performance and technical standards for low-carbon products could influence trade and investment patterns. Increasing trade in services relating to climate change adaptation as well as emissions reduction (e.g. building design, energy efficiency management) could provide real benefits for EU companies and for increasing know-how and management skills in China. As with previous economic reform processes, many of these policy innovations could be tested in designated 'low-carbon economic zones' (LCZs) in China, which would benefit from focused European support.

Mapping the pathways

This report outlines a number of options to assist policy-makers and stakeholders in China and Europe in mapping the pathways in the transition to a low-carbon future.

1. Building 'low-carbon economic zones' in China – one in the more prosperous east and the other in the less developed west – could be a bold initiative for policy-makers to consider. These LCZs would be the testing grounds for policies promoting the economic transformation necessary for a low-carbon future. Their focus on attracting investment in research and high-end manufacturing would be consistent with the Chinese leadership's desire to shift away from simple processing and assembly. The LCZs could be to China's next industrial revolution what Shenzhen was to the current one – and a powerful demonstration of the viability of the low-carbon economy. The EU could focus its energy and climate cooperation with China around these zones to demonstrate the real possibility of large-scale transformations to other regions and countries.

2. Setting world-class standards for energy efficiency goods could bring benefits to major producers such as China and the EU; for example, under the Eco-Design Directive the EU will soon be setting increasingly tight energy efficiency standards on major energy-using goods. China and the EU could set up a consultative committee to define aggressive standards for energy efficiency and low-carbon goods which could drive progress in both markets.

3. Making coal more sustainable is central as future dependence on coal is expected to increase in China and the EU. Both could enhance existing cooperation to deliver an agreed set of benchmarks and practices for improving efficiency and reducing the sustainability impacts across the coal fuel chain, including enhancing cooperation on development of carbon capture and storage as a potential future energy option.

4. An EU–China ultra-efficiency building research platform could be developed to capture the joint technical and development opportunities with China in this very fast-growing sector and to avoid energy consumption lock-in.

5. Exploring an EU–China low-carbon free trade agreement. A joint China–EU working group could be established to develop a framework to facilitate trade in high efficiency and low-carbon

products. This could be the first step towards defining the scope of a potential China–EU low-carbon free trade agreement. Such an initiative could establish a global precedent for the treatment of climate-friendly technologies which could be extended to other markets.

6. Pioneering sectoral approaches to climate change. Competitiveness concerns about climate change policies have generated significant interest in global sectoral standards agreements for energy-intensive sectors. China and Europe could develop a model sectoral agreement, commencing with the cement sector, which would help to drive efficiency and reduce emissions.

7. Tackling global supply constraints on renewable energy could help meet China's and the EU's shared targets on renewables and the corresponding cost concerns. The two powers could establish a high-level joint commission to tackle production bottlenecks and facilitate advanced investment.

8. Reducing dependency on imported oil from unstable regions to meet growing transport needs is central for China and the EU in the coming decades. With more than 80% of vehicles manufactured in China through joint venture companies, many with European partners, a unique opportunity exists for China and EU to work together to reduce import dependency through harmonizing higher energy efficiency and pollution standards.

9. Developing a low-carbon investment regime could help address the twin objectives of rapid diffusion of key technologies and ensuring competitiveness of domestic businesses for China and the EU. This could include relaxing Chinese restrictions on inward investment in return for access to carbon finance and enhanced technology cooperation.

10. Increasing energy-efficient and low-carbon technology cooperation for China and the EU could start with an agreement on practical steps to address structural issues in low-carbon technology cooperation around intellectual property rights. This could focus on practical mechanisms such as conditional or compulsory licensing, fair use rights and guidelines for standardization, to enhance technological diffusion. Other joint initiatives could include combining EU and Chinese public R&D budgets in strategic areas; using existing supply chain links to drive the creation and spread of technology; and setting up a China–EU climate technologies prize fund to encourage innovation in the field of energy-efficient and environmental products.

A note about the project

The Interdependencies on Energy and Climate Security for China and Europe Project is an independent initiative of European and Chinese research institutions to facilitate further understanding of China–EU interdependence and the potential for collaboration on energy and climate security issues. The Steering Committee of this initiative comprises representatives from Chatham House (Royal Institute of International Affairs), E3G (Third Generation Environmentalism), the Chinese Academy of Social Sciences (CASS), the Chinese Energy Research Institute (ERI) and the Institute for Sustainable Development and International Relations (IDDRI), the Swedish Ministry for Foreign Affairs, and the Potsdam Institute for Climate Impacts Research (PIK).

The broad aims of the project are to identify the mutual interests, challenges and opportunities for China and the EU in energy security and climate security over the next 25 years; and to produce high-quality independent analysis on the priorities for future collaboration to meet both regions' climate and energy security goals.

1

From Interdependencies to Action

We are on the cusp of a new industrial revolution driven by energy and climate security concerns. As the world wakes up to the imperative of a sustainable energy future, the ripple effects can be felt across the global economy. Governments and businesses are beginning to adjust decisions on trade, financing and production planning. The tightening global supply of oil and natural gas is fuelling the development of new technologies. High prices and supply volatility are motivating the more efficient use of energy. Even the US National Petroleum Council believes it is unlikely that the projected growth in demand for oil and gas in the next 25 years will be met (NPC, 2007).

Central to the vision for a low-carbon future is enlightened thinking about the potential economic and political benefits – rather than the costs – of this transition. Many perceived costs could be offset by energy efficiency gains, for example. And a transition would create lucrative new opportunities. Markets for low-carbon energy products are likely to be worth at least $500 billion per year by 2050, and perhaps much more, according to the Stern Review (2006: Executive Summary). A recent study estimates that China alone will need $25 billion per year for investment in low-carbon technologies (Zhuang, 2007).

Harnessing the dynamics of globalization to help the move towards a global low-carbon economy – thus preserving energy and climate security – will require strategic decisions at the highest level. To meet their long-term national security interests, governments and citizens will need to ensure that policies made in environment, planning, trade, investment and technology ministries all reinforce the drive towards a sustainable energy future.

This report explores the mutual interests between China and the European Union (EU), and outlines strategic opportunities for collaboration to produce mutual benefits for energy and climate security. Energy security is understood here as having adequate and predictably priced energy services from sustainable and, to the extent it is economically possible, localized sources. Climate security pertains to a set of measures that will contain global temperature rise within the two degrees Celsius range recommended by the Intergovernmental Panel on Climate Change (IPCC, 1995) to avoid irreversible damage that would threaten global security.

While reducing greenhouse gas (GHG) emissions is a critical imperative, it is not the sole global environmental concern. Nor are emissions the only environmental impact associated with energy use. The introduction of low-carbon goods and services must take these into consideration, and avoid causing other environmental and security risks.

This report assumes the following:

1. ‘Business as Usual’ (BAU) is not an option. There is a need to move towards alternative development paths. This is particularly important for China and the EU, which together account for 30% of global energy consumption and 30% of global emissions.

2. Choices made in China matter. China's decisions over the coming decades about its infrastructure needs and patterns of consumption will have a decisive impact on global efforts to stabilize greenhouse gas emissions and begin the reduction to sustainable levels.
3. Common interests between China and the EU provide a rationale for deepening collaborative efforts on energy and climate security over the next quarter-century.
4. The combined power of the EU, the world's largest single market, and China, the fastest- growing economy, can provide unprecedented opportunities to generate the benefits of scale that will help drive down the costs of climate-friendly goods and services. This could bring benefits for the rest of the world as well.

1.1 Business as Usual is not an option

1.1.1 Energy security

Energy security concerns dominate the highest level of political discourse today. High oil prices are fuelling civil unrest and political challenges across the globe, from Burma/Myanmar and Nigeria to the US and China. Meanwhile, resource-rich regions in Asia, Africa and the Middle East remain characterized by fragility and political instability.

Looking to the next 25 years, several points are clear. There is no sign that energy demand – and consumption – will abate in the near future. Under the BAU scenario, the International Energy Agency (IEA, 2007b) forecasts a 55% increase in global energy consumption by 2030. Demand will grow across the world, but at considerably varying rates.[1]

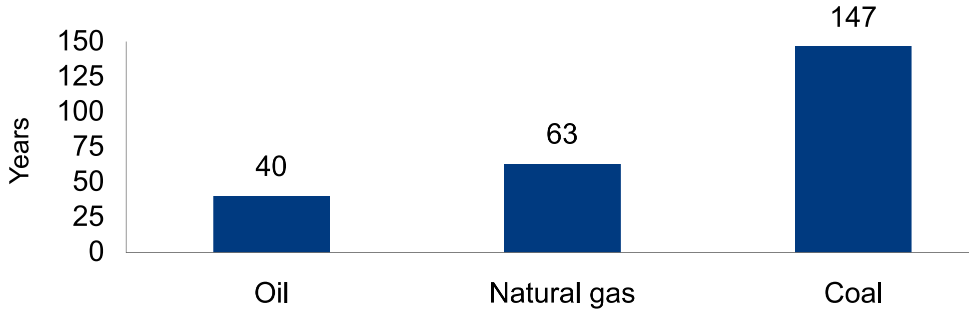
Today, views differ about the medium- to long-term availability of fossil fuels. The general assumption is that new technologies and new markets will enable the continual discovery of new reserves. The fivefold increase in oil prices since 1999 should also drive both wider exploration and the recovery of previously uneconomic resources. The latter may have especially dangerous implications for climate security: exploiting the Canadian tar sands as well as coal-to-oil technology is associated with heavy energy costs and significant additional CO_2 emissions.

Despite a measure of optimism about future reserves, fossil fuel resources are by nature finite, and a vast array of studies attempt to predict the time at which global oil production will reach a plateau from which it will go into irrevocable decline. Some suggest that this maximum point has already occurred, while others maintain it is impossible to predict or shows no sign of peaking (Hirsch, 2007). What we do know is that in 54 out of 65 major oil-producing countries, production has been in decline. Production in the EU is falling. Britain accounts for 75% of EU production, but even there it is at 56% of the 1997 peak (BP, 2007). In China the production peak is expected in 2015. According to the US National Petroleum Council, 'the global supply of oil and natural gas from the conventional sources relied upon historically is unlikely to meet projected 50 to 60 percent growth in demand over the next 25 years' (NPC, 2007).

The pattern of international oil trade is changing, with the increasing demand from Asian countries being met by increasing supply from the Middle East; this in turn carries perceptions of increasing risks of short-term disruptions related to political events. However, the Middle East's increasing

[1] In the EU a 0.4% annual growth rate is forecast, while in China the growth rate is expected to be 3.2% (IEA, 2007b).

Figure 1.1: Reserves-to-production ratio (years)



Source: BP.

dependence on Asia – and especially Chinese markets – offers opportunities for reciprocal investments if policies supporting them can be developed.

The longevity of the reserves is affected not only by their availability but also by the rate of consumption. Of the three fossil fuels, oil has the smallest reserves-to-consumption ratio, followed by natural gas and coal. Figure 1.1 illustrates the reserves-to-production ratios of the three major fossil fuels according to BP. Over the last decades, the total oil reserve volumes have at best kept pace with the rate of consumption, although there has been an increase in overall reserves of natural gas. China's net imports of crude oil rose 18.1% in the first eight months of 2007, with net imports reaching 108.2 million tones (Xinhua, 2007b).

Waiting for world oil production to reach its maximum capacity before taking serious action could leave the world with a significant liquid fuel deficit for more than two decades, as suggested by a US Department of Energy study (Hirsch, 2007). This would result in sustained high prices far above current levels, and the likelihood of sharply increased geopolitical tensions over access to available reserves. Initiating a mitigation crash programme 10 years before that point helps considerably. Doing so 20 years in advance appears to offer the possibility of avoiding the costs of a worldwide liquid fuels shortfall (Hirsch, 2007). This view is echoed by Lord Oxburgh, former chairman of Shell: 'We may be sleepwalking into a problem which is actually going to be very serious and it may be too late to do anything about it by the time we are fully aware.' (Strahan and Murray-Watson, 2007).

In the immediate future, fossil fuel use is constrained by the ability to extract, refine and distribute the raw material – both geologically and economically. There is growing anxiety over the costs of the investment necessary to meet predicted demand. The IEA estimates that by 2030, $22 trillion of additional investment in the global supply-side infrastructure will be needed to meet the BAU scenario. It also warned that currently there is significant 'underinvestment in basic energy infrastructure' and therefore this 'energy future is not only unsustainable, it is doomed to failure' (Platts, 2006).

The economics of oil extraction and use is of fundamental importance for the development of alternatives. Statements from energy ministers across the world – including those from the US and Russia – highlight the growing consensus that the era of cheap hydrocarbons may well be over.

In the short term, moves towards alternatives such as biofuels add to the uncertainty about future demand for oil, and thus raise the risks of investing in the sector. The President of the Organization of the Petroleum Exporting Countries (OPEC) has said that members are unlikely to increase production capacity unless consumers ensure stability of demand (Blas and Crooks, 2007; UPI, 2007). Venezuela and Iran have made similar statements, and many countries are tightening the terms for foreign investment in the oil sector.

More broadly, uncertainty about the future growth of oil supply and demand, along with trade patterns and the structure of future refineries, combine to confront investors, governments and consumers with a difficult risk management problem. If investments – be they in conventional or non-conventional oil or alternatives – are made 'too early', resources will be left unnecessarily idle. If they are made 'too late', the scramble for adjustment will add other costs and risks – including the risk of sharp price increases and physical shortages. Furthermore, precautionary actions will themselves change the projections on which they were based.

One thing is clear. There is a growing consensus on the need for urgent global action to address energy security – not least owing to the complexity and breadth of policy actions necessary to do something about it.

1.1.2 Climate change and the avoidable cost of inaction

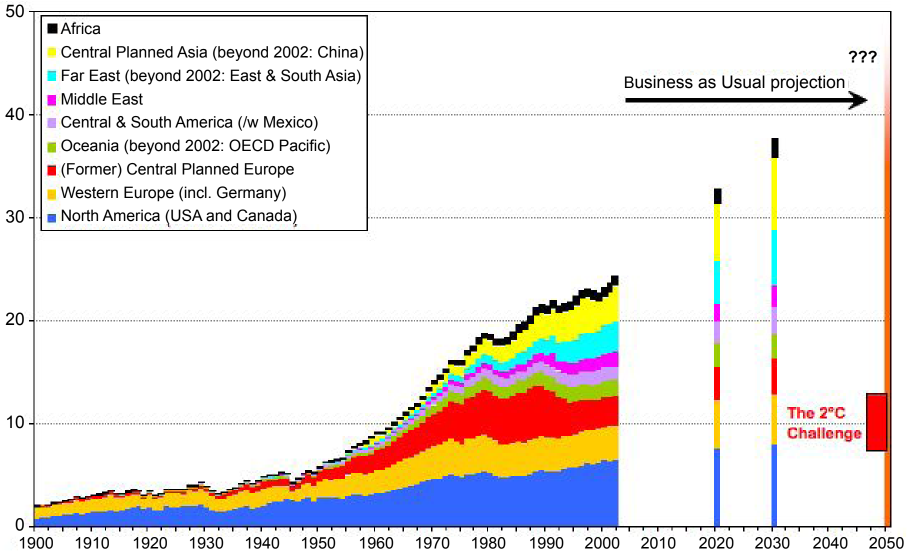
According to the IPCC, atmospheric concentrations of the key greenhouse gases – such as carbon dioxide (CO_2), methane and nitrous oxide – have increased significantly since the Industrial Revolution. Mean temperatures in Europe have increased by 0.8°C since 1900 (Joint Research Centre, 2005). China's average ground temperature has increased by 0.5–0.8°C over the last hundred years. Many aspects of the climate system other than temperature are also changing.

The consequences of climate change are manifold. Conservative estimates project that sea levels will rise by between 0.18m and 0.59m by the end of this century (IPCC, 2007a). There will be reduced access to safe drinking water and an expansion of drought-affected areas. Over one billion people currently rely on glacier meltwater, which will eventually disappear (EEA, 2005). Meanwhile, those living on floodplains and in coastal regions will experience increased risk of flooding. In China, there is likely to be an increase in desertification of semi-arid areas. Regional warming and drying reduce wetland surfaces. Large swathes of swamp will become meadow wetland.

With an average global temperature rise of 2°C over pre-industrial levels, reduced access to safe and reliable water supply will pose major challenges for agriculture and food security on all continents (Shellnhuber, ed., 2005). Increased risks to hydroelectric power generation will mean higher prices (WWF, 2005). The onset of coral reef dieback will affect many local fisheries and tourism. Between 90 million and 200 million more people are likely to be at greater risk of malaria and other vector- and water-borne diseases, with increased rates of diarrhoeal disease and malnutrition in low-income countries (Hare, 2003). At higher levels the risks of catastrophic impacts increase sharply: there is a strong likelihood that the Greenland and Western Antarctic ice shelves could melt completely, raising global sea levels by 14 metres, although the timescale for this change is uncertain and could be hundreds of years. More severe climate change could also affect the absorption of CO_2 in the sea or the release of methane from Siberian tundra, which could potentially lead to runaway global warming with temperature rises of 5–7°C.

These alarming projected impacts point to the range of risks and vulnerabilities policy-makers and citizens face in the short, medium and longer term. They also highlight the all-too-avoidable costs of inaction. To reduce the risk of irreversible and catastrophic damage, especially for the poorest, recent

Figure 1.2: Business as Usual CO_2 emissions increase projections



Source: Matthes (2006).

science suggests a global limit of 2°C on temperature rise (with some areas seeing much higher rises) as a reasonable benchmark for policy-makers.

Recent analysis on climate sensitivity suggests that a responsible risk management strategy would be to keep to emissions levels within the lower end of the probability range associated with a 2°C increase. The case for this more risk-averse stance is justified by the enormous scale of potential negative impacts versus the relatively reasonable costs of earlier mitigation. A concentration level of 450ppmv CO_2eq (parts per million by volume of CO_2 equivalent) would maintain a 50% chance of staying below 2°C, with a 400ppmv CO_2eq providing a greater than 50% chance.[2]

To achieve 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 (Den Elzen and Meinshausen, 2006; Den Elzen, 2005).

A paper prepared by Chinese scholars commissioned by this project suggests that limiting warming to 2°C would not allow China to increase emissions, thus denying it further economic development – a position that the country would find difficult to accept. Their proposed alternative pathway is to limit warming to 2.8–3.2°C above pre-industrial temperatures, and use market measures and new technologies to restrain the rise of greenhouse gas concentrations to approximately 550ppmv by 2100 (Liu et al., 2007). Of course, this pathway would substantially increase damages from climate change, and increase the risks of more extreme scenarios occurring. Other scenarios envisage that the 2°C global target can be met, while still allowing a continual rise in emissions from China, prior to a decline (Wang and Watson, 2007a).

[2] Meinshausen and Hare (2004), Figure 8. According to the Swedish Scientific Council on Climate Change (2007), 'A Scientific Basis for Climate Policy', the two-degree target can probably be achieved if greenhouse gas concentration in the atmosphere is stabilized in the long term at 400ppmv CO_2eq. If it is stabilized at 450 ppmv CO_2eq there is a significant risk that the two-degree target will not be achieved. Full report available at: www.sweden.gov.se/content/1/c6/08/69/68/f8d98215.pdf.

BAU scenarios, however, are projecting concentration levels of 650–750ppmv CO_2eq, a pathway that would be likely to result in irreversible climate change and the onset of climate impacts at such a rate that global adjustment would be difficult.

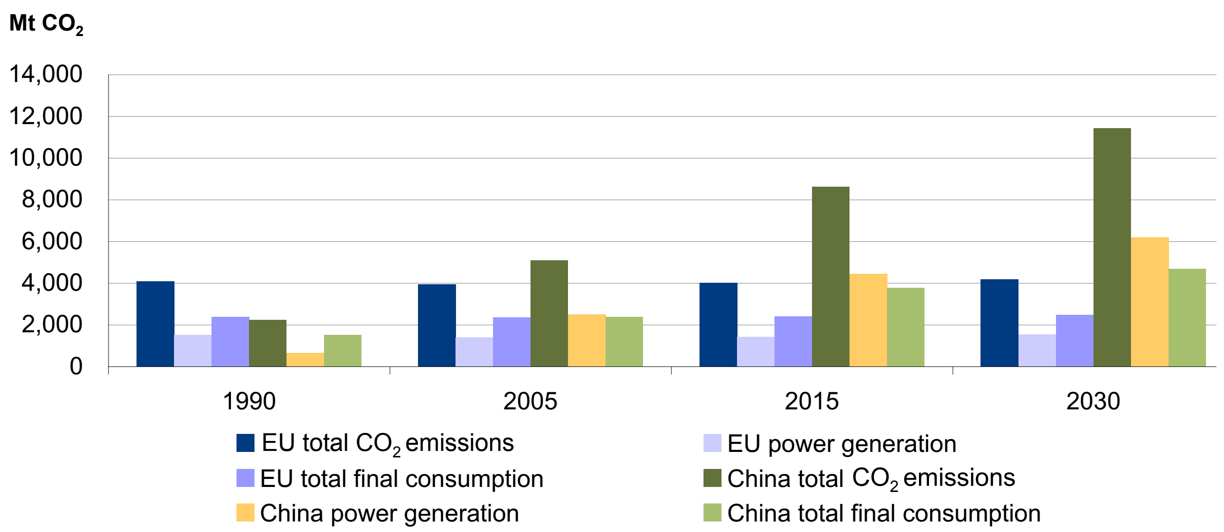
Climate science therefore shows the imperative for rapid action on climate change. The continual increase in CO_2 emissions expected over the next decade means that much deeper cuts will be needed in subsequent years if stabilization is to occur. Work undertaken for the Dutch Environmental Assessment Agency suggests that delaying the peaking of global emissions to 2013 will double the maximum reduction rates needed as compared with immediate action (Den Elzen and Meinshausen, 2005).

The economic case for immediate action is compelling. The Stern Review puts the costs of inaction on climate change at between 5% and 20% of GDP, the combined cost of both world wars and the Great Depression. One need look no further than losses associated with extreme weather-related events to comprehend the potential scale of impacts: 2005 saw the highest ever global financial losses due to weather-related disorders, amounting to $185 billion. The UN projects that weather disasters could cost a trillion dollars per year by 2040 (Wallis, 2006).

Failure to achieve acceptable climate stability will disproportionately harm poor people and poor countries, already dependent on damaged and vulnerable ecosystems with limited capacity to adapt. Without appropriate action, the risk of instability will rise, increasing the pressure for humanitarian aid and conflict resolution.

Time is of the essence. Delaying global action until 2020 would make it virtually impossible to keep global temperatures from overshooting the 2°C limit and exposing society to ever-increasing risks of catastrophic climate change.

Figure 1.3: IEA projections for European and Chinese emissions up to 2030



1.2 Understanding China–EU interdependencies

'Europe's economic health increasingly depends on a thriving Chinese economy. Should China falter as we progress through this century, European pension funds would struggle to earn the returns necessary to pay our pensions. As Europe's population ages, the drag on our economies would be immense.'

John Ashton, UK's Climate Ambassador

In July 2007, EU trade officials voted informally to remove anti-dumping duties on energy-efficient compact fluorescent lamps from China. A month later, the European Commission proposed to retain the duties for a further year. These duties add import taxes of up to 66% on the Chinese imports. Cutting the duties appears logical, since the EU is moving towards phasing out less efficient lighting by 2009. China today produces four-fifths of the world's energy-saving light bulbs, with exports worth $1.5 billion in 2006. According to the World Wildlife Fund, lifting the duties could help save 23 million tonnes of carbon dioxide in the EU each year (WWF, 2007).

Quibbling over anti-dumping duties has been typical of recent EU–China trade relations. But the light bulbs case illuminates how energy security and climate change, along with economic globalization, are altering the terms of these discussions. The pros and cons have been argued by European, rather than Chinese, actors.

Osram, an arm of Germany's Siemens, pushed for the duties to be extended, citing risks to hundreds of jobs in the EU. The Dutch manufacturer Philips, and other manufacturers, wanted the duties lifted, supporting an aggressive expansion in the European market for high-efficiency lighting. Most of Philips' energy-efficient bulbs are produced outside the EU, including in China.

As economies integrate, it is commonplace to set the competing needs of producers against those of importers and consumers. During the so-called 'bra wars' in August 2005, over 50 million sweaters, T-shirts and bras from China were stuck in European ports because of protests from French and Italian manufacturers.

In reality, the public policy choices for the Chinese and EU economies are far more complex. They will need to be made against a backdrop of globally integrated supply chains and an increasingly complex political economy landscape. Different interest groups will hold drastically different positions on many of these key issues. Balancing energy security, climate change, employment and export competitiveness will become a central part of the political conversation between citizens and governments.

This section seeks to outline the range of common interests between China and the European Union which provide the foundation for deepening collaboration on energy and climate security.

1.2.1 Integrated political economy

'How do we define what is a European company in a world of global supply chains and multinational assembly lines?'

Peter Mandelson, Trade Commissioner, 2007

Trade. China and the EU are economically entwined. China today is the EU's largest trading partner. The EU is China's second largest, responsible for some 18.9% of China's external trade value (China Statistical Yearbook, 2005). The EU is also the largest supplier of technologies (50%), foreign direct investment (FDI) (7.9%) and services (17.5%) to China.[3] Between 1999 and 2005, EU exports to and imports from China have more than doubled, to €72.2bn and €168.7bn respectively.

Chinese exports to the EU comprise primarily clothing, office machines, computers and electrical goods. EU exports to China are dominated by general and specialized machinery, and equipment for power generation or other industrial production. China is the EU's largest source for imported cement, plaster and stone, as well as iron and steel, even though only a minuscule percentage of the cement and steel produced in China is exported to the EU.

China is increasingly the main source of the EU's trade deficits, which grew from around €35bn in 1999 to €110bn in 2005. Increasing consumer and capital goods imports from China contribute to the widening gap.

Beneath the surface. Taken at face value, the widening trade gap may worry Europeans, especially if viewed from a mercantilist mindset. But the reality of integrated political economy belies such reactions. Foreign enterprises are key contributors to China's expanding trade capacity. More than half of China's foreign trade is conducted by multinationals – most of which are European. (See Figure 1.4 on foreign investments in the Chinese auto industry.) Most of China's exports to the EU are products from processing trade or produced by joint ventures or foreign-invested enterprises (FIEs). This means that in many cases the majority of the value added of goods traded from China to the EU is retained by European companies and does not return to China.

A recent study suggested that for the year 2002, for every US$1,000 of Chinese exports to the United States, only US$386 of value accrued in China (Lau et al., 2006). Only 35 cents of a Barbie doll that sells for US$20 go to China (cited in Barboza, 2006). The majority of China's trade in high-tech products stems from processing operations, 80% of which are carried out by foreign companies established in China (Gaulier et al., 2005).

As manufacturing supply chains integrate across borders, components are often manufactured in one country and then shipped to another country, such as China, for final assembly. Goods are tagged only at their final assembly point. This means that the gross value of exports is not necessarily indicative of economic benefits for the exporting country. Trade figures, as a result, are increasingly inaccurate guides to reality: while China has a trade surplus of some $200 billion with the US and €110 billion with the EU, it also runs a $74.1 billion trade deficit with the rest of Asia (Ministry of Finance, 2007). China has effectively absorbed part of the rest of Asia's surplus with the developed world.

Investment. The EU is the largest source of foreign direct investment into China. European FDI outflows to China soared to €9bn in 2005, almost triple the volume from the United States. China's own growing outflows to Europe stood at £505m.

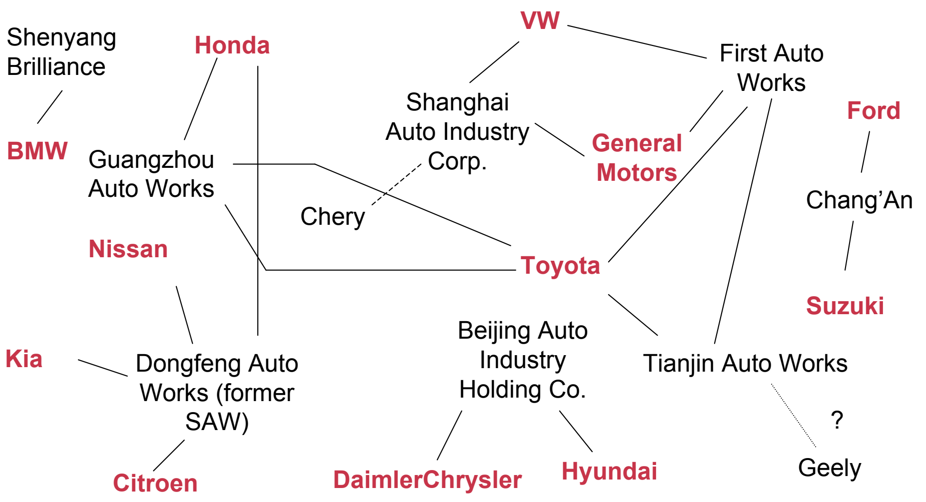
Most foreign investment in China goes to manufacturing (70%), followed by utilities. According to analysts, European investment in China is primarily market-seeking, driven by market expansion strategies and less by cost considerations (Lemoine, 2000; Lemoine and Unal-Kesenci, 2004). This differs from Japanese (and some American) investments in China, which concentrate on enhancing vertical trade.

[3] National Bureau of Statistics, *China Statistical Yearbook*, 2005 and http://trade.ec.europa.eu/doclib/docs/2006/september/tradoc_113366.pdf; http://ec.europa.eu/trade/issues/bilateral/countries/china/index_en.htm.

EU investments in China focus on capital- and technology-intensive manufacturing industries such as automotive, chemicals and pharmaceuticals, electronics, communication equipment and instruments. Investments in these relatively capital-intensive sectors make up a large share of the total FDI (Wang, ed., 2000). Average investment in each project amounts to $3.8 million, higher than that from the US ($2.09m), Japan ($2.02m) and Korea ($1.35m) (Song, 2006). It has been estimated that some 19,738 enterprises had been established by Europeans in China by 2005 (Song, 2006).

The EU is also a major source of government loans to China, providing $16.1 billion, about 44% of all government loans to China (European Commission, 2006d).

Figure 1.4: Foreign investment in China's auto industry: a complicated network



Source: Kelly Sims Gallagher (2006).

Economic gains for the EU. As pointed out by the European Commission,

> *Investments in China have allowed EU firms to remain competitive by gaining access to lower-cost inputs. A significant part of the value added of products 'made in China' accrues to European companies. It has also helped European business maintain jobs and viable economic activities in the EU such as research, design, marketing, global management and complex manufacturing. Some investments in China have allowed EU firms to gain market share in the China market and supported our exports.*

Additionally, cheap imports from China have meant lower input prices for EU businesses as well as lower prices for manufactured products in Europe. These have generally translated into lower prices for consumers. The total effect on inflation was estimated by the OECD to be –0.2% for the Eurozone for the period 2001–05. This in turn has helped keep global interest rates low. Savings generated as a result of cheaper goods and inputs have been invested in other parts of the European economy, as the Commission suggested (European Commission, 2006d).

FDI in East Asia is more profitable than that in other countries. Europe's investments in that region in 2003 generated 12% of all EU revenues from FDI. China had a major role in that process. The rate of return from EU FDI in China is increasing: the average rate of return on stocks in China between 2001 and 2003 was 7.5%, while in 2004 it was 11%. The average return on EU capital from investments in other countries in 2003 was 6%. It has been estimated that European wages in 30 years will be 16–40% lower if China fails to sustain its economic growth (Fehr et al., 2005).

Technological benefits for China. In addition to investment, by the end of 2004, technology transfer from the EU to China was represented by over 19,008 projects worth some $80 billion – half of China's total technological imports (Song, 2006). One analysis based on information from 20 leading EU companies involved in China's high-technology sectors suggested 'a measure of reluctance on the part of EU companies to transfer their core technologies to China and to base R&D capability there' throughout the 1990s (Bennett et al., 2001). The same analysis also questioned the sustainability of this approach in the longer term, given China's determination in acquiring know-how and technology. (It is important to note that technology transfer encompasses not only the physical hardware but also know-how.)

1.2.2 Common energy and climate security

Energy security and import dependencies. China is the world's second-largest consumer of oil after the United States. It is also the third-largest net importer, despite significant domestic oil reserves. Domestic energy shortages in China in 2004 pushed up demands for imported oil, propelling international energy prices to 20-year highs. Over three-quarters (78%) of the increase in worldwide oil consumption in 2006 was attributable to China in 2006, although it accounts for only 9% of global consumption. According to IEA forecasts, by 2030 China's energy consumption – currently equal to the EU's – will be 40% greater than the EU's (see Figure 1.6). It will also be the world's largest consumer of energy.

As major importers of energy, China and the EU will continue to face serious import dependency challenges. The IEA estimates that both will be importing 80% of their oil supply by 2030 (see Figure 1.5). The top exporters of oil to China are Angola, Saudi Arabia and Iran (see Figure 1.6).

China's expectation of growing dependence on oil imports has led to acquisitions in exploration and production in Kazakhstan, Russia, Venezuela, Sudan, West Africa, Iran, Saudi Arabia and Canada. This is changing the geopolitical landscape in unstable regions such as Central Asia, the Middle East and Africa.

But despite its efforts to diversify its sources, China has become increasingly dependent on Middle Eastern oil. Today, 44% of China's oil imports come from that region, followed by Africa (32%) and

Figure 1.5: EU–China oil import dependency

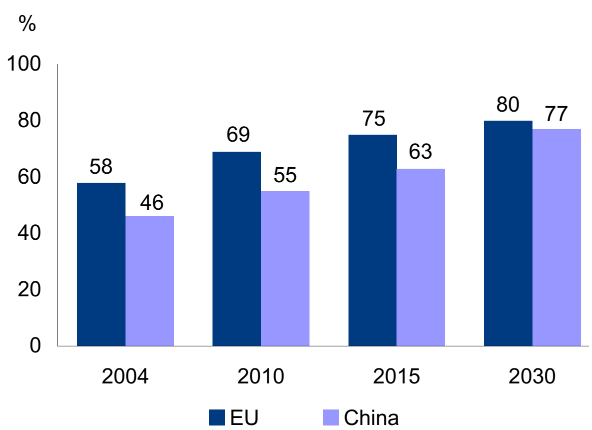


Figure 1.6: EU–China energy consumption forecast

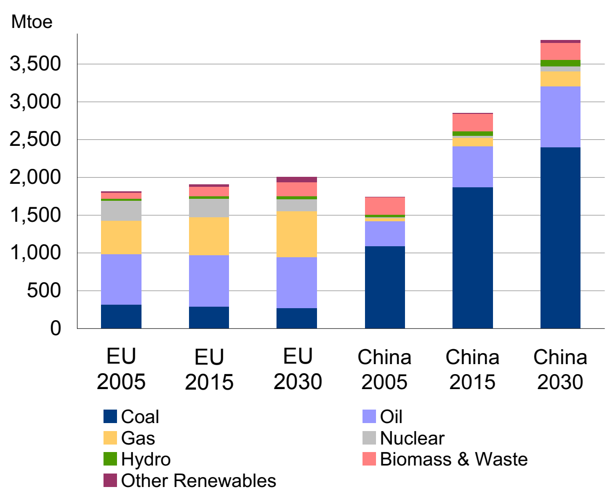
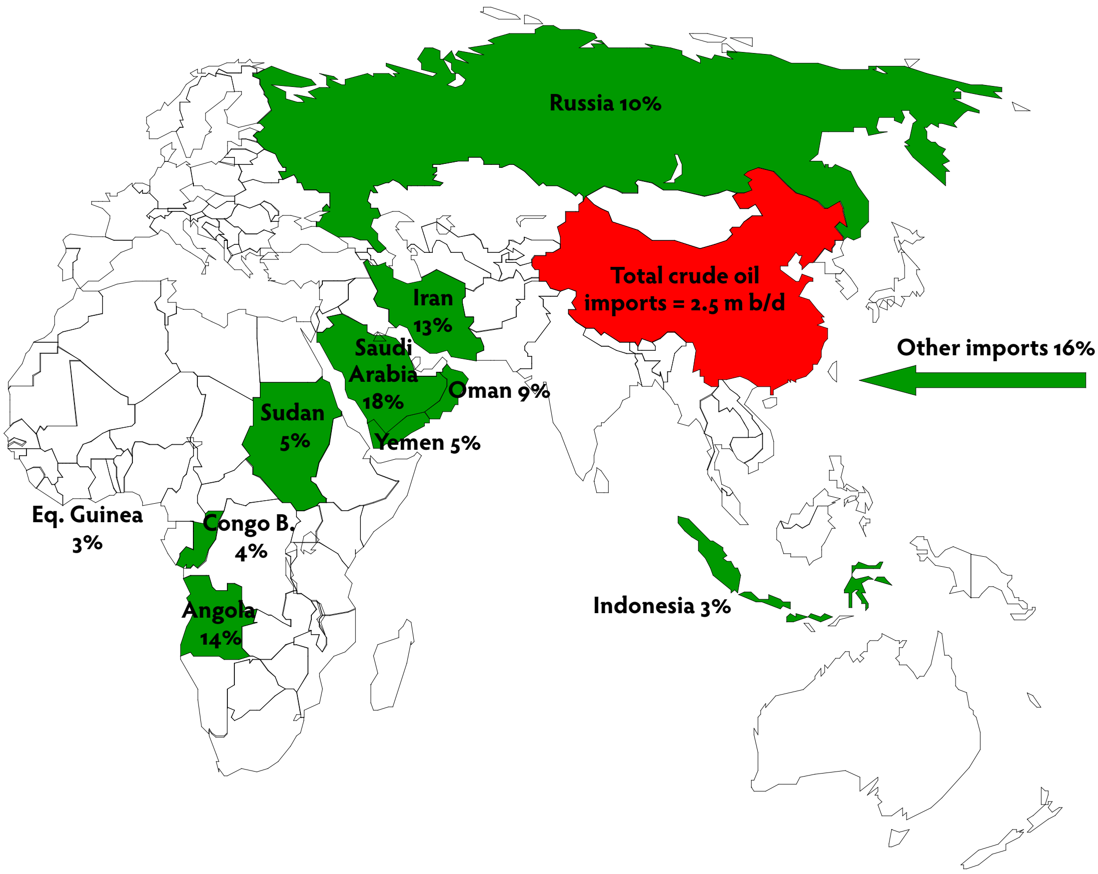


Figure 1.7: Sources of Chinese crude oil imports (2005)



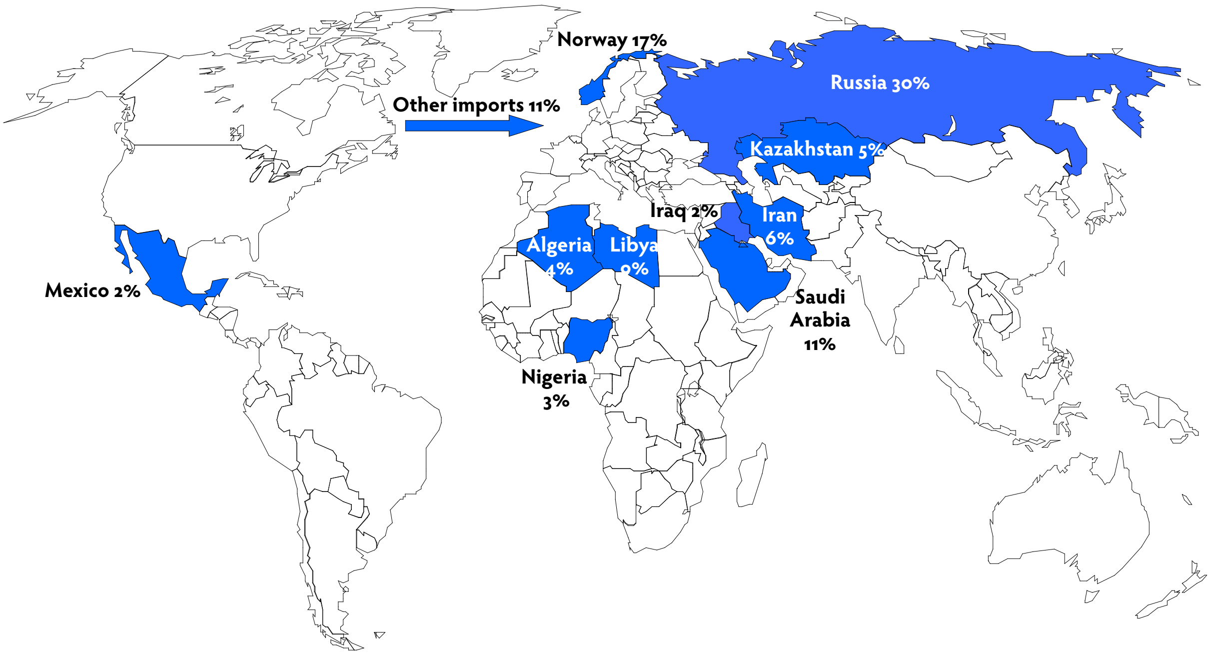
the former Soviet Union (11%). By 2015, the share of Middle East oil will rise to 70%.[4] As much as 80% of China's oil imports (including all its oil from the Middle East) passes through the Malacca straits (IEA, 2000). Alternative routes exist but are more expensive owing to longer sailing times, and in an emergency a sudden switch would create a worldwide shipping shortage. Oil pipelines from Central Asia and Russia, gas pipelines from Central Asia and Burma/Myanmar, pipelines transiting the Burma/Myanmar–Thai isthmus and liquefied natural gas (LNG) imports from Australia will reduce dependence on the Middle East and the Malacca straits, but these large projects are progressing only slowly.

The risks of temporary disruption of either supply or transport routes can be mitigated by strategic stockpiles held under government control. The EU has its own compulsory oil stock requirements, which mesh in with the requirements of the IEA and the latter's emergency sharing mechanisms. The EU has also announced that it will introduce a compulsory stockpile scheme for natural gas. China plans to increase its oil stockpile to 12 million tons by 2010 – about three times the current level. China's oil reserves, which now stand at 2–3 million tonnes, are expected to cover the equivalent of 30 days' imports by 2010 whereas they will be about equivalent to three months' imports by 2020 – an IEA recommendation.

Meeting existing targets. China and the EU also have remarkably similar – and ambitious – plans to improve energy security through much greater energy efficiency and the use of renewables.

[4] http://www.iags.org/china.htm.

Figure 1.8: Sources of European oil imports (2005)



The EU has committed to a 20% reduction in energy intensity (energy consumption per unit of GDP) by 2020, by which time 20% of energy is to come from the renewable sector (including 10% of transport fuels from biofuels). Post-2020, if possible, the EU also commits to have carbon capture and storage for all new fossil fuel power stations.

On a parallel track, China's 2005–10 Five-Year Plan commits to a 10% reduction in all pollutants; a 20% reduction in energy intensity; and a 30% reduction in water usage by industry. It also encompasses plans to diversify energy resources and increase energy efficiency by 2020 through installing capacity in wind (30 GW in 2020), hydro (300 GW in 2020) and nuclear (40 GW in 2020). In addition to the target of a 20% reduction in energy intensity by 2010, China has committed to a further 20% reduction between 2010 and 2020. However, evidence suggests that it will struggle to meet its 2010 energy intensity target owing to the surge in investment in heavy industry in the past five years (McGregor, 2007).

The EU's own performance with regard to its targets has been highly variable. Increased emissions across several EU-15 member states are masked by trends for the EU-27. From 1990 to 2005, total GHG emissions (from industrial and energy sources) in the 27 countries of the current EU decreased by 7.9%, but the reduction in the EU-15 was only 2% and industrial restructuring in Eastern Europe accounted for the bulk of reductions. Germany and the UK together account for one-third of EU-27 GHG emissions and have reduced their combined emissions by 340mt CO_2eq compared with 1990. On the other hand, Spain's emissions increased by 53% from 1990 to 2005, largely owing to emissions from electricity and heat production, manufacturing and road transport.

The role of carbon trade. Purchasing carbon credits from China's Clean Development Mechanism (CDM) projects is an increasingly important way to help EU-15 member states to accomplish compliance with the Kyoto targets and private companies to meet the EU Emissions Trading Scheme (ETS) target. Investments from the EU provide huge opportunities in China's energy-related industries.

EU-15 countries are the largest buyers of China's Certified Emissions Reductions (CERs). A total of 873.6mt CO_2eq had been contracted as of 18 July 2007, to be delivered by 2012 – 77% of the total CERs generated in China. According to recent analysis, the total compliance gap for both EU-15 governments and private sectors will be 2,073–3,275mt CO_2eq by 2012 (Capoor and Ambrosi, 2007; European Commission, 2006c). Thus China's CERs are important for the EU to meet its GHG emissions target. The average CER price was $10.90 in 2006. Assuming the price per unit of CER stays the same, China could raise up to $9.52 billion in investment from the EU (Capoor and Ambrosi, 2007).

Managing climate impacts. China and the EU need to manage the impacts of climate change, including water stress, shifting agricultural zones and extreme weather events. These are likely to affect food, water and human security adversely, with implications far beyond national borders.

Water scarcity and heat stress are expected to affect crop yields and livestock activities in southern Europe (EEA, 2005; European Climate Change Programme, 2007). Changes in the distribution and structure of agricultural production are also anticipated in China, causing wider fluctuations in output. Predictions suggest that, if no measures are taken, the overall productivity of the Chinese farming industry may decline by 5–10% by 2030. By 2050 the production of major crops, such as wheat, rice and corn, may fall as much as 37% (MOST, 2006).

The frequency of droughts and floods is also set to increase in China, with an accompanying deterioration in the gap between water demand and supply. It is estimated that by 2050 the areas of glaciers in western China will have retreated by 27.2% (China Daily, 2007b). The total water available from glacial meltwater will increase in the short term, with supplies expected to peak between 2030 and 2050 and then decline (MOST, 2006). According to the Stern Report, 23% of China's population – around 250 million people – live 'in the western region that depends principally on glacier meltwater' (Stern Review, 2006).

These threats to food and water security for the world's most populous country could have significant consequences for regional stability and global security, and for the economic prosperity on which European economies and companies depend.

1.2.3 Choices made in China matter

The growth of China has been historically significant in the past quarter-century. Today, it is a propelling force for the global economy. Along with the United States, China and other emerging economies today are becoming powerful engines that keep the global economy afloat. China alone will – at market exchange rates – account for more of global GDP growth than the US in 2007. This has positive side-effects for all countries as, according to the *Economist*, a multi-engined plane is less likely to crash (Economist, 2007).

China's extraordinary demand growth has other more challenging and complex impacts. Its demand has changed global production patterns in food and other key commodities. On the basis of current trends, by 2030 it will need to import some 369 million tonnes of grain, an amount roughly double that of world grain exports in 2007. Its rapid economic growth has come at the expense of the environment – water and food security, air quality and biodiversity losses. Initial evaluations by China's State Environment Protection Agency (SEPA) suggest that 10 million hectares of farmland (10%) are polluted, resulting in losses of over US$2.5 billion a year (Associated Press, 2006). Sixteen out of the world's 20 most polluted cities are in China.

Other domestic challenges abound. Despite the impressive growth rates, the vast majority of China's population live on under US$2 a day. An estimated 7% of GDP per annum is lost to environmental degradation. China also needs to maintain a high level of growth, also estimated at 7% p.a., to ensure that the benefits spread to poorer, especially rural, regions. As *Xinhua* reported in October 2007, 'China has scored glaring economic gains since the reform and opening drive launched three decades ago, but the countryside lags behind, causing concerns that the urban and rural gap might undermine social harmony. [...] To narrow the gap has been on top of the agenda of the Party and government in recent years and observers believe it will remain an important mission for the Party after its 17th National Congress [...]' (Xinhua, 2007c). The equity gap between rich and poor has widened considerably in the past two decades, presenting new challenges to Chinese policy-makers.

China's decisions about its infrastructure needs and consumption patterns will play a central role in determining the extent of global achievement in terms of stabilizing and, ultimately, reducing GHG emissions. China currently emits about 14% of the world's CO_2 and is expected to contribute about 17% by 2020. In preliminary estimates for 2006, China topped the list of CO_2-emitting countries, surpassing the US by an estimated 8% (MNP, 2007). China's growth is also energy-intensive: energy consumption per unit of GDP is about 6.2 times the EU average. An average Chinese person still consumes only 10–15% of the energy used by an American, but this gap is expected to narrow significantly over the next 30 years.

In recent months, there have been many positive signals from China about curbing high-carbon production processes (see Box 1.1). Additionally, bank loans to high-polluting sectors slowed down in the first five months in 2007. These energy-hungry industries include oil processing and coking, chemicals, construction materials, iron and steel, non-ferrous metals and power generation. The China Banking Regulatory Commission (CBRC), the banking watchdog, also said that banking institutions should 'resolutely recall' loans from firms that failed to meet environmental standards (Xinhua, 2007a). In the first half of 2007, 5.5 GW of the least efficient coal-fired plants were closed down, with a target of 50 GW of closures by 2010.

The scale of China's market – and its corresponding clean energy needs – offers one of the quickest routes to bringing new, clean energy technologies to maturity. The combined strength of the Chinese and EU economies could help substantially to cut the cost of low-carbon technologies and make them available to other, less industrialized countries around the world.

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 (NDRC), 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.' (Batson, 2006).

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. It emphasizes the need to create an innovation-oriented country, build indigenous innovative capacity and strengthen intellectual property rights (IPR) protection. As China's Premier, Hu Jintao, said at the 17th Party Congress in October 2007, 'We need to keep

Box 1.1: Positive signals from China on climate change

- First National Climate Change Assessment (December 2006).
- China's National Climate Change Programme (June 2007).
- Policy statements around G-8 (July 2005 and June 2007).
- Premier Wen Jiabao told the State Council Executive Meeting, 'All levels of government must realize fully the seriousness and urgency of achieving the energy saving and emission reduction targets.' (11 July 2007[a])
- National Medium- and Long-term Science and Technology Development Plan (2006–20) – creating an innovation-oriented economy with the emphasis on strengthening both indigenous innovative capacity and intellectual property protection.

[a] See http://www.juccce.com/press_clippings/JUCCCE_kick-off_press_release_EN_070718.pdf , press release by JUCCCE (Joint U.S.-China Cooperation on Clean Energy). The language of the English translation has been edited.

to the path of independent innovation with Chinese characteristics and improve our capacity for independent innovation in all areas of modernization [...] [We need to] increase spending on independent innovation, and make breakthroughs in key technologies vital to our economic and social development. We will speed up forming a national innovation system and support basic research, research in frontier technology and technological research for public welfare.' (Hu, 2007)

In short, China's strategic aspirations for an innovation-based economy are in line with the requirements of the transition to a low-carbon future. For the rest of the world, ensuring that China gains a sizeable piece of the low-carbon pie is central to the undertaking. It would also provide incentives for China to play a larger role in the successor agreement to the Kyoto Protocol on climate change.

Historically, when countries reach $5,000 per capita GDP, the commercial and transport sectors start to surpass industry as drivers of energy demand.[5] Already the average per capita income in China has exceeded $2,000 (up from $200 in 1978). Government statistics suggest that there are now 80 million people in China described as middle-income, an increase of 15 million in the last two years (China Daily, 2007a). The number of middle-class people in China is expected within a decade or so to outnumber those in the EU or US.

1.2.4 Harnessing EU global leadership

The EU is a significant consumer of global energy and a major emitter of GHGs. While the rate of increase of energy consumption is slowing, the EU still consumes around 15% of global energy. Furthermore, per capita energy consumption in the EU is more than double the world average and three times that of China. The EU directly generates around 15% of the global emissions of CO_2.

Since the early 1990s the EU has called on developed and advanced developing countries to commit

[8] Rosen and Houser (2007). The paper also pointed out that in more affluent coastal provinces, per capita GDP has surpassed the $5,000 mark. Shanghai and Beijing, with a combined population of over 33 million, are at the same per capita level as South Korea in 1990; and Tianjin, Zhejiang, Jiangsu and Guangdong, with a population of 225 million, are not far behind.

Box 1.2: Looking to the future: three key sectors

Three sectors – coal, buildings and transport – best capture the importance of China's decisions in the coming quarter-century.

Coal accounts for 70% of the China's energy needs, including 80% of electricity, 50% of industrial fuel use, and 60% of the chemical feed-stock. China produces and consumes 38% of the world's coal, approximately double the share of any other country. The use of coal in China is unprecedented, in terms of the total amount, its contribution to the energy sector and the growth in its consumption. China produced 2.4 billion tonnes of coal in 2006, nearly doubling the 2000 level.

Under the BAU scenarios, China's energy demand is projected to rise, with coal continuing to play the major role. The IEA forecasts that coal demand will double by 2030, with far-reaching implications for global energy supply and the world's climate. The Chinese coal sector currently emits approximately 4,200mt CO_2 (16% of the global total of CO_2 emissions). Under this IEA scenario this will rise to 9,000mt CO_2, one-fifth of the world's total. Known coal reserves in China are estimated at 115bn tonnes (13% of global reserves), and forecasts suggest that at current consumption rates, they will be sufficient for less than 50 years.

With the anticipated construction of generating capacity in China between now and 2030 at 36 GW per year (and 5–10 GW in the EU), cleaner coal is a key area for action.

Buildings account for nearly 20% of final energy consumption in China. This is likely to increase to 35% by 2020 (Long, 2005). Energy-related CO_2 emissions by the construction sector represented 20% of the country's total in 1999 (Chen et al., 2005). About 1.2–1.4bn m^2 of residential buildings have been constructed in China since 2000, with an investment of nearly 1,000 billion yuan, amounting to almost 20% of total fixed assets investment and

to substantially reducing their greenhouse gas emissions.[6] Its own climate and energy policy package 'confirms Europe's world leadership on climate change', according to Stavros Dimas, EU Environment Commissioner (Dimas, 2007). Al Gore also suggests that the EU is 'absolutely key to helping the world make the change it must'.[7]

To date, Europe has played a global leadership role with the establishment of its climate change policies, especially the Emissions Trading Scheme. It is critical that these policies and measures are contributing to reductions in GHG emissions. Between 2003 and 2004 there was a net increase of 0.4% in GHG emissions in the EU-27. An overall reduction of 0.8% was achieved in 2005. While some countries, notably Germany and Finland, did make significant reductions, 13 of the 27 member states saw an overall increase in GHG emissions (EEA, 2006). The European Commission anticipates that only six of the EU-15 member states (Luxembourg, Germany, the UK, Finland, Sweden and France)

[6] 'IPCC Report Confirms EU Call for Deep Cuts in Global Greenhouse Gas Emissions', EU Press Release, 4 May 2007, http://www.eurunion.org/News/press/2007/2007050.htm.

[7] 'Gore says EU leadership on climate change vital', Reuters, 7 March 2007, http://uk.reuters.com/article/scienceNews/idUKL 078248420070307.

8–10% of China's GDP (China Statistical Yearbook, 2005). Housing construction necessitates enormous consumption of natural and energy resources. By 2020, China will probably have equalled the entire existing building stock of the EU-15 in 2002.[a]

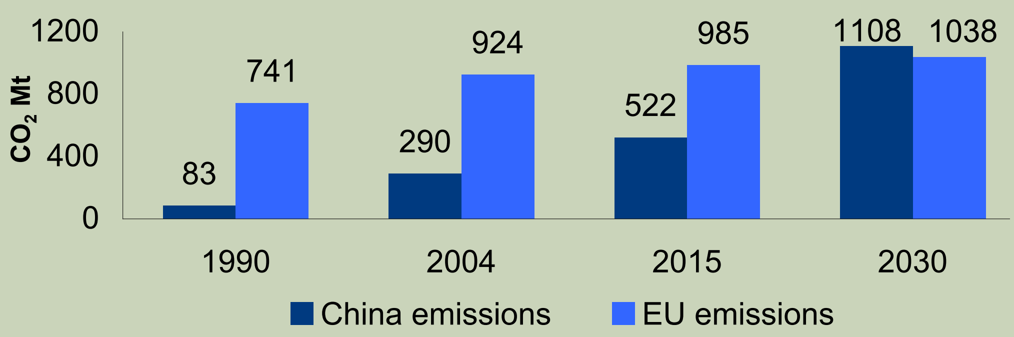
Housing construction in China consumes 20% of total steel output and 17.6% of cement production each year (Centre for Housing Industrialization, 2007). The cement industry is a prime high-carbon emitter, accounting for up to 10% of global CO_2 emissions. China has a large and increasing share of global cement production, accounting for 47% of the world total in 2006. Energy consumption in 2005 reached 117 million tons of standard coal, and the 2006 figure is estimated to exceed 150 million tons of standard coal (Wang, 2007).

Transport CO_2 emissions from the transport sector account for 20% of the global total, with about three-quarters coming from road vehicles. Globally the EU accounts for 18% of all transport CO_2 emissions, as compared with only 4.8% for China. However, China's domestic market for vehicles is growing, as is demand for passenger cars and high-value components from the EU.

Growth in aviation is expected in both China and Europe. The number of flights in China is expected to double between 2005 and 2010 (China Daily, 2006), and more than double in the EU by 2030 (European Commission, 2006e).

[a] China's Population Development Plan 2020 projected that the Chinese population would increase to 1.45 billion in 2020, and the urbanization rate could reach 60%, which means the urban population in China would amount to 870 million. Per capita living area is expected to increase to 35m² by 2020 according to the Ministry of Construction's 'Overall society housing objective 2020'. The total existing housing stock in urban areas would thus amount to 30.4 billion m². By subtracting the total existing housing floor space in 2005 (10 billion m²), we can derive that China needs to build nearly 20 billion m² of housing in the next 15 years, which is equivalent to the total building stock in the EU-15 in 2002 (Ecofys, 2006).

Figure 1.9: IEA projections for transport emissions in the EU and China up to 2030



are likely to meet their emissions reduction targets.

For the EU, meeting its Kyoto target as well as its 2020 objectives is central to retaining its leadership position in global climate discussions and assisting the global transition to a low-carbon future.

1.3 Building a joint vision towards a low-carbon future

In the next quarter-century, according to the IEA, investment worth US$22 trillion will be needed for energy supply infrastructure worldwide. China alone requires about $3.7 trillion. To avoid locking into carbon-intensive options, serious decisions are needed today to ensure a smoother transition to a low-carbon future.

Two very different paths lie ahead. One takes us down the road of old-style mercantilism, emphasizing export interests and the obsessive cultivation of national champions. The other takes advantage of the opportunities offered by globalization and interdependence to ensure win-win solutions that bring both national economic benefits and the public goods of energy and climate security.

This report argues that China and the EU have a strong strategic rationale for deepening collaboration on energy and climate security that reflects their strong common interests. Together, the two powers can use their combined political and economic weight to map the pathways towards a low-carbon future. But this will not happen under BAU, where entrenched interests argue for national preferences and promote the politics of fear *vis-à-vis* foreign investment. Below we outline some key pathways towards enhancing China–EU collaboration on energy and climate security over the next 25 years.

Both China and the EU have been major proponents of multilateral engagement within an international system that is based on cooperation and rule of law, free from the domination of one single power. As pointed out by Pierre Defraigne, China and Europe are both 'committed to a multipolar world whose stability does not rest on a balance of powers but upon the rule of law and effective multilateralism' (Defraigne, ed., 2006: Foreword). But the road towards multilateral action on energy and climate security is far from view, blocked by a myriad of difficult political and economic adjustment challenges.

1.3.1 Changing attitudes

Increasing cooperation between China and the EU will not be straightforward. Newspaper headlines tend to paint rather unsettling pictures. China faces trade barriers in Europe, while the Europeans complain about investment obstacles and weak intellectual property rights enforcement in China. One might even forget that bilateral trade and investment flows have been booming – a trend likely to continue into the future – but as is usual with trade politics, the losers have much louder voices than the winners in this debate. Western skittishness about welcoming money from China's new sovereign investment fund seems hypocritical to Chinese officials, who are trying to emulate the success of similar funds in Norway and California.

More seriously still, many European citizens are increasingly uneasy about China's growing prowess. According to the Pew Centre Global Attitudes Project, 33% of Germans believe China stands out as a contributor to global environmental problems. Majorities in Italy, the Czech Republic, Germany and France report overall unfavourable feelings about China – though the view is more favourable in the UK and Bulgaria (Pew Research Center, 2007). It is not clear whether European leaders would be able to count automatically on public support for a major programme of cooperation with China.

European leaders have spoken of leading the world into a new industrial revolution, one which produces a low-carbon economy. No single country would be more crucial to this revolution's effectiveness than China. Cooperation between China and the EU could be invaluable. But new initiatives to strengthen engagement will be impossible unless politicians in both places exhibit the leadership necessary to transcend the current fear and anxiety. Before it can make any serious overtures on climate and energy security to China, Europe needs to curb the kind of political rhetoric that feeds on exaggerated fears of Chinese competition. China could also be less reticent when it comes to talking about climate change.

Energy and climate security are a public concern in both the EU and China. An overwhelming majority of Europeans – 88% according to a June 2007 poll – think it is urgent for the EU to address global warming (Eurobarometer, 2007). In China, research published by HSBC found that citizens' concern about climate change was higher than in the European countries surveyed. Furthermore, the percentage of people who thought that climate change could be stopped was substantially greater in China than in France, the UK or Germany (HSBC, 2007). Thus political leadership that can outline a compelling vision for deepening China–EU cooperation on climate and energy security could well be pushing at an open door.

1.3.2 Avoiding lock-in of carbon-intensive investments

High prices and energy security concerns have been driving investment in all energy options including carbon-intensive technologies and infrastructure. There has been a rapid rise in coal-related investment in China.

While China's expected demand increase in the power sector has attracted considerable attention, there is less awareness of the construction needs in Europe. With the anticipated closure of power stations due to ageing infrastructure and modest demand increases, the EU – and indeed the US – requires about as much new generating capacity as China. China is expected to construct over 1,260 GW of new electricity capacity in a BAU scenario by 2030 in order to meet rising demand, while 862 GW is predicted for the EU and 932 GW for the US. This means both China and the EU will need to avoid locking investment into carbon-intensive projects in the next decade, well before technologies such as carbon capture and storage become commercially viable.

Chapter 2 discusses the current status of energy use in Europe and China to highlight the differences in structures and fuel sources, as well as their similar intentions. Most notable is the intention in both to increase the energy efficiency of the economy and the greater use of renewable energy. It explores how policies must play an important role in avoiding investment in carbon-intensive infrastructure and facilities. Delaying action on climate change and security of supply will require a faster rate of change in the future if targets and objectives are to be met, while reducing the scope and opportunity for action later on.

1.3.3 Leading the race for radical technological solutions

The need for rapid diffusion of new energy and climate technologies is clear. Once infrastructure is adapted to certain technologies, it is costly to alter – the lock-in effect. In this context, rapid diffusion of almost market-ready, climate-friendly technology is urgently needed in both regions. Embracing technological diffusion as a policy goal does not mean reducing profits for the innovators or investors who have developed the products. Rather, it is about maximizing access to climate technologies at affordable prices. Clean and high-efficiency energy conversion technologies, as well as new and renewable energy utilization technologies, are all central to enhancing efforts towards meeting energy and climate security goals.

The race for technological solutions offers genuine opportunities for China and the EU to embrace new models of cooperation. R&D investments need to be complemented by other policies to create or expand markets and drive the large-scale deployment of low-carbon technologies. Chapter 3 explores mechanisms to enhance the enabling environment to drive the innovation and diffusion processes.

1.3.4 Capturing gains through trade and investment

Encouraging the transition to a low-carbon future requires easing the barriers to trade in low-carbon, energy-efficient and environmentally friendly goods and services. Chapter 4 outlines how China and the EU can jointly explore win-win options to capture both carbon and economic gains through scaling up low-carbon trade and investment. This involves specific mechanisms to encourage trade and investment in low-carbon goods and services, as well as cooperation on low-carbon standards to help speed the needed transformations.

Following the success of the Special Economic Zones (SEZs) in early 1980s, policy-makers may wish to consider establishing 'low-carbon economic zones' (LCZs) in China. Just as the SEZs functioned as laboratories for liberal economic practices, these LCZs, at the regional or provincial level, could become pioneering testing grounds for the large-scale economic and efficient commercial transformation required for a low-carbon future.

Chapter 5 offers some policy options for mapping the pathways towards deepening China–EU collaboration on energy and climate security in the next 25 years.

2

Avoiding Carbon Lock-in

China and the EU consume around one-third of the world's primary energy. While China is the world's second-largest consumer, behind the US (which consumes 20% by itself), it has the fastest-growing energy demand of any major consuming country.

Energy consumption in China grew by 14.7% in 2005 and 8.3% in 2006, although per capita consumption remains roughly one-third of that in the EU. The boom in China has been strongly driven by the increase in output from energy-intensive manufacturing. The increasing demand for goods such as concrete, iron and steel is predominantly driven by domestic infrastructure needs, but also to some extent by exports. The government is attempting to taper the growth of some of these sectors by increasing export tariffs on goods with heavy energy consumption.

The energy efficiency of the two regions can be compared in different ways. Measuring the energy intensity of the economy by using a simple calculation of the amount of energy used per unit of GDP shows that the Chinese economy is over four times less efficient than that of the EU. This reflects the inefficient processes and machines used in the production and consumption of energy, as well as the broader structure of the economy and the manufacturing sector. However, when purchasing power parity (PPP) is factored into the calculation, the gap in energy intensity is much narrower.

Table 2.1: Main energy indicators in 2004

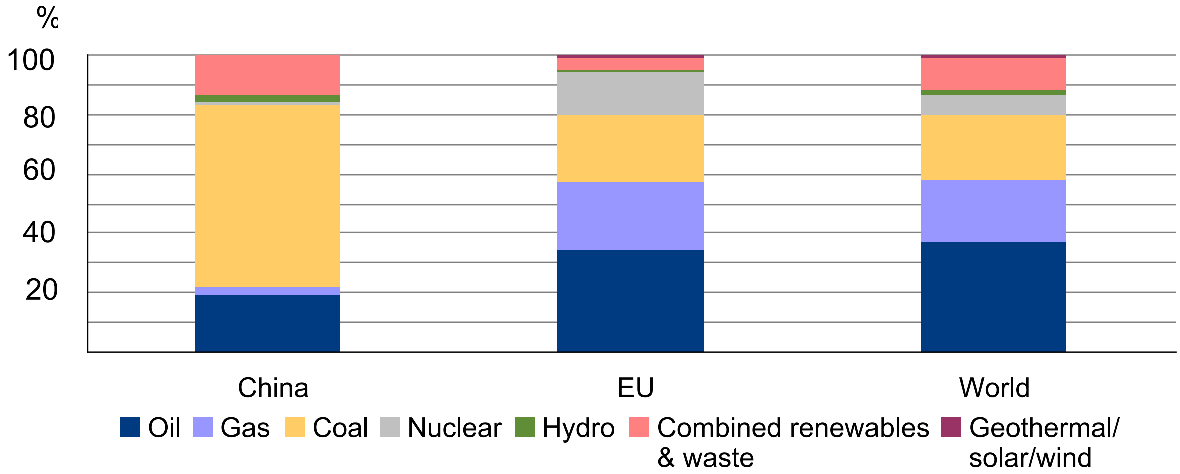
Energy indicator	China	EU-27	World
Total primary energy supply (TPES) [mtoe]	1609.35	1814.77	11223.3
TPES/population [toe/capita]	1.24	3.78	1.77
TPES/GDP [toe/000 2000$]	0.94	0.20	0.32
TPES/GDP (PPP) [toe/000 2000$ PPP]	0.23	0.16	0.21
CO_2/population [tCO_2/capita -2002][a]	2.6	[EU15] 8.40	3.90
CO_2/TPES [tCO_2/toe]	2.94	2.27	2.37
CO_2/GDP [kg CO_2/2000$]	2.76	0.46	0.76

Source: European Commission (2007e), p. 12.
[a] IEA (2004).

China's growth is CO_2-intensive. According to some estimates, in 2006 China became the world's largest emitter of CO_2, exceeding US emissions by around 8% (MNP, 2007). The country's large population and inefficient energy use are partially responsible. But another factor is the fuel used to generate much of the energy – coal. The high use of coal means that every unit of energy produced in China results in 30% more CO_2 emissions than in the EU.

The use of coal in China is uniquely large, more than double the world average, as demonstrated by Figure 2.1. Also of note is the fact that while fossil fuels – coal, oil, and gas – account for roughly

Figure 2.1: Comparison of fuel mix in China, EU and world



Source: European Commission (2007e), p. 12.

80% of the fuel mix in China, the EU and the world as a whole, the roles of biomass and nuclear power vary significantly. Biomass (mainly agriculture and forestry residues and animal manure) is used primarily in rural areas and is often overlooked, although it contributes around 13% to China's primary energy supply.

The relatively low contribution of oil to China's energy supply is a reflection of the lower proportion of transport (10%) in the country's energy consumption, compared with 29% in the EU (Laponche, 2006).

In the EU the largest energy sector is oil, dominated by transport. It is followed by gas, which is used both for heating and increasingly for electricity generation (currently around two-thirds of new generating capacity is natural gas). Nuclear power has a dominant share of the electricity supply industry (30%). The use of renewables is increasing but still relatively marginal. Biofuels[8] for transport are an increasingly important part of energy policy in both the EU and China. They have the potential to replace substantial amounts of imported oil with renewable fuels, produced either domestically or abroad. This would increase the diversity of a country's energy mix, enhancing energy security.

2.1 Avoiding carbon lock-in

The quantity and type of energy used worldwide are unsustainable, in both environmental and supply terms. Forecasts show that, without a dramatic change in direction, the situation will become worse in the coming decades, as demand increases significantly. Much of this increase is expected to occur in developing countries, particularly China and India. However, demand growth is predicted even in the industrialized world, which will also be replacing much of its existing energy infrastructure in the next two decades.

There is thus an urgent need for action, not only to curb energy consumption or reduce energy intensity, but also to set in place the opportunity for much larger cuts in the future. The wrong type

[8] Biofuels refer to liquid transport fuels derived from biomass, including bioethanol and biodiesel.

of investment now will not only affect current consumption, but will also make future changes even more difficult.

2.1.1 Power sector

The current expansion of the power sector in China is unprecedented, with over 100 GW of new capacity being installed in 2006. This growth results from a combination of factors. These include the rural electrification programme, which now enables access to electricity for 99% of the population; powering the 11% GDP growth in the economy; developing the country's infrastructure; and increased individual consumption. This level of energy and electricity growth is not anticipated to continue over the long term but will do so for at least a decade.

In Europe, much steadier growth is anticipated but it will follow a similar path. The Commission anticipates a 1.9% increase in power demand up until 2010, but a halving of the rate by 2020–30.

The IEA anticipates that from 2005 to 2030, the global energy sector under BAU scenarios will need $22 trillion of infrastructural investment. Of this, the power sector will require $11.6 trillion (IEA, 2007b) to meet increased demand, especially in developing countries, and to replace ageing infrastructure, largely in the OECD.

Table 2.2 gives the current BAU predictions of the capacity needs for the EU and China. These numbers give some important insights. First, they all point to the expected massive increase in installed capacity in China over the next two decades. China currently has around 25% less installed capacity than the EU. By 2030 it will have 40% more. China will increase its installed capacity by 1,258 GW; the EU by only 443 GW. Given China's continued reliance on coal, it will have six times as many coal stations as the EU by 2030. The numbers also point to the acceptance of the importance of renewable energy. Renewable energy sources (excluding hydro) currently have the smallest installed capacity of all Chinese energy sources, but by 2030 they will have the fourth-largest share, behind coal, gas and hydro. In the EU they also account for the smallest share of installed capacity, but will become the second-largest, behind gas. Oil will be the least used of the sources by 2030, as it is primarily used for transport. Nuclear power in both China and the EU is projected to have the second-smallest share of generating capacity by 2030, although the EU will use twice as much as China.

Table 2.2: Anticipated installed capacity in the power sectors of China and the EU (GW)

China[a]	2005	2015	2030	EU[b]	2005	2015	2030
Coal	368	814	1259	Coal	197	179	212
Oil	12	14	11	Oil	75	63	29
Gas	10	31	98	Gas	160	240	396
Nuclear	7	15	31	Nuclear	131	118	80
Hydro	117	215	300	Hydro	132	158	169
Renewables	3	21	77	Renewables	56	143	308
Total	517	1,100	1,775	Total	751	901	1,194

[a] IEA (2007b).
[b] Antony Froggatt: Estimated figures calculated on basis of the installed capacity for 2004, included in IEA (2006b), corresponding to increased electricity output reported in IEA (2007b).

As noted above, China is closing its smallest and least efficient coal-fired power stations, for economic and environmental reasons. The total installed capacity of the stations to be closed is unclear, but IEA data suggest it would be approximately 50 GW by 2020. In Europe, the last construction boom for conventional fossil and nuclear power plants was in the 1980s. Since then, new capacity has been mainly in natural gas and renewable energy (primarily on-shore wind). Around 40% of thermal and nuclear power stations are more than 25 years old, as are 60% of hard-coal plants (RWE, 2007).

The IEA estimated in 2006 that between 2005 and 2030, the EU will need 862 GW in total new capacity in order to replace ageing conventional and nuclear power plants and meet increases in demand (IEA, 2006b, Table 6, p. 148). Of this, 435 GW is additional installed capacity, which means that 427 GW of capacity – 61% of the current total – will be replaced during this period. Eurelectric (the Brussels-based European electricity industry union) assumes a similar construction requirement in its baseline scenario. The group further estimates that in 2030–50, 605 GW in new investment will be necessary and 470 GW decommissioned during the period (Eurelectric, 2007b).

Precisely when existing plants will be shut down depends on several variables; the lifetimes of facilities will be affected by engineering, economics and regulatory changes. A comparable situation is seen in the United States, where the total new capacity is expected to be 750 GW, of which 436 GW is due to increased demand and the rest replacement. Globally, approximately 25% of the IEA's estimated 5,000 GW of new generation capacity will be required owing to the retirement of existing capacity.

However, investment costs for the power sector as a whole will not just be limited to generation. For instance, China alone is expected to invest significantly in distribution grids, with a total requirement of over $1 trillion by 2030. This figure points to the economic advantages for China of undertaking energy efficiency programmes that can remove or delay the need for investment in new energy supply capacity.

This unprecedented global construction programme raises a number of problems of availability of:

- Qualified and experienced engineers;
- Regulatory/commissioning personnel;
- Equipment manufacturing infrastructure;
- Raw materials, concrete, iron and steel.

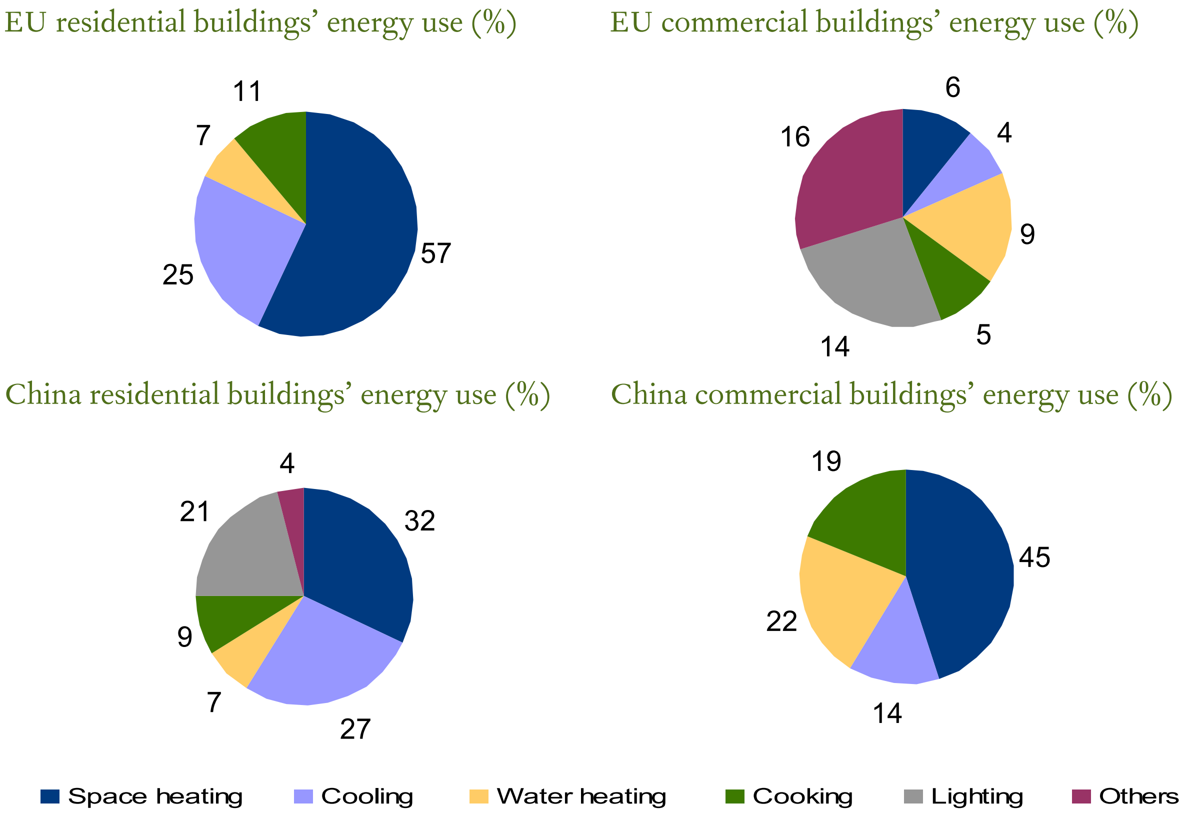
The price of constructing power stations is already rising, with one report suggesting a 30% increase since 2005 (RWE, 2007). In Germany, where many power plants are under construction, costs have risen significantly. For example, a project in Schildesche proposed in the autumn of 2005 had an estimated cost of €110 million, but by August 2007 was expected to cost €207 million (Platts, 2007).

As noted, China and the EU combined are expected to need more than 2,000 GW of new electricity generating capacity over the next two to three decades. Once built, this capacity is scheduled to operate for around 50 years. Therefore, if new power plants have high CO_2 emissions/kWh, this is likely to substantially determine power-sector emissions for a generation.

2.1.2 Building sector

Construction accounts for nearly 40% of final energy consumption in EU countries (European Commission, 2006i). Space heating-related CO_2 emissions by buildings in EU-15 countries amounted to 725mt in 2002 (Ecofys, 2006). Implementing the Directive on the Energy Performance

Figure 2.2: Buildings' energy use in EU and China



Sources: IPCC 2007b; Bowie and Jahn, 2003.

of Buildings (EPBD) (European Commission, 2002a), as of 2006, would enable savings of 40 mtoe between now and 2020 (European Commission, 2005a). Implementing the directive throughout the entire European building stock would potentially reduce CO_2 emissions by 398mt per year (European Commission, 2005a).

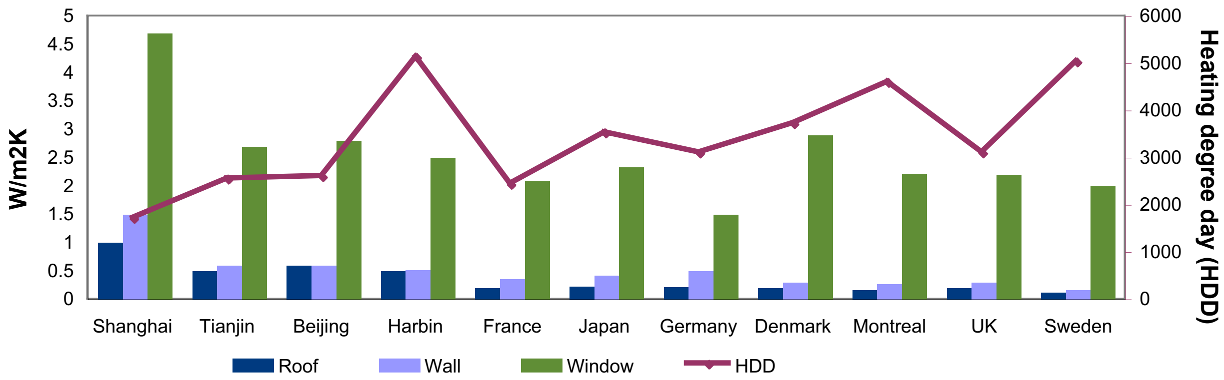
In China, energy demand in buildings has been increasing rapidly in recent years. Final energy consumption in the sector jumped 175% from 1990 to 2005 (ERI, 2007). Currently, residential and commercial buildings account for an estimated 18–20% of final energy consumption (Long, 2005). They accounted for roughly 25% of China's total CO_2 emissions in 2004.[9] Since 2000, more than 2bn m^2 of building space have been constructed in China each year (China Statistical Yearbook, 2006). As noted in Chapter 1, about 1.2–1.4bn m^2 of residential buildings are constructed in China per year, consuming 20% of total steel output and 17.6% of cement production (Liu, 2005).

The way the buildings are designed and constructed will shape energy perspectives in the next decades as buildings tend to undergo major refurbishment only every 30–50 years. Inefficient buildings therefore represent a similar level of lock-in to major power-sector investments. Inefficient construction will have tremendous implications and render climate and energy security more vulnerable. The IPCC estimates that global CO_2 emissions related to energy use in buildings could potentially be cost-effectively cut by 29% by 2020 (IPCC, 2007b).

[9] Derived from IEA(2006c): 'the energy-related CO_2 emissions in buildings in China is estimated to be around 1162 Mt, roughly 25% of China's total CO_2 emissions (4732mt) in 2004.'

In China district heating in northern urban areas consumes more than 130mt of coal equivalent per year, which represents nearly 50% of total energy demand in the building sector in China (Y. Jiang et al., 2007). Each year, district heating-related CO_2 emissions in China is equivalent to the total emissions of Poland (World Bank, 2001). As shown in Figure 2.3, China's building standards for insulation are still lower than in most developed countries, in particular north European states. Furthermore, even these are not fully implemented in local provinces owing to technical and institutional barriers.

Figure 2.3: Comparison of energy efficiency requirements in buildings



Sources: MOC 1996, p. 35; MOC 2001, p.35 ; RT 2000 ; RT 2005 ; www.worldenergy.org; www.eere.energy.gov; Waide (2006) ; Eichhammer and Schlomann (2000).

Key:
MOC 1996 (China's national building code for cold climate area).
MOC 2001 (building code for Shanghai).
RT 2005 (building code for France).
RT 2000 (building code UK).

From a life-cycle perspective, energy consumption in buildings includes both the operational and embodied energy. The embodied energy of a building includes the energy used to manufacture, transport and install the components used to construct it, from the acquisition of raw materials through to the structure's completion. This accounts for about 10–15% of the energy used in the whole life-cycle of a house.

The major components of building materials, such as cement and steel, are derived from the most energy- and carbon-intensive industries, with tremendous environmental impacts. Improving the thermal efficiency of building envelopes and the innovation of low-carbon building materials is imperative for reducing buildings' embodied energy as well as overall environmental impacts. A house in full compliance with Chinese building codes can save about 45% of life-cycle energy compared with a non-efficient house.[10] Life-cycle energy consumption could be reduced by more than 60% if buildings in China were designed using current standards in Sweden.

According to a European Commission study, EU member states could save more than one-fifth of present energy consumption and up to 30–45mt of CO_2 per year by 2010 by applying more ambitious standards to new buildings, and refurbishing old ones (European Commission, 2002). In China, energy consumption in buildings could be reduced annually by 100–300 mtoe by 2030 compared with the BAU scenario. This would mean a reduction of 600–700 million metric tonnes in CO_2 emissions.[11]

[10] This is based on climate conditions in Beijing.
[11] Estimated according to Reference and Policy scenarios in IEA (2006b); Jiang and Hu (2006).

A large range of accessible and cost-effective technologies exists for significantly mitigating GHG emissions in buildings. Although further innovation will be useful, there is much that can be done now to reduced locked-in emissions. Realizing these energy-saving measures requires an integrated design process involving architects, engineers, contractors and end-users, with full consideration of opportunities for reducing building energy demands (IPCC, 2007b, p. 6).

It is unrealistic to expect developers or constructors to improve efficiency performance spontaneously without additional market and regulatory incentives, since their sole objective is profit maximization. Removing barriers to implementing energy efficiency in buildings requires a holistic approach integrating energy infrastructure quality, building energy efficiency, energy pricing and public policies.

2.1.3 Transport sector

The IEA estimates that transport-sector oil use in China will increase from 115 mtoe p.a. in 2005 to 442 mtoe in 2030, roughly the same as the EU at that time (IEA, 2007b). This is a 5% annual increase, double the expected demand growth for energy as a whole. Currently, the transport sector accounts for a relatively small share of China's total oil demand (33%), compared with the global average of 50%.

China already imports around half the oil it uses, despite only having become a net importer in 1993. This dependency on imported oil will increase, as demand is expected to rise to around 800mt p.a. by 2030, while domestic production is expected to peak in 2015 at 200mt (Berrah et al., 2007).

Huge road-building programmes are an integral part of China's rural poverty reduction efforts. A particularly remarkable programme concerns the development of expressways. In 1988 there were only 147km of expressways. By 2002, this had risen to 25,130km, an annual growth rate of 44% (Fan and Chan-Kang, 2005). This growth has enabled and encouraged the doubling of the number of passenger vehicles on the roads since 2002 to more than 25 million, with over 5 million new cars sold in 2006. The total number of vehicles in China is currently around 37 million, and could increase tenfold in the next 25 years (Rosen and Houser, 2007). Although others put this number lower – at around 150 million (Energy Foundation, 2007) – even the lower forecasts represent a phenomenal increase.

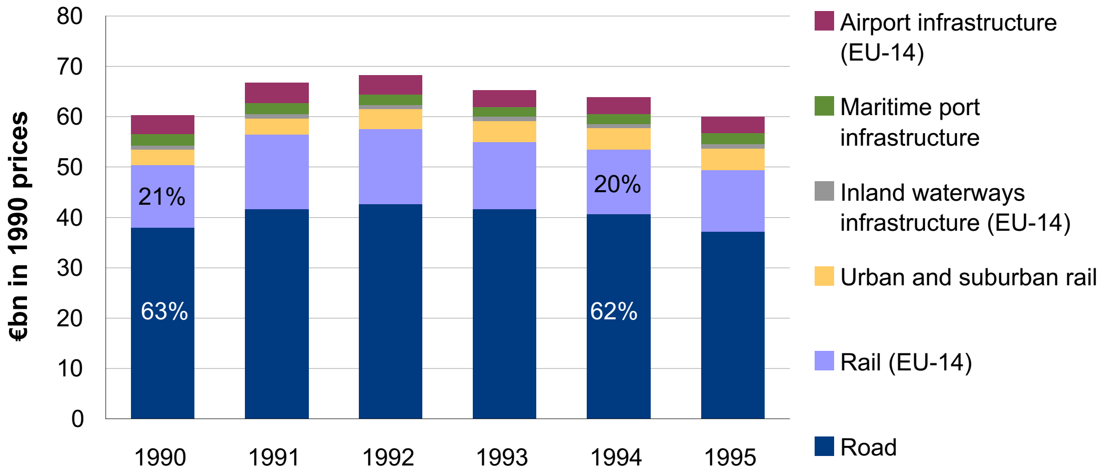
This massive projection is directly linked to the expected growth in personal income, as noted in Chapter 1 of this report. The huge increase in vehicle use is having a major impact on the global oil market. Since 2003, China has been responsible for 30% of the total rise in global oil consumption, and it accounted for fully 80% of the increase in 2006.

The 11th Five-Year Plan also calls for significant investment in all modes of transport.

However, infrastructure development should only be one part of China's energy policy. Other measures need to be introduced to increase the efficiency and reduce the environmental impact of the sector. Cross-sector initiatives could include:

- Strengthening the management of externalities such as pollution, health and safety;
- Creating a Ministry of Transport to develop effective multi-mode institutional and regulatory capacity;
- Selecting investments that will improve accessibility for the less developed provinces and reduce regional disparities (World Bank, 2004a).

Figure 2.4: Investments in EU transport sector



Source: Eurostat, *Figure: Infrastructure investment EU by mode, 1990 to 1995, and shares in 1990 and 1995 of rail and road*, http://themes.eea.europa.eu/Sectors_and_activities/transport/indicators/supply/TERM19%2C2002/Investment_EU.gif/view (2002).

Within the EU, transport is the fastest-growing consumer of energy and producer of greenhouse gases. Figure 2.4 illustrates the extent to which investment in new transport infrastructure is dominated by the road sector (62% of total expenditure). By 2030 the transport sector is expected to require nearly 400mt of oil. This increase is unlikely to be homogeneous, and the use of private vehicles in the newer member states will be twice that of the EU-15. CO_2 emissions from transport are expected to grow by 12.7% between 2000 and 2030 and to account for 27.6% of the total (European Commission, 2006e, p. 39).

2.2 Measures to avoid lock-in

2.2.1 Energy efficiency

Objectives for mitigating climate change and ensuring security of supply will simply not be met unless energy demands in the EU and energy intensity in China are both reduced. Energy efficiency has the added advantage of removing the need for installing new carbon-intensive infrastructure and enabling the more rapid phase-out of the more polluting facilities. This can enable the development and diffusion of genuinely sustainable and low-carbon technologies for energy generation, transporting and conversion.

Energy efficiency is complicated to deliver, monitor and enforce, as action is required across a whole range of activities, not just those associated with the energy sector. However, the need for comprehensive action is recognized in both China and the EU, and policies are being put in place to capture the economic and environmental advantages and potential for energy efficiency in China and the EU. These largely reach the same conclusion – that energy efficiency is possible with current technology, but changes in policy and behaviour will be needed to achieve it.

Priority areas for energy efficiency in China

Action to meet China's energy efficiency targets has been proposed in a number of areas including:

Energy-intensive industry. Eleven major sectors – coal, petroleum refining, power, steel, non-ferrous metal, building materials, chemistry, light industry, textiles, railways and transport – account for 82% of the energy consumed in industry and transport. An analysis by the World Bank showed that the energy intensity of the 13 major products from these industries exceeded international averages by 6–36% in 2000 (World Bank, 2005a).

A comprehensive scheme has been developed to address these concerns, targeting the Top-1000 energy-consuming enterprises, which accounted for 33% of national and 47% of industrial energy use in 2004. Energy audits, training programmes, benchmarking and energy-saving plans were introduced under the scheme and early indications are that the programme is beginning to have positive results, with a decrease in the energy intensity of the economy in 2006 (Price et al., 2007).

Energy conservation in electrical motors. Electric motors account for more than 50% of electricity consumption in China. If these systems were optimized, their efficiency could be improved by 20% or more (LBNL, 2003).

Energy conservation in buildings. The country will adopt and strictly adhere to a standard aimed at yielding energy savings of 30% in residential buildings and public structures by 2030 (Ecofys, 2007), by speeding up heat-supply system reforms and enhancing the promotion of energy efficiency technology and related products in buildings.

Environment-friendly lighting. Lighting accounts for 13% of the total power use of the country. As much as 70–80% of power could be saved by replacing ordinary incandescent lamps with high-efficiency energy-saving fluorescent lamps; 20–30% could be saved by replacing traditional ballast; and 90% of power use in traffic lights could be saved by replacing incandescent lamps with light emitting diodes (LEDs). Estimates from the China National Institute of Standardization suggest that adopting cost-effective minimum standards could save 42 TWh by 2010 (World Bank, 2005a).

Energy management will boost the capability of centres for monitoring energy savings at the provincial level and in major energy-consuming industries, through upgrading equipment, strengthening personnel training and popularizing energy management. It will also legislate to monitor and manage energy conservation.

Priority areas for energy efficiency in the EU

Under the EU's energy efficiency action plan, member states are to produce national plans that should see a 20% increase in energy efficiency by 2020. The EU has identified the following six areas for specific action.

Dynamic energy performance requirements for energy-using products, buildings and energy services. This is primarily focused on ensuring that member states contribute to the development of an internal market for energy-efficient goods and services by transposing, implementing and enforcing European Community legislation. These include the Eco-design Directive (2005/32/EC); Labelling Framework Directive (92/75/EC); Energy Star Agreement – efficiency of office equipment; Energy End-use Efficiency and Energy Services Directive (2006/32/EC); and the Energy Performance of Buildings Directive (2002/91/EC).

Improving energy transformation. Energy transformation accounts for around one-third of all primary energy, in particular through losses in the power sector. Therefore measures are expected that set minimum efficiency standards for small generation capacity; improve existing transmission and distribution systems; and promote combined heat and power (CHP) technology.

Moving on transport. Transport accounts for one-fifth of total primary energy, and continues to be the fastest-growing sector. Key initiatives include fuel efficiency in road vehicles; energy saving through designs and components; an integrated approach to urban transport; and improving energy efficiency in the aviation, maritime and rail sectors.

Financing energy efficiency, economic incentives and energy pricing. The Commission believes that to enable cost-effective energy efficiency initiatives, action is needed on a number of levels. These include developing clearinghouses for information and bundling of small investment projects; establishing financial facilities for energy service companies for small and medium-sized enterprises (SMEs) and housing; tax credits for the production of energy-efficient goods; and taxation and incentive frameworks for energy efficiency.

Changing energy behaviour. Behavioural change needs to be encouraged though public education and concrete action in government buildings. Further measures should be introduced through the establishment of European and national networks and partnerships.

International partnerships. Countries around the globe are interconnected through international trade and development policy as well as international agreements and treaties. These same instruments can be used to increase the application of energy-efficient technologies not only in the EU but abroad. These could include an international initiative on energy efficiency, inclusion of efficiency in bilateral trade agreements and voluntary agreements with export industries.

2.2.2 Generation options

While there is near-universal support for the need for energy efficiency, there is much less unanimity over the appropriateness, viability and timing of the different electricity supply options available to avoid carbon lock-in.

Renewable energy. The various renewable energy technologies have differing timetables until they reach full diffusion, based on the state of current research and experience. For instance, the different engineering challenges posed by on-shore versus off-shore wind power have delayed full commercialization of the technology.

Both China and the EU are in the process of adopting ambitious renewable energy targets. China has proposed that the share of electricity from renewable energy sources, excluding large hydropower, should be 20%, as indicated in Table 2.3.

The EU also has an active programme to support the development of renewable energy in general. A 2001 Renewable Electricity Directive calls for 21% of the EU's electricity to come from renewable energy sources by 2010. According to the European Commission, member states are not on track to meet this objective at this point, but are likely to manage 18–19% (European Commission, 2004a).

In March 2007, EU member states proposed to adopt a binding target that would require the EU to obtain 20% of its energy from renewable energy sources. To be included within this target is a sector-

Table 2.3: Renewable electricity projections in China

Year	2005	2010	2020
Hydropower	115 GW	180 GW	300 GW
Wind power	1.3 GW	5 GW	30 GW
Biomass power	2 GW	5 GW	30 GW
Solar PV	0.07 GW	0.3 GW	1.8 GW
Share of total primary energy (including large hydropower)	~7.5%	10%	16%
Share of electric power capacity (excluding large hydropower)	~8%	10%	20%

Sources: Preliminary development planning targets provided by China Energy Research Institute, Energy Bureau of NDRC, and conference presentations by others. Current figures: REN21 Renewables 2005 Global Status Report and 2006 Update. Martinot (2006).

specific objective that 10% of liquid transport fuels should come from biofuels by 2020. This builds on the current biofuels target of 5.75% by 2010, as outlined in the 2003 directive (2003/30/EC).

Coal – supply-side efficiency. Efficiencies vary globally for coal-fired power stations. China's average efficiency is around 33%, while Germany averages 39% and Japan over 41% (Graus et al., 2007). Efforts are being made in China and the EU to close down the least efficient and most polluting facilities. Globally, the current generation of pulverized combustion (PC) coal plants has efficiency levels in the range of 30–37%. However, new technology is now being deployed at supercritical PC plants, which increases the temperature and pressure of the steam to increase the efficiency to between 37% and 43%. The next generation of PC stations – known as ultra-supercritical stations – is expected to produce efficiency levels in excess of 50% (Dresdner Kleinwort, 2007).

A second branch of the technology development is the Integrated Gasification Combined Cycle (IGCC) which, instead of pulverizing the coal, gasifies it and then uses it in a combined cycle, similar to the modern gas-fired power stations. It is suggested that the IGCC power stations will have efficiencies in the order of 38–43% (Dresdner Kleinwort, 2007).

The widespread commercialization of higher-efficiency coal-fired power stations is significant not only for climate security but also for security of supply in the short and long term. Raising the average efficiency of coal-fired power stations from a percentage in the low 30s (China) and mid-30s (EU) to over 50% would significantly reduce the volume of coal that has to be mined, transported and burned.

Carbon capture and storage (CCS). In China, it is assumed that by 2030 new coal-fired power stations with a combined capacity of around 900 GW will become operational. This is an extraordinary amount of additional coal, more than four times the current installed capacity in the EU (IEA, 2007b).

In the EU the exact capacity of coal-fired stations that will have to be closed or retrofitted in the coming decades is unclear, in part because these decisions are left to individual utilities. However, it is clear that age of the existing facilities – 75% are over 25 years old, and 45% are over 30 – makes it likely that the majority of the existing power stations will be closed by or around 2020. The European Commission gives different estimations of the precise capacity figure, ranging from around 70 GW[12] to 150 GW (European Commission, 2006h). As only a handful of coal-fired stations have been built in the last decade, the vast majority of currently existing plants that remain are likely to be closed by 2030. Both the IEA and the European Commission assume that by 2030 coal capacity in operation will be roughly 30 GW over 2005 levels, suggesting that approximately 220 GW worth will have been built in the meantime.

Both China and the EU are developing carbon capture and storage (CCS) technology as a means to enable the continued exploitation of coal. This is designed to enable the majority of the emissions (around 80%) from a fossil fuel station to be captured and stored underground, rather than being released into the atmosphere.

While efforts to develop CCS technology are under way, a number of technical, legal, economic and political issues need to be overcome. These may further delay or even block its widespread use. The obstacles include high costs and energy use.

Costs. The costs associated are not well defined owing to the lack of operating experience. However, a wide variety of suggested costs has been put forward for the price of CO_2 at which CCS becomes economical, including: MIT ($30/tonne), Ecofys (€33–52/tonne), Dresdner Kleinwort (€19.4–24/tonne) and the IPCC ($25–30/tonne).[13] On the other hand, industrial estimates can be significantly higher: BP suggested in evidence to the UK Parliament (House of Commons, 2006) that a minimum price would need to be £40/tonne (€57/tonne).

Energy penalty. Another key issue is the quantity of energy required during the CCS process. This is of particular importance in countries currently facing limited opportunities to meet all of their energy demand requirements. Once again there are different assessments of energy use during the CCS process. According to the IPCC, 'A power plant equipped with a CCS system (with access to geological or ocean storage) would need roughly 10-40% more energy than a plant of equivalent output without CCS, of which most is for capture and compression'. These higher ranges are associated with retrofitting existing plants, particularly pulverized coal plants (IPCC, 2006). The economic and energy viability of retrofitting existing power stations has also been questioned; the MIT report suggested that even the 'pre-investment in "capture ready" features for IGCC or pulverized coal combustion plants designed to operate initially without CCS is unlikely to be economically attractive'. The importance of the energy penalty issue has been recognized by the industry in both the EU and China. Eurelectric believes 'a key prerequisite for developing CCS is to reduce the efficiency penalty arising from the capture process' (Eurelectric, 2007a).

Energy and cost penalties have the potential to severely curtail the introduction of new technology, as demonstrated by the use of flue gas desulphurization units in coal-fired stations in China. Despite the known health benefits of the technology, currently only around 15% of these stations have such units installed, and reports suggest that not even all of these are being used. One reason for this is the energy penalty associated with their use (between 4% and 8%).

[12] European Commission (2007e). This figure can be obtained using a 4.5 GW per year replacement/upgrade requirement document on p. 35, while a 100 GW/year in 10–15 years is cited on p. 15.
[13] MIT (2007), Ecofys (2004), Dresdner Kleinwort (2007) and IPCC (2006) respectively.

Combined heat and power (CHP). In addition to burning coal more efficiently, efficiency can be boosted by capturing more of the energy released. The most widely used and available technology is CHP and the so-called tri-generation power plants, which also includes cooling. CHP enables the heat generated in combustion to be utilized rather than being released directly into the atmosphere (through cooling towers or water bodies).

New CHP designs are being deployed, such as the Bubbling Bed Fluidized Combustor, with efficiency levels in the order of 80–90% (Tzimas et al., 2007). An operating facility at Rauhulahti in Finland has an efficiency output of 85%. This contrasts with the average efficiency of the EU's thermal power plants of 37.5% (European Commission, 2006d), and the 33% average efficiency of Chinese coal stations in 2003 (Graus et al., 2007). Another advantage of CHP is that it can be used for a variety of fuel sources including peat, wood chips, oil and coal.[14]

The use of CHP is already widespread in parts of China and the EU. In China 32 GW of installed capacity used the technology in 2001, accounting for 13.37% of the installed thermal capacity. As a result, 60% of central heating in urban areas (mainly in the north) was produced by CHP. It is said that this programme has saved 25mt of coal equivalent, as well as 65mt of CO_2 (OPET, 2005).

China's 11th Five-Year Plan aims to increase the coverage of centralized heat supply in urban areas from 27% in 2002 to 40% by 2010. This will require the installation of 40 GW of co-generation and result in the saving of 35 million tons of coal (People's Daily, 2004).

In 1997, the EU recognized the importance of CHP and introduced an indicative target, calling for a doubling to 18% of the share of electricity produced by co-generation by 2010. It is estimated that meeting this target could help avoid CO_2 emissions of over 65mt CO_2/year by 2010. Further measures were outlined in the 2004 directive on the promotion of co-generation, which detailed measures that could be adopted by member states to support this sector (OJEU, 2004).

Currently, CHP is used to generate 16.4% of electricity in the EU, with significant variations among member states. In general the new member states have a higher level, averaging 25.4%. However, Denmark has the highest percentage (74.7%) (European Commission, 2006e).

Nuclear. Within the EU, nuclear power remains a divisive issue at a public and political level. In the EU-27, 15 member states use nuclear power, with a total of 145 nuclear reactors providing 30% of the EU's electricity. France has by far the largest number, operating 45% of the EU's total capacity.

After the Chernobyl accident in 1986, the fortunes of the nuclear industry took a downturn in Europe, and the total number of reactors in operation is expected to decline from 172 in 1987 to 135 by 2010. Eight reactors were shut in 2006. There is currently renewed interest in nuclear power, and reactors are being built in Bulgaria, Finland, France and Romania, with plans and proposals for more in a number of other countries. However, as noted, under BAU scenarios the number of new reactors will not replace those due to be closed at the end of their working lives. Both the IEA and European Commission anticipate a drop in installed nuclear capacity by 2030, by 44% (IEA, 2006b) and 25% (European Commission, 2006e) respectively.

In China the current level of nuclear power is very modest. Only 2% of the country's electricity comes from its 11 operating reactors, the lowest share of any country that uses nuclear power

[14] Finnish Funding Agency for Technology and Innovation (TEKES). Bubbling fluidised bed boiler - Rauhalahti CHP plant, available from: http://www.tekes.fi/opet/bublfluid.htm.

generation. However, this appears set to change. Five reactors are under construction, and there are ambitious plans for much greater nuclear power use in the future. The existing reactors were constructed by a variety of firms from Canada, France and Russia. Recently signed agreements will enable the deployment of the most advanced 'Generation III' reactors from both the United States (the AP1000 – not yet ordered anywhere else in the world) and France (the EPR – currently being built in Finland). Under government plans the output and contribution from nuclear power is expected to increase over the coming decades, with an installed capacity of 40 GW envisaged by 2020 – 27.3 GW more than what is already operating or under construction.

Even nuclear power, however, is not immune to fuel supply concerns. 'In the longer term, beyond 50 years, uranium resources availability also becomes a limiting factor, unless breakthroughs occur in mining or extraction technologies,' according to a paper published in 2002 (GIF, 2002, p. 13).

A 12-member international programme called the Generation IV International Forum (GIF), led by the US with participation from governments including China and the EU (through Euratom), is developing six new reactor designs. Most of these deploy a closed fuel cycle and therefore use plutonium fuels, which will further utilize the potential energy available from nuclear power. However, the deployment of these reactors raises engineering problems, owing to the high temperatures and pressures proposed. Proliferation concerns are also an issue, since nuclear material could be diverted for military uses. The current projects aim for demonstration Generation IV facilities to be available post-2020.

Nuclear fusion is also the subject of joint EU–China research – the ITER project. This multinational project includes the European Union (represented by Euratom), Japan, China, India, South Korea, Russia and the US. The legal agreement on the establishment of the ITER is expected to be signed in November 2007. The demonstration project, due to be located in Cadarache in southern France, is expected to take 10 years to build and then to operate for a further 10 years. The total cost is expected to be in the order of €16 billion, over half of which is expected to be funded by the Europeans, mainly the EU and France.

Priority areas for generation

Given the need for rapid action to improve the security of supply and reduce the risks of climate change, the prioritization of different technologies must also reflect the time at which they will be available for widespread dissemination. To avoid having to invest in electricity capacity, it is clear that energy efficiency can and should play a major role in minimizing investment in unsustainable energy options. A rapid programme of energy efficiency can remove or at least reduce the need for new infrastructure and power plants.

The renewables sector, with a diverse portfolio of technologies and uses, should be given the next priority. Renewable energy is not only low-carbon and advantageous from a supply security perspective, it also meets wider sustainability and non-conflict criteria. Furthermore, the low technology requirement of much renewable generation makes scaling-up of production more feasible.

The potential for nuclear power has been reinvigorated at the political level in recent years. However, even if the ambitious plans for a fivefold increase in China's nuclear power are realized, it will remain marginal, accounting for less than half of the share of energy currently provided by biomass. Within the EU, public and political resistance to nuclear power, coupled with the ageing of the existing nuclear capacity, make it unlikely that nuclear power will increase its share in the next few decades. The development of the later fusion and fission nuclear designs is continuing with successful international collaboration.

There is widespread hope for the development and diffusion of CCS. Without further action it is unlikely that widespread deployment of CCS will be achieved globally before 2020. Therefore unless the capability and financing for CCS retrofitting is a requirement for all coal-fired power stations which are built in the interim, considerable new generating capacity will be locked into high-carbon emissions. However, significant improvements can be made immediately to reduce the environmental impact of the coal sector and improve its energy efficiency.

2.2.3 Heating and cooling

Current EU policy for energy efficiency is framed by the European Commission's Action Plan for Energy Efficiency (European Commission, 2006a). Regarding the building sector, the 2002 directive establishes the general policy framework relating to the efficiency of buildings and energy supply systems. It is the individual responsibility of each EU member state to choose measures that correspond best to its particular situation.

In China, building construction and management, the formulation of energy efficiency policies and supervision are the responsibility of different public institutions. The Ministry of Construction is the central body for formulating national-level policies for energy efficiency in buildings. Four successive building energy conservation standards have come into force since 1995 regarding the energy consumption of space heating and cooling in China's different climatic zones. The common objective is to halve energy consumption in new buildings compared to the old non-efficient designs and practices dating back to the early 1980s.

Priority areas for heating and cooling

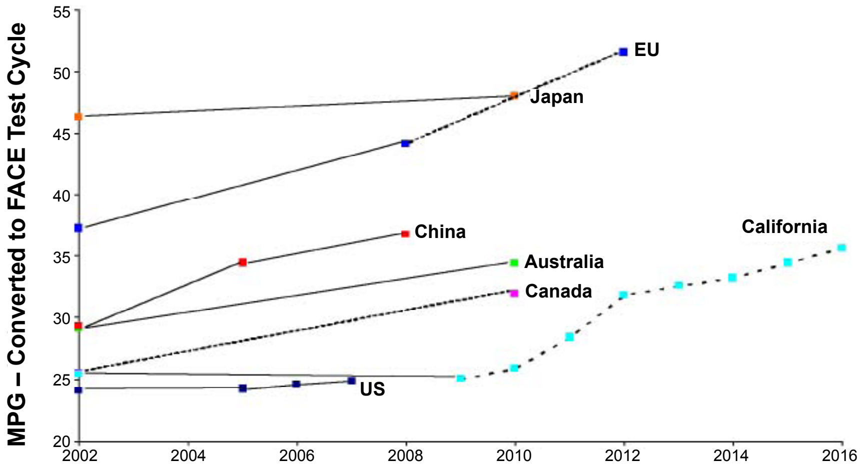
Policy instruments. Aside from mandatory standards for the efficiency of building structures and heating equipment, EU countries use various policies to address building energy efficiency. Market incentives work in combination with both public and private initiatives such as capital subsidies, feed-in tariffs (guaranteeing a fixed price for electricity or energy over a specified period of time), building energy passports, certificates/labelling, fiscal mechanisms, town planning obligation exemptions, etc. In China, energy efficiency management in the building sector still follows the traditional command-and-control approach; policy instruments are hardly considered and are in most cases underdeveloped. Builders and consumers are not given any economic incentives to save energy during construction and operation. No price signals are delivered to the end-users of energy.

Scaling-up of low-carbon or eco-building experiences and expertise and technology transfer. Cooperation between the EU and China will focus primarily on sharing experiences and expertise; creating business opportunities; promoting cooperation in research and development in high-performing building technologies; mobilizing financial resources for programmes; improving capacity-building of political institutions; and other ways of facilitating the building efficiency market. Constructing large-scale energy-efficient and environment-friendly buildings will help expand the spread of new technologies and the sustainable development model. The EU's construction and energy industries could find unprecedented business opportunities in China in the coming decades, given the tremendous market potential for construction-sector energy efficiency. Moreover, technology transfer for low-carbon buildings comprises not only the purchase of hardware (equipment, materials etc.) but also transfer of 'software', including technical training of personnel in operation, maintenance and management.

2.2.4 Transport sector

Vehicle efficiency. China has fuel economy standards for passenger vehicles, which require increased efficiency for both existing and future models. As Figure 2.5 shows, these standards are more stringent than those in the US and a number of other Western countries, but not the EU. The Chinese government has proposed to bring domestic vehicle emissions standards into line with international norms by 2010.

Figure 2.5: Comparison of fuel economy and GHG emission standards – normalized by CAFE-converted mpg



Source: An and Sauer (2004).

In March 1998, EU vehicle manufacturers made a voluntary agreement with the European Commission which would see emissions reduced to 140gCO_2/km by 2008, with a possible further extension to 120gCO_2/km by 2012. The car manufacturers are not on track to reach the 2008 target, and the Commission is expected to bring forward legislation in this area at the end of 2007.

Environmental and efficiency standards for vehicles in both China and the EU not isolated from each other. In 2006, China exported 76,600 cars to Europe, a 171% increase over the previous year. The EU has become an important market for Chinese cars – and thus its emissions standards will have an impact on vehicle manufacturing in China.

In China, a significant barrier to the greater use of lower-emission cars is the quality of the fuel. The Chinese State Environmental Protection Agency has said that the high sulphur level in imported crude oil poses challenges for the production of the clean automotive fuel necessary to reduce emissions (SEPA, 2006).

Biofuels. Estimates by the IEA for 2004 put the share of biofuels in China's transport fuel consumption at zero. Oil accounts for an estimated 95% of transport fuel use. In the EU, biofuels currently represent approximately 0.6% of total transport fuel consumption.

In the IEA's BAU scenarios, China's use of biofuels in transport fuel consumption is expected to increase to 0.5% by 2015; Europe's to 4.5%. Under the alternative scenario, Chinese use will increase to 1.6% by 2015 and to 3.5% by 2030. In Europe, the proportion will rise to 5.4% of total fuel use by 2015, and 6.4% by 2030.

In order to achieve these alternative scenarios, significant investment will be needed both to increase capacity and to develop the technology for second- and third-generation biofuels. Worldwide investment (venture capital and private equity) in biofuels in 2006 was US$2.2 billion, a 337% increase on investment in 2005, with 89% of investment going into capacity and 11% into technological development.

In 2006, Chinese investment in biofuels was $765.2 million, a 443% increase on 2005. Also that year, stipulations on biofuel targets were drafted as part of China's 11th Five-Year Plan and were due to be introduced at the end of that year (USDA, 2006). According to the draft, by the end of the period in 2010, China's biofuel production would be 5.2 million metric tons (MMT). The draft also included a variety of programmes to expand demand for ethanol.

However, the State Council rejected the proposals for biofuels development owing to increased concerns about food security. Corn prices have surged as a result of the rise in biofuel production as well as increasing manufacturing costs. Wheat prices have also soared as farmers shift production to corn plantations. The NDRC suspended all new grain-based biofuel projects (although it did not ban new investment in biodiesel projects). As a US Department of Agriculture report suggests, although the old target was scrapped, no new production targets have been set. The report states that 'a realistic goal given the new constraints on the sector has been suggested to be between 3 and 4 MMT by the 2010 target' (USDA, 2006).

As a part of its energy policy, the EU has adopted a Strategy for Biofuels (2006), which aims to assist EU members in meeting the requirements of the Biofuels Directive (2003). That directive itself was adopted to encourage the substitution of petrol or diesel in the transport sector, and set targets for biofuel use (these targets were later amended). An assessment of the 2003 Biofuels Directive in the Biofuels Progress Report (European Commission, 2007f) showed that the 2010 targets were unlikely to be met. In 2007, the EU's Roadmap for Renewable Energy proposed legally binding targets for biofuels to account for 10% of total petrol and diesel consumption by 2020, along with an overall requirement for 20% of energy consumed to come from renewable sources. Member states have adopted a variety of production- and consumption-based incentives to encourage the use of biofuels.

Modal shifts. The importance of changing transport patterns is widely recognized. Mass transit is a key component of national and regional plans in both China and the EU. In China the movement of citizens to urban areas has created specific requirements. Bus Rapid Transit (BRT) systems have been successfully deployed in large cities in Latin America. In December 2005, Beijing completed its – and China's – first BRT corridor, a 15.8km section of a project expected to extend to 300km. In the EU, there are similar plans to further integrate transport modes and increase the use of mass transit systems in urban areas.

Cooperation and joint programmes, such as the C40 climate leadership group,[15] are facilitating the introduction of innovative integrated systems and technology, through pooling the buying power of

[15] C40 Climate Leadership Group: http://www.c40cities.org/.

Box 2.1: Coal-to-liquids

The widespread availability of coal in countries including Australia, China, India and the US has encouraged the development of its use as a liquid transport fuel. South Africa is the world leader. Coal-to-liquids (CTL) has been used there for over 50 years and now supplies 30% of its gasoline and diesel. In other countries CTL does not currently play a major role, but plans for its expansion are being developed.

China plans to introduce significant CTL infrastructure and is looking to South Africa for its technology. In 2006 an agreement was signed with Sasol in South Africa to build two plants. The overall objective in China is to use CTL to reduce petroleum imports by 10–20 mt/year by 2020.

Despite the abundance of coal in China, there are environmental constraints on the use of CTL. Water is the principal one, since CTL technology requires 5–10 litres of water for every litre of fuel output. This has already had an impact on the development of the sector, with plans rejected in July 2006 for the construction of a 3 mt/year processing plant.[a]

Further constraints on the technology's use are its large CO_2 emissions. The life-cycle analysis of CTL suggests that the CO_2 emissions are 50% higher than for conventional gasoline. Making the emissions of conventional gasoline and CTL comparable would require the latter to include carbon capture and storage.[b]

[a] Planet Ark (2006).
[b] Jaramillo and Samaras (2007).

cities, mobilizing expertise and creating and deploying common measurement tools to increase the efficiency of public transit systems. The C40 group comprises of large cities from around the world, including two in China (Beijing, Shanghai) and a number in Europe (Berlin, London, Madrid, Paris etc.), committed to reducing CO_2 emissions and energy consumption.

2.3 Looking forward

In order to avoid being locked into a high-emissions and high-energy-consumption future, alternative investment approaches are needed. For energy efficiency, many technologies exist and are already in the market. Their use must become widespread. This will be accelerated by adjusting the policy framework by removing barriers to compliance, and creating incentives and penalties to discourage non-compliance.

Renewable energy could also become key options for a secure and environmentally friendly energy system. The growth rate for renewables has increased in recent years and ambitious targets mean that it is forecast to continue. To achieve these necessary objectives, combined research programmes, along with joint production techniques and operations, can assist in reducing bottlenecks and lead to lower manufacturing costs. Significant other improvements can be achieved by developing innovative and holistic approaches to energy management.

A clear framework detailing the possible timetable for the introduction of different technologies would be beneficial for a smooth transition to a sustainable energy sector. This could facilitate the introduction of technologies and policies that can bring energy security and emissions reductions in the short term while also enabling the technological and market development of medium- and longer-term solutions.

The costs of being locked into an inefficient and high-carbon investment path should be better factored into public and private investment decisions. The exclusion of environmental externalities from energy pricing means that decisions are being made in China and elsewhere that do not reflect the reality of the emission reductions needed to preserve energy and climate security in the next two decades. Currently, commercial investment does not seem to have adjusted to the expectation of long-term high oil prices. Unless investment patterns are changed now – encouraged not only by market prices but also by complementary public policy signals – choices in the future will be seriously limited. Both Europe and China have critical interests in ensuring a minimum of lock-in in their own economies, as do other economies with similar projections for new build, such as India and the US.

3

Leading the Technology Race

> *'Energy technology has a vital role to play in breaking once and for all the link between economic development and environmental degradation.'*
>
> European Commission (2007g, p. 9)

The rapid development and adoption of new technologies are critical to meeting the challenges of energy insecurity and climate change. Embracing technological innovation and diffusion as a policy goal involves creatively balancing the incentives for the innovators or investors to develop new products, while maximizing access to climate technologies at affordable prices as soon as possible, in order to avoid technology lock-in.

The race for low-carbon technology solutions offers genuine opportunities for China and the EU to embrace new models of technological cooperation, with mutual benefits. For China, it means increasing its share of value addition from production while de-linking its economic growth from environmental harm. For the EU, it means driving down the costs of the energy transition, and building new markets for its low-carbon goods and services. Joint R&D investments can be complemented by mechanisms that facilitate innovation and the diffusion of technology, that create or expand markets, and that thereby drive large-scale deployment of low-carbon technologies.

Despite broad agreement on the importance of clean energy technology, there has been only slow progress on developing the practical and effective innovation incentives needed to drive the transition to a low-carbon economy at a global scale (Mabey, 2007a and b). Initiatives are under way at the national and regional level in China and the EU, but the question remains how best to align existing efforts to promote transformative impacts at scale.

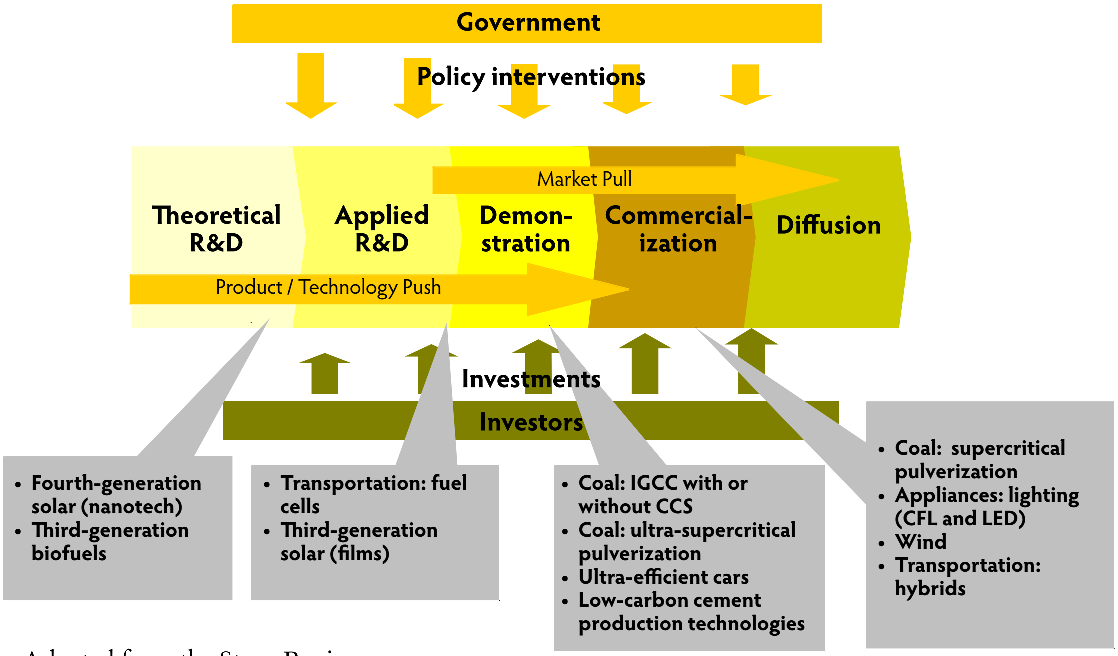
According to Nicholas Ashford:

> *technological change is a general – and imprecise – term that encompasses invention, innovation, diffusion, and technology transfer. Technological innovation is the first commercially successful application of a new technical idea. It should be distinguished from invention, which is the development of a new technical idea, and from diffusion, which is the subsequent widespread adoption of an innovation beyond those who developed it* (Ashford, 2001).

Technology strategies need to embrace the whole innovation system, rather than focusing on particular areas such as research and development. Several mutually reinforcing elements are needed:

- Consistent policy signals to move energy system investment towards low-carbon alternatives;
- Growth of the capital pool available for investment in research and commercial-scale demonstration projects;
- Clear market-pull instruments to drive commercialization e.g. through renewable energy portfolio mandates, tax credits, investment 'matching funds', public procurement policies and funds from CO_2 compliance payments;

Figure 3.1: Selected key technologies at different stages of technological development



Source: Adapted from the Stern Review.

- Implementation of a supportive institutional framework, so that the market, regulatory and business models currently shaping the energy system drive low-carbon investment, and favour novel technologies over BAU practices; and
- Reduced constraints on the free flow of people, ideas and experience.

3.1 Target areas for low-carbon technological innovation

Technological innovation is needed across a broad range of areas, encompassing high technology, materials, industrial process, consumer products and business practice, in particular:

- Power generation – including fossil fuel, renewables and carbon capture and sequestration;
- Industrial efficiency;
- Energy-efficient consumer goods;
- Transportation;
- Building-sector efficiency;
- Vulnerability assessment and adaptation technologies.

Avoiding high-tech myopia. Facing the need for high-tech and 'disruptive' technologies to move onto a low-carbon path, it becomes easy to overlook the range of substantive gains to be achieved through the diffusion of incremental technologies (e.g. improved insulation and furnace technologies) as well as of 'soft' practices (e.g. congestion charges, industrial process optimization training, lean manufacturing/quality management). Certainly, soft practices and incremental improvements have fewer barriers to implementation than large-scale capital investment in emerging technologies such as gasification and carbon capture and storage.

While the traditional concept of 'technology transfer' implies a process through which a piece of equipment or a blueprint is transferred to a recipient company or country, this is only half the story. Moving up the technological ladder is as much about acquiring the knowledge and know-how to

Table 3.1: Typology of target areas for low-carbon technology innovation

Types	Examples	Rationale
Power generation	Renewables – wind, solar, biomass, micro-hydro; fossil – fuel cells, combined heat and power (CHP), pulverized coal (PC), Integrated Gasification Combined Cycle (IGCC), natural gas combustion turbines (NGCT), combined cycle gas turbines (CCGT); carbon capture and storage (CCS); nuclear (fission and fusion).	Power generation in Europe and China produces more CO_2 than any other sector. This is due to the large demand for electricity, the inefficiency with which it is produced and distributed, and the dependence on combustion of fossil fuels. Addressing these factors can bring significant improvements. The efficiency of currently deployed coal power stations ranges from 33% to percentages in the low 40s. However, new technologies can take this to over 50%, through the use of IGCC or PC. Even higher efficiency levels are possible through the use of combined cycle technologies, while the use of CHP creates an opportunity to achieve efficiency levels of up to 80%. By developing and exploiting these technologies, significant fuel savings are possible. Renewable energies are nearly carbon free, and reduce dependence on imported fuels, thereby enhancing security of supply.
Industrial production efficiency	Less carbon-intensive and more energy-efficient production methods: cement; iron and steel; chemicals and other heavy manufacturing.	The heavy industrial sector offers the opportunity for considerable energy and CO_2 savings. The best available technologies can save between 30% and 50% of energy compared with the previous generation of technologies. Significant CO_2 emission reductions are possible through process innovations.
Energy-efficient consumer goods	From lighting (such as compact fluorescent lamps (CFLs) and LEDs) to white goods (fridges, temperature control and other electronic goods).	The high development rate, turnover and growing demand for electronic goods offer a unique opportunity to rapidly implement energy efficiency technologies. Order-of-magnitude improvements in the lifespan and energy intensity of lighting appliances are already possible through the replacement of incandescent bulbs with LEDs and other solid-state alternatives.
Transportation	Advanced diesels, hybrids, fuel cells/specific emissions standards, electric, hydrogen; public transport design; non-transportation alternatives.	The predicted rate of growth in transport coupled with its importance to the globalized economy offer an important incentive for action to diversify away from fossil fuel sources and to create non-transport options (such as through urban design practices that reduce private vehicle dependence and traffic loading) and alternatives to travel (e.g. through internet-based services, telecommuting, and staggered shift hours).

Building-sector efficiency	Building design, insulation, energy-efficient building materials production.	Energy use in buildings is large and has huge potential for energy saving. Using current best practice as a benchmark would reduce energy use by two-thirds, while the best available technologies would bring energy use to zero.
Vulnerability assessment and adaptation technologies	From drought-resistant seeds, sea walls and irrigation technology to knowledge around insurance schemes and crop rotation patterns.	Novel technologies can be helpful for vulnerability assessment and adaptation planning (e.g. high-resolution spatial models linking climate science with socio-economic data at the regional and local level). Innovation is also required to 'reduce vulnerability or enhance the resilience of natural or human systems to the impacts of climate change' at least cost, in areas ranging from building technologies to disaster response and recovery (Vladu, 2005, p. 24).

use equipment effectively as it is about access to the physical hardware. For example, a large part of technology transfer related to low-carbon and energy-efficient buildings deals with the technical training of personnel for maintenance, management and operation (Cheng, 2005, p. 262). As production processes become more knowledge-intensive, technology transfer increasingly demands 'learning by doing', through use and interpersonal interaction with experts, rather than solely through physical ownership of a particular technology (Mytelka, 1999).

3.2 Focusing domestic innovation systems towards a low-carbon future

Two complementary forces govern the incentives for innovation (see Figure 3.1). These are *technology push* – targeted R&D investment by governments and the private sector to move scientific discovery towards commercialization; and *market pull* – incentives to bring products to market that include pricing mechanisms and regulatory standards.

Both push and pull instruments can be used by governments to shape and accelerate the innovation chain. 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 (Jones and Williams, 1998). Governments have sought to correct this market failure by offering some type of reward to encourage innovation. These 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 (e.g. small population diseases, environmental controls). Incentives can include research grants, tax credits, and direct or partnership-based research by governmental agencies. Making these incentives accessible to new entrants is critical, since it is unlikely that transformative innovation will emerge from established industry players (Ashford, 2001).

Where market demand does not favour investment, government action may be necessary through market-pull initiatives, e.g. by setting a long-term carbon price, creating regulatory requirements, targeting government procurement, offering technology prizes, etc. Table 3.2 provides some policy options for overcoming barriers to innovation.

Table 3.2: Policy options for strengthening the innovation system for low-carbon technologies

	Research and development (theoretical and applied)	Demonstration (pilot to market)	Commercialization (technology cost buy-down)	Widespread diffusion (overcoming institutional barriers and increasing investment)
Key barriers	• Governments consider R&D funding problematic • Private firms cannot appropriate full benefits of their R&D investments	• Governments consider allocating funds for demonstration projects difficult • Difficult for private sector to capture benefits • Technological risks • High capital costs	• Financing for incremental cost reduction (which can be substantial) • Uncertainties relating to potential for cost reduction • Environmental and other social costs not fully internalized	• Weaknesses in investment, savings, and legal institutions and processes • Subsidies to conventional technologies and lack of competition • Prices for competing technologies exclude externalities • Weaknesses in retail supply financing and service • Lack of information for consumers and inertia • Environmental and other social costs not fully internalized
Policy options to address barriers	• Direct public funding (national or international) • Tax incentives • Incentives for collaborative R&D partnerships	• Direct national or international support for demonstration projects • Tax incentives • Low-cost or guaranteed loans • Temporary price guarantees for energy products of demonstration projects	• Temporary subsidies through tax incentives, government procurement, or competitive market transformation initiatives	• Phasing out subsidies to established energy technologies • Measures to promote competition • Full costing of externalities in energy prices • 'Green' labelling and marketing • Concessions and other market-aggregating mechanisms • Innovative retail financing and consumer credit schemes • Clean Development Mechanism and other carbon finance transfer mechanisms

Source: Adapted from UNDP (2000), p. 435.

3.2.1 National efforts to support research and development

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. The 11th Five-Year Plan (2006–10) outlines its aim of increasing research and development (R&D) to 2% of GDP. Today, only 10% of China's GDP comes from high technology, and nearly nine-tenths of this comes from locally operating foreign companies or joint ventures with Chinese companies.

For the energy sector, areas of interest to China include coal-fired power generation equipment, nuclear, biomass utilization technologies, hydropower generation as well as oil exploitation and coal-mining technologies (K. Jiang, 2007).

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 achieve breakthroughs in energy development and conservation technologies, and clean energy technologies, as well as on 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.[16] The Ministry of Science and Technology (MOST) draws up the technology R&D plans and provides funding for the national programmes.[17]

In 2006, China's State Council put forward *Several Suggestions for Accelerating Equipment Manufacture Development in China*. A group of large Chinese equipment manufacturing companies is expected to be internationally competitive to meet the demands of energy, transport and raw material production by 2010 (cited in K Jiang et al., 2005).

For its part, the European Union has significantly expanded its research and development budget in recent years. The 7th Framework Programme, which runs from 2007 to 2013, has an R&D budget of €53 billion, compared with €17.5 billion for the five preceding years. The largest share goes to collaborative research (over €32 billion), but there are also specific-issue programmes for energy (€2.3 billion), environment including climate (€1.9 billion) and transport (€4.2 billion). Nuclear power has a separate research budget, through Euratom, which has a five-year budget of €2.7 billion.

Over half of the renewable energy research within the EU is conducted by the public sector, which spent €349.3 million in 2002; the figure for the private sector was €340 million (European Commission, 2004b).

In addition to EU-wide schemes, member states run their own R&D programmes. According to the IEA, energy-related spending from these programmes amounted to US$1.8 billion in 2004 – a modest

[16] For a complete text of the plan see for example http://politics.people.com.cn/GB/1026/4089311.html.

[17] The objectives of the 873 programme 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-tech fields in which China enjoys relative advantages or should take strategic positions in order to provide high-tech support to fulfil strategic objectives in the implementation of the third step of our modernization process.' See website: http://www.most.gov.cn/eng/programmes/programmes1.htm. The 973 programme is the National Programme on Key Basic Research Project. The programme seeks to build a solid science and technology foundation for the sustainable socio-economic development of China. Through the implementation of the programme, a contingent of scientific talents will be trained and a number of high-level national research bases will be established to upgrade the primary innovative capacity of the nation. See website: http://www.most.gov.cn/eng/programmes/programmes3.htm.

decrease in R&D finance, which during the 1990s exceeded US$2 billion (IEA, 2007a). Neither member states nor Europe-wide research programmes have been increased at a scale commensurate with the political imperative accorded to energy and climate security by European leaders.

3.2.2 Challenges to existing efforts to stimulate low-carbon innovation

In 2005, China and Germany were the world's top investors in renewable energy, responsible for US$7bn out of US$38bn (Merrill Lynch, 2007).

Nevertheless, according to recent analysis by the OECD (2007a), 'China's national innovation system is not fully developed and still imperfectly integrated.' Links between regional and national actors, for example, remain weak. The same report also suggested that more investment is needed in 'sectors such as services, energy and environmental technology'. R&D programmes continued to be led by the state, 'characterised by a top-down, "picking the winner" approach … with little involvement of other stakeholders'.

The OECD also pointed out that China's

> *current regional patterns of R&D and innovation activities are not optimal from the perspective of the efficiency of the national innovation system. For example, they create too great a 'physical' separation between knowledge producers and potential users. They are also not optimal from a social equity perspective as innovation systems in lagging regions are underdeveloped.*

Like China, the EU faces dilemmas in coordinating innovation efforts among its constituencies – in this case EU member states, which all have national research programmes, even centres of excellence, on energy, largely sharing similar objectives and targeting the same technologies. Further, as described by a Communication from the Commission, 'public and private research centres, universities and dedicated agencies complete a picture of scattered, fragmented and sub-critical capacities', and working together 'will benefit all, exploiting the federating role that the European Union can play in the field of energy' (European Commission, 2007g).

In short, China has strong development interests in developing sustainable energy technologies but needs to reform its innovation systems in several areas. Europe faces challenges in coordinating its disparate national innovation systems in key areas.

A crucial challenge for both regions is that national innovation policy remains little more than an extension of national industrial policy. The desire to cultivate national champions is commonplace for rich and poor countries alike, especially for countries such as China that are bent on capturing a larger share of the value chain. Industrial policy reflects this through the direction of subsidies and tax credits towards a few leading firms. However, given the importance of climate and energy security, the building of national champions should not take precedence over reducing the carbon footprint. Areas where these objectives may conflict include infant industry protection, regulation of domestic electricity markets, preventing foreign acquisition of domestic firms, terms of access to public and private finance, etc. At the same time, the emergence of low-carbon and energy efficiency markets offers significant international expansion opportunities in areas of national comparative advantage.

3.3 Creating the enabling conditions for innovation and diffusion of key technologies

The estimated subsidy for fossil fuels is between $20–30 billion for OECD countries in 2002 and $15–250 billion per year globally. The IEA estimate that world energy subsidies were $250 billion in 2005 of which subsidies to oil products amounted to $90 billion. Such subsidies compound any failure to internalise the environmental externality of greenhouse gases, and affect the incentive to innovate by reducing the expectations of innovators that their products will be able to compete with existing choices.

Stern Review, 2006, p. 355.

With appropriate frameworks in place, the enormous combined market power and innovative capacity of China and the EU can provide the incentives needed for the development of the low-carbon and energy-efficient technological solutions necessary to meet energy and climate security goals. To create the necessary enabling framework, energy and climate policies need to contain incentives for innovation and diffusion; and all innovation policy should take climate and energy security objectives into account. Existing subsidies that favour inefficient technologies to the detriment of low-carbon alternatives need to be reformed.

There will be no 'one size fits all' solution. Different technologies have varying needs; they will be accelerated down the innovation chain in different ways, but there are concrete mechanisms that will make a difference.

R&D investments need to be complemented by other policies to create or expand markets and to drive large-scale deployment of low-carbon technologies. Most new renewable technologies, for example, are unlikely to be successfully deployed without subsidies or regulations, until scale and scope efficiencies emerge and carbon prices begin to disfavour conventional fossil fuel use. In many sectors (such as wind or solar power), the incentives have come from requiring electrical utilities to use renewable sources for a certain percentage of their energy – or allowing them to sell renewable energy on favourable terms through 'feed-in tariffs' (Barton, 2007b). Market pull from regulation, prices and public procurement strategies will all be critical.

3.3.1 Sending a strong signal to the market

As suggested by the Stern Review, 'putting an appropriate price on carbon – explicitly through tax or trading, or implicitly through regulation – means that people are faced with the full social cost of their actions. This will lead individuals and businesses to switch away from high-carbon goods and services, and to invest in low-carbon alternatives.' (Stern Review, 2006, p. 18)

Additionally, it maintained that carbon pricing 'gives an incentive to invest in new technologies to reduce carbon; indeed, without it, there is little reason to make such investments. But investing in new lower-carbon technologies carries risks. Companies may worry that they will not have a market for their new product if carbon-pricing policy is not maintained into the future.' (Stern Review, 2006, p. 19)

The current carbon market, with its regional nature, creates market distortions as there are too many sellers and not enough buyers. Investment in low-carbon technologies needs assurances. Investors and consumers need to believe that the carbon price will be maintained into the future (Stern Review, 2006).

Policy-makers could signal their seriousness in ensuring the creation and implementation of a low-carbon economy through setting a common carbon price. China and the EU could assist in this, not least through a joint assessment of how carbon prices are encouraging or hindering the pursuit of their respective policy objectives.

3.3.2 Harnessing EU–China links

Box 3.1: Applied R&D and technology pilot cooperation: clean coal technology

Emissions from China's increasing coal use are set to increase from 5,000–9,000[a] mt CO_2/year by 2030, owing to its reliance on inefficient coal-fired electricity generation processes. There are two levels of technology innovation needed in order to use coal for energy production while minimizing its carbon footprint: first, to carry out the basic energy production process as efficiently as possible; and, secondly, to capture and sequester the CO_2 emissions, preventing their release into the atmosphere.[b] Because of the likely impact of Chinese coal use on global greenhouse gas emissions, joint initiatives have been established on clean coal technologies, bringing together Chinese and international agencies and firms. Leading examples include:

- *The Near-Zero Emission Coal Project (nZEC)*:[c] Established as part of the EU–China Climate Change Partnership in 2005, this bilateral effort between the UK and Chinese governments will study the feasibility of different technology options for the capture of CO_2 emissions from power generation and the potential for geological storage in China, and culminate in a possible demonstration project, starting up between 2010 and 2015.
- *The US FutureGen Project:*[d] Launched in 2005, this public–private partnership aims to build and operate a commercial-scale coal gasification plant with CCS. Among its members are European mining interests and Huaneng Group, reportedly the largest coal-based power generator in China (representing about 9% of China's generating capacity).

[a] IEA (2007b).
[b] Barton (2007a).
[c] www.defra.gov.uk/environment/climatechange/internat/devcountry/china.htm.
[d] www.futuregenalliance.org.

The EU is one of China's biggest sources of technology imports – through private and public transactions, as discussed in Chapter 1 of this report. The China–EU Science and Technology Cooperation and China–EU Partnership on Climate Change are the main bilateral cooperation programmes. The former is an overall science and technology programme that led to a Memorandum of Understanding in 2005 on transport and energy strategies, among them clean coal.[18] The latter focuses specifically on low-carbon technologies, with a high priority given to renewable energy technologies and energy efficiency, as well as a range of near-zero-emission/clean coal technologies including carbon capture and storage.[19]

Formal EU research programmes for R&D are open to Chinese participation, with some items in the 7th Framework Programme specifically targeting Chinese partners. Discussion is under way

[18] http://ec.europa.eu/comm/external_relations/china/intro/sect.htm.
[19] http://europa.eu.int/rapid/pressReleasesAction.do?reference=MEMO/05/298.

on a joint initiative for sustainable power generation from fossil fuels, which includes Near–Zero Emission Coal technologies (see Box 3.1 below) and the construction of demonstration plants in Europe and China. In the previous (6th) EU Framework Programme, China was involved in 28 projects for energy with a total project cost of €66 million (Kougionas, 2007).

Given the increasing interest in clean energy technologies and generally expanding research budgets in both China and the EU, there are significant opportunities to accelerate R&D and technology development collaboration. Depending upon where in the technological innovation value chain they want to cooperate, there are a variety of approaches that could be adopted.

- *Cooperative R&D* – setting up jointly managed and funded laboratories in pursuit of key mutually defined, long-term technology objectives, with or without industry participation. This approach has been used in pre-competitive research in the semi-conductor field.
- *Applied R&D/technology pilots* – expanding the ongoing efforts between China and the EU to develop prototype processes and demonstration pilot projects of targeted clean energy technologies.
- *Growing markets for commercially viable technologies* – development of joint venture companies, cross-training programmes, cross-licensing arrangements, trade tariff exemptions on selected technologies, and joint manufacturing programmes.
- *Joint China–EU climate technologies prize* – a joint fund to promote innovation in energy-efficient and environmental products. This fund could function as a patent pool and/or a repository for cross-licensing of technologies developed by either Chinese or European actors.

China and the EU are both well aware not only that existing technologies must be more widely used, but also that it is imperative to find radical new solutions to address energy and climate security challenges. As the European Commission put it,

> *Business as usual is not an option. The current trends and their projections into the future demonstrate that we are simply not doing enough. To put the European Union and global*

Box 3.2: Technology competition to accelerate development and proof-of-concept[a]

In order to accelerate the introduction of new technologies into the marketplace, numerous variants of a technology competition for reward have emerged. Pioneered by the Swedish Agency for Public Management's Energy Efficiency Department in the 1990s, the 'golden carrot' programme offered state procurement contracts for 32 energy-saving products in exchange for meeting certain specifications. In 1993, through the Consortium for Energy Efficiency, the US EPA and 24 utilities initiated a 'Super Efficient Refrigerator' competition, offering US$30 million to the manufacturer who could produce the most efficient refrigerator at the lowest price. Most recently, UK billionaire Richard Branson has offered US$25 million to the first person or group to find a way to remove a billion tonnes of greenhouse gases from the atmosphere each year for 10 years.[b]

[a] Lovins and Datta et al. (2005), pp. 200–202.
[b] 'Branson offers $25M prize to fight climate change', CBC News, 9 February 2007, www.cbc.ca/technology/story/2007/02/09/branson-greenhouse.html.

Box 3.3: Uncertainties around the viability of climate-friendly technologies

Uncertainties persist around implementing or scaling up climate-friendly technologies, as does the likelihood of the emergence of technologies that would dramatically change the competitiveness of renewable energy sources.

Uncertainty in wider deployment of near-term technological solutions …	
Wind energy	Rate of cost reductions as global markets grow
Solar energy	Rate of cost reductions as global markets grow
Biomass energy	Cost-effectiveness of next generation technology
Nuclear energy	Cost-effectiveness and safety/proliferation
	Characteristics of next generation technology
Carbon sequestration	Cost-effectiveness and environmental integrity
… and uncertainty regarding the potential for 'game-changing' innovation to emerge	
Solar technology	Appearance of ultra-cheap solar technology
Biotechnology	Development of high-efficiency cellulose conversion
Nanotechnology	Development of ultra-efficient energy use technologies

Source: Mabey (2007a, b).

energy systems onto a sustainable path, to benefit from the consequent market opportunities and to achieve the ambitious vision outlined above, will require a sea-change in European energy technology innovation, from basic research right through to market take-up (European Commission, 2007g).

A factor impeding more rapid technology deployment is the high degree of uncertainty inherent in many existing technologies in terms of their performance at scale, and it is unclear whether horizon technologies will materialize (see Box 3.3). Cooperation is valuable in such settings, allowing parties to pool risk, lower costs and accelerate technological progress. Consequently, it is in the interest of both the EU and China to collaborate in the development of the new generation of energy technologies, and to reform legal frameworks and trade and investment policies to encourage such collaboration.

3.3.3 Making better use of integrated production chains

The integrated nature of the EU–China production chain should be better utilized to drive the innovation and diffusion of new technologies in both directions.

Wholly foreign-owned enterprises have significantly increased their share in high-technology exports during the past decade,[20] while that of joint ventures and especially state-owned enterprises has decreased (OECD, 2007a). To date, these foreign firms have been the primary channel for transfer of technology to China, through imports of intermediate and capital goods, for example.

China's strategy for moving up the value-added chain has been to gain understanding and know-how on a technology through a joint venture or licensing arrangement, and then to build towards independent design and manufacturing capability (Barton, 2007a, p. 10). Foreign firms have, however,

[20] The share of technological exports from China produced by multinational companies is increasing, up from 80% in 2003 to 88% in 2005. See OECD (2007a).

Box 3.4: Domestic legal reforms are needed to facilitate international technology transfer[a]

The widespread use of coal-fired industrial boilers has been critical to China's economic growth but is highly inefficient and dangerously polluting. Emissions from coal-fired industrial boilers may account for as much as a third of China's total greenhouse gas emissions, and are a primary cause of severe air pollution and acid rain, threatening public health, eroding labour productivity and damaging agricultural production and forestry. The Global Environment Facility's China Efficient Boiler Project, started in 1994, was designed to obtain technology for more efficient boilers from developed-world firms and then to transfer that technology to Chinese boiler-manufacturing firms.

While the project was deemed successful by the World Bank, there were significant difficulties in getting international firms to license their technology to local operators, owing to concerns regarding giving up core technologies, and the possibility that the technologies would be spread within China further than they had been licensed. This resulted in delays, and inadequate funding for capacity-building.[b]

These issues are likely to arise when firms are asked to share proprietary technology with potential competitors. To enhance the prospects for success of similar initiatives:

- Care should be taken in defining the rights that are to be transferred;
- Availability of legal remedies to enforce those rights should be guaranteed;[c]
- Efforts should focus on sharing technologies that are secondary to and not the core element of differentiation among competing products.[d]

[a] Drawn from Barton (2007a) and World Bank (2004b).
[b] Global Environment Facility (2001); Birner and Martinot (2005).
[c] Watson et al. (2000).
[d] For example, in the case of automobiles made by competing companies, the engine is core, but the catalytic converter is secondary.

undertaken little technological innovation or product design inside the country, thereby limiting the potential spillover to the domestic Chinese economy. Many core technologies remain controlled by the foreign partners in joint ventures or by company headquarters abroad.

The rewards available to industrialized-country firms from bringing R&D and design to China are potentially high, and include economies of scale and labour cost reductions, as well as access to new ideas, markets, and knowledge of local conditions (Wilkins, 2002, p. 71). According to the OECD, however, reluctance to share core technologies and innovation functions with domestic Chinese partners may stem from current specialization patterns, the dearth of absorptive capacity in Chinese firms, and in particular ineffective intellectual property rights (IPR) protection – see Box 3.4 (OECD, 2007a). Other concerns common to international investment may include the availability of appropriately skilled local professionals and labourers, language barriers, regulatory 'transaction costs' and competing and overlapping legislative authority structures (Wilkins, 2002).

Despite these concerns, multinationals continue to play an important role in contributing to the share of R&D in China. By June 2004, accumulated R&D investment of multinationals in China was estimated to have reached $4 billion, and there were an estimated 700 foreign-affiliated R&D centres. In recent years, China's high-tech exports have risen dramatically. Their share in total exports increased from 5% in the early 1990s to over 30% in 2005. For example, China has been the world's largest exporter of information and communication technology (ICT) products since 2004 (OECD, 2007a).

3.3.4 Getting intellectual property right for innovation and diffusion

Many questions have been raised about whether the current intellectual property (IP) protection systems – enshrined in bilateral rules and multilateral regimes at the World Trade Organization (WTO) and the World Intellectual Property Organization (WIPO) – will drive or hinder the cross-border diffusion of low-carbon technologies.

In countries where little inventive activity takes place, for example, would encouraging the easier flow of technical and scientific information generate more technological capacity-building than stronger exclusive rights? As pointed out by the European Patent Office (EPO) in its *Scenarios for the Future*,

> *Complex new technologies based on a highly cumulative innovation process are seen as the key to solving systemic problems such as climate change, and diffusion of technology in these fields is of paramount importance. The IP needs of these new technologies come increasingly into conflict with the needs of classic, discrete technologies.*[21]

The Stern Review postulates that costs associated with royalty payments for patent licences do not constitute significant barriers in the diffusion of low-carbon technologies. This is due mainly to the relatively low cost of royalty payments as a proportion of total investments. Depending on a technology's stage of development, however, patent protection regimes (or weak enforcement of intellectual property rights) may change the incentive calculus for technological development in ways that impede widespread technology diffusion.

The wide range of and need for low-carbon technology arguably necessitate different models of innovation, deployment and diffusion – including intellectual property flexibilities. For example, many steps are needed to take technologies from theory to market. Especially in the early stages of technological development – from theoretical and applied R&D to demonstration efforts – many prototypes compete for resources. While innovators may come to realize that their technologies are unlikely to be commercialized, they often remain reluctant to share proprietary knowledge gained as a result of 'failed' efforts. This can considerably escalate the cost of developing viable technologies, by preventing successors from building on the lessons of past efforts. Mechanisms can be established through the public sector to facilitate and reward sharing this learning, e.g. through conferences, innovation incubators or case studies.

Standardization and technical regulation will be important issues in the diffusion of low-carbon technologies. As pointed out by the Chinese delegation to the WTO in November 2006, meeting certain standards often involves the use of patented technologies, creating a barrier to market entry. Standards and technical regulations may thus (inadvertently or by design) reduce options for the use of existing and future technologies – whether in the form of technical production methods or as product-specific features.

[21] See European Patent Office, Scenarios for the Future, http://www.epo.org/focus/patent-system/scenarios-for-the-future/scenario4.html.

Box 3.5: IP and technical standards can act as barriers to renewables diffusion[a]

Intellectual property rights govern the technologies needed to link a solar photovoltaic cell (PV) or wind turbine to an electricity grid, owing to the variability of these power sources. National grid requirements could be written in a way that favours particular linking technology providers over others. Together, these IP protections and regulatory standards could impede the growth of renewables. Similarly, the absence of common standards ensuring interoperability of manufacturing equipment and components elevates costs, likewise impeding diffusion.

[a] Barton (2007a, p. 23).

The implications of dual 'lock-in' – proprietary/closed standards and patent protection – for the diffusion of existing and horizon climate technologies (from fuel efficiency to low-carbon industrial production standards) must be factored into policy and regulations.

The speed at which new technologies are diffused will be crucial in meeting emissions reduction and security of supply objectives. A significant impediment to the diffusion to China of low-carbon technologies will be the extent to which firms can imitate or develop leading technologies. Another potential obstacle is the willingness of leading firms to license their technology to others. This may depend on their confidence that they can do so without losing control over them – which is determined in part on the strength of China's IP system (Barton, 2007a, p. 10). Mechanisms for obtaining control of a technology would include deliberate transfer of the production process (to reduce production costs) or integration between Chinese and European firms following a merger or buy-out.

'Compulsory licence' describes a number of mechanisms for non-voluntary authorization to use patents. While contentious, it is a tool used by many governments to accelerate the diffusion of the latest technologies.[22] It is often justified as necessary to correct a market failure in the service of a public good. The US Clean Air Act, for example, mandates the compulsory licensing of patented technologies needed to meet agreed standards. In August 2006, a court in the US granted Toyota a compulsory licence on three Paice patents for hybrid transmissions, for a royalty of $25 per automobile.[23] The most important global norm for the use of compulsory licences is Article 31 of the WTO Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement, which addresses uses 'of a patent without the authorization of the right holder, including use by the government or third parties authorized by the government'.[24]

In response to urgent energy security and climate needs, China and the EU could consider requiring compulsory licensing as a precondition for public-sector assistance in deploying technologies at scale. For example, a condition for state funding of carbon capture and storage could be a requirement to enter into joint ventures or issue licences in third countries that are party to EU clean coal agreements.

[22] See, for example, Reichman with Hasenzahl (2003).

[23] Paice LLC v. Toyota Motor Corporation, 2006 WL 2385139 (E.D.Tex. Aug 16, 2006) (NO. 2:04CV211DF).

[24] See Love (2007). Other TRIPS provisions that are important are Articles 1, 6, 7, 8, 31bis, 40 and 44, as well as the provisions of the 2001 Doha Declaration on TRIPS and Public Health.

Compulsory licensing comes at a cost, reducing the potential value of successful R&D. Stanford University Law Professor John Barton cautions that while it is possible to insist on making technologies available to developing nation firms 'on a low-royalty humanitarian basis', this 'may not be wise if the developing world market is the primary one in which research costs would be expected to be recovered' (Barton, 2007a).

In sum, the interaction between technical standards, intellectual property rights and legal enforcement capacity needs to be addressed directly as part of the necessary framework for low-carbon innovation and diffusion. The EU and China could agree on practical steps to address structural issues in low-carbon technology cooperation around intellectual property rights – with a focus on practical mechanisms such as conditional or compulsory licensing, fair use rights, and guidelines for standardization – to enhance the diffusion of key technologies.

4

Capturing Gains through Trade and Investment

4.1 Towards smarter trade and investment

'We have to redefine what we consider to be a European product. It is not the same as it used to be.'
Sten Tolgfors, Trade Minister, Sweden[25]

Trade and investment can play a key role in facilitating the worldwide transition to a low-carbon economy, by creating new market incentives for low-carbon economic activities. The Stern Review, for example, highlights the need for large-scale transformation of international carbon finance flows. The incremental costs of low-carbon investments in developing countries are estimated to reach at least US$20–30 billion per year (Stern Review, 2006). This points to windows of opportunity to pilot new approaches to creating large-scale flows for investment in low-carbon development paths.

This chapter explores how China and the EU can jointly explore win-win options to capture both carbon and economic gains through scaling up low-carbon trade and investment.

The sheer size of the two markets means that a China–EU trade agenda will influence the global marketplace. As already noted in Chapter 1, the EU is China's largest trading partner and China is the EU's second-largest trading partner. The EU is China's largest supplier of foreign direct investment, technology and services. Enhancing low-carbon trade between the EU and China could create a virtuous circle in which trade stimulates a larger global market for low-carbon products, generating further trading opportunities. Experience shows that by working together to define compatible standards for key products, China and the EU could enhance bilateral trade; they could also begin to set the *de facto* global standards in these areas. These potential opportunities could help offset any competitiveness concerns entrepreneurs might have about moving quickly towards low-carbon alternatives.

Trade and investment also enhance the two markets' access to each other's comparative advantages, leading to cheaper inputs and prices. China's clear advantage in manufacturing energy-efficient light bulbs, for example, can help the EU meet energy efficiency targets. Other potential areas of mutual benefit might include solar panels and micro wind turbines, where domestic production will not be enough to meet the EU's demanding targets. The EU is a world leader in environmental services and technologies that China needs for climate mitigation and adaptation. Increased trade in select areas can lead to wider market expansion strategies for Chinese and European businesses alike.

Looking to the future, increased trade engenders stronger ties and promotes collaboration on R&D. Enhanced cooperation could, for instance, help the Chinese building industry, which often fails to comply with standards owing to a lack of energy-efficient technology. Foreign investment in China could become one of the main drivers of this process, until Chinese technological development matures further. Increased investment can also help upgrade existing facilities, foster competition in the host country, bring in new technology and facilitate its dissemination, and provide more

[25] Cited in Andrew Bounds, 'EU trade chief warns over anti-dumping tariffs', *Financial Times*, 3 September 2007.

know-how in today's more knowledge-intensive production processes. In the case of China, where a large proportion of exports comes from foreign-owned enterprises, increased investment is likely to lead to increased trade.

All of these scenarios, however, require the removal of tariff and non-tariff barriers to trade and investment in low-carbon products. This may involve an assessment of likely economic and social impacts, in order to ascertain whether other policies will be necessary to remedy dislocation.

Winning political support for liberalization will require an expansive vision of how countries benefit from trade and investment, rather than the standard wrangling over trade deficits. As discussed in Chapter 1, China's rising trade surplus with the EU (standing at €110bn in 2005) is of great concern to the Europeans. However, the quantitatively impressive figure does not necessarily translate into significant advantage for China if those products are only assembled there.

A report by Sweden's National Board of Trade vividly demonstrates the dilemma (Kommers-kollegium, 2007). Anti-dumping duties imposed on Chinese leather have, in the name of protecting EU interests, incurred heavy losses for European importers. Even more pointedly, the report found that most of the value added during the production of Chinese shoes can accrue to the EU! EU value added is above 50% for low-priced shoes, and can surpass 80% for up-market shoes with high design and marketing costs. 'A shoe manufactured in China still can be regarded as a "European shoe"', the report concludes, when most of the value can be generated through European product design. Shoe importers, in any case, can simply switch to another low-cost country.

4.2 A snapshot of the current state of play

4.2.1 Tariff and non-tariff barriers

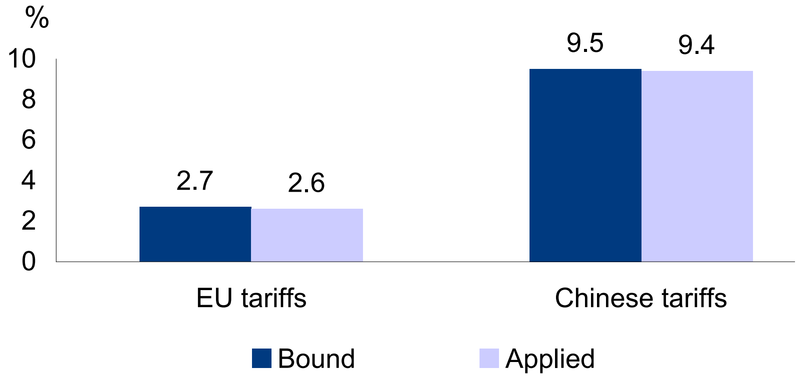
On average, EU and Chinese tariffs for high-carbon goods are higher than for low-carbon goods. For example, the EU's tariffs on environmental goods are half that of high-polluting goods. At present, tariffs for low-carbon goods are not generally high, although the EU tariffs are generally lower than Chinese ones: EU bound tariffs average 2.7%, and are applied at 2.6%, while Chinese bound tariffs average 9.5%, and are applied at 9.4%.[26]

There are important exceptions. The EU has high tariffs on certain low-carbon products, including some biofuels. Also subject to high duties are glass fibre mats for saving energy in buildings, aluminium reservoirs/tanks/containers for biogas and water management, and lenses/prisms/mirrors for solar energy systems. Three types of hydraulic turbines and water-wheel products for hydroelectric power generation have tariffs above the average for industrial products. China's biofuels industry is not yet very significant, but tariff escalation for these products in the EU might become a constraint.

Two major non-tariff barriers to trade exist, especially in the EU, with anti-dumping protection and some higher standards. There are several barriers to investment, especially in China, including local content/ownership rules, labour requirements as well as uncertainty over the strength of intellectual property protection. A more fundamental inhibition on investment could be a lack of demand in the would-be investor country – and the ensuing low rate of return – as in the case of Chinese air conditioners and cement, which are made to a lower environmental standard than in the EU.

[26] Bound tariffs refer to those duties that governments commit to not raising in future. The current tariff rate on a good is the applied tariff.

Figure 4.1: Average Chinese and EU tariffs on low-carbon goods



Source: UN Comtrade Database.

4.2.2 Mechanisms to discourage trade in carbon-intensive sectors

No formal mechanisms are in place to discourage trade in carbon-intensive sectors. In fact, countries have demonstrated significant resistance to the notion of giving products different tariff treatment on the basis of how they are produced or processed. Although several WTO Dispute Settlement Body decisions have allowed importing countries to establish trade restrictions on products on such a basis,[27] or on the basis of environmental/health impact,[28] this remains a contentious area of trade policy.

From a political point of view, it is easier to restrict trade on the basis of a product's impact (e.g. on health or the environment) than on the way it is produced. Many traded products are high-carbon because of their production process (e.g. concrete), while others differ from low-carbon products in terms of their characteristics and impacts (e.g. light bulbs, air conditioners). In the latter case, there are some product standards that promote trade in low-carbon versions, effectively discouraging trade in carbon-intensive ones (e.g. buildings standards). In addition to formal standards, there are informal ones that perform similar functions, such as 'energy star' ratings for appliances.

Another mechanism that could encourage trade in low-carbon products is public procurement. Green procurement is a growing policy area throughout the EU.

China has recently moved to discourage exports of high-carbon products, using a variety of instruments. For example, as of July 2007, the government cut export tax rebates for 2,831 commodities to curb the growth of energy-consuming industries. From August, 15% export taxes have been imposed on some aluminium products to restrict exports of high energy-consuming and -polluting resources, products and encourage imports of raw materials. Other resource taxes on lead, zinc, copper and tungsten ore have been raised three- to sixteen-fold. In recent discussions at the WTO, the EU, Japan and the US questioned the motivations for these export restrictions, asking whether they had been accompanied by corresponding domestic measures to curb consumption. They also suggested that the higher prices for raw materials were affecting input prices for their industries. Concerns were raised by the US over the impacts of the export taxes on its overseas investors in China, who required the raw materials for the production of steel, chemicals, airplanes and automobiles. From the Japanese end, questions were asked about the legality of the taxes, given that they apply only to exports and thus cannot be justified under the General Agreement on Tariffs and Trade (GATT)

[27] For example, United States — Import Prohibition of Certain Shrimp and Shrimp Products, WTO dispute DS58.

[28] For example, European Communities — Measures Affecting Asbestos and Products Containing Asbestos, WTO dispute DS135.

rules on the preservation of natural resources. The EU asked China to justify the taxes in particular on coke, a highly-polluting commodity of great importance for Europe's steel industry. Evidently, while calls for domestic measures are understandable, these governments should be careful not to discourage Chinese efforts in curbing trade in high-carbon goods.

4.2.3 Thinking through embedded carbon

Just as it has clouded the picture of who benefits when a product is exported, globalization has made it harder to assess accountability for CO_2 emissions.

The EU, the US and other parts of the world are increasingly dependent on China to manufacture entire ranges of goods, goods which may otherwise have been produced domestically using substantially cleaner energy systems. To some extent, therefore, the EU and other countries are exporting their emissions, whether to China or elsewhere. This is true for all manufactured goods in a globalized world, but it is of particular relevance in the light of China's large and growing trade surplus with the EU and the US (see Figure 4.2) (Wang and Watson, 2007b).

Booming international commerce and the growing concerns over climate change have spurred research into the CO_2 emissions associated with trade, so-called embedded or embodied carbon. The current system of carbon accounting in the Kyoto Protocol attributes carbon only to the producer of goods, rather than the consumers (Kraemer et al., 2007). Today, there are increasing calls for a change in thinking around how carbon should be accounted for and who is to be held responsible for the emissions – the producers or the consumers.

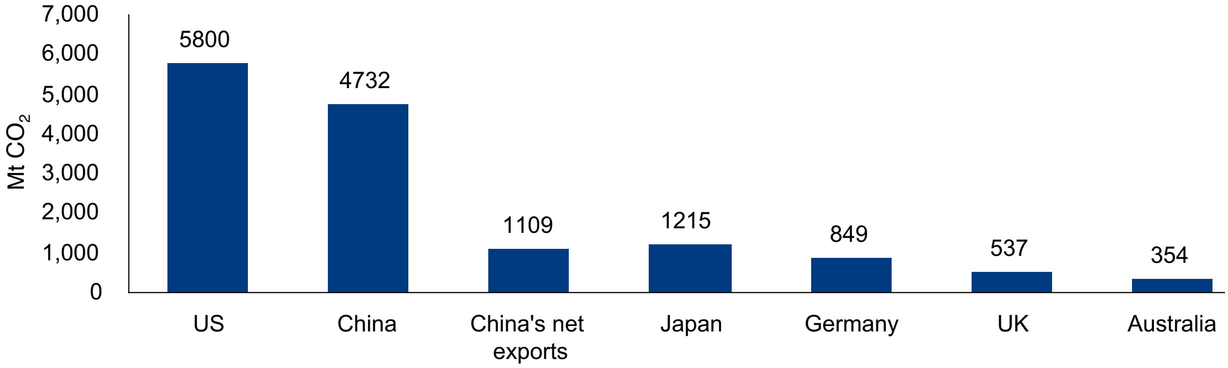
Taking consumption into account has the advantage of directly linking the environmental impact of the goods manufacturing process to the final user. However, it may also be more complex. In a world of integrated production, for instance, assessing the carbon accrued across a global supply chain would be difficult, especially if life-cycle considerations are taken into account. This differs from the relative simplicity of assessing the CO_2 emissions from the production process of primary materials, such as steel.

Despite the obvious methodological challenges, assessments are being undertaken to look at the impacts of trade and CO_2 in relation to China. For example, a study on trade with the US estimated that between 7% and 14% of China's total CO_2 emissions are caused by goods produced for the US. The study further found that if these goods had been made in the US, with higher energy efficiency standards and a different fuel mix, there would have been a decrease in emissions of around 720 million tonnes of CO_2 (Shui and Harris, 2006).

A WWF study concluded that Chinese emissions associated with exported goods amounted to 2,870mt of CO_2 per year (Lei et al., 2007). Another study, by the Tyndall Centre, put total emissions from exports at 1,490mt of CO_2 per year (equivalent to 40% of total Chinese CO_2 emissions). However, Chinese imports accounted for 380mt of CO_2, which created a net balance of around 1,100mt in 'exported' CO_2, equivalent to 23% of Chinese emissions (Wang and Watson, 2007b).

The importance of further research is widely recognized, and several groups are making assessments. The UK government is 'currently researching ways of calculating the embedded carbon in imported goods' (Hansard, 2007), as is the Chinese government. Perhaps more important than refining specific measures of embedded carbon is the need for country diplomacy and cooperation to recognize the

Figure 4.2: CO_2 emissions from China's net exports in 2004



Source: Wang and Watson (2007b).

complexity of global supply chains in allocating value addition and pollution to countries, and thus the increased premium of cooperation.

Increasing attention is focused on the carbon emissions from different energy-intensive sectors such as cement and iron and steel, each accounting for around 5% of global emissions. These sectors are aware of their responsibilities, and the steel industry has launched a task force to develop global sector specific approaches to CO_2 reduction in the post-Kyoto period (IISI, 2007), while the cement manufacturers have established an Emissions Reduction Task Force (CSI, 2007).

The notion of a sectoral approach to emissions reductions is gaining momentum in the global climate change discussions around the post-2012 framework. Such an approach is welcomed by some who feel that it would enable the better transfer and diffusion of technologies, and would broaden participation in the international regime (Hitomi, 2007). However, others fear that this approach will undermine attempts to reach a binding global emissions reduction target.

4.3 Forging closer links

4.3.1 Smarter trade

Scaling up China–EU trade allows the two sides to access each other's comparative advantages and help meet their respective energy and climate security goals, as mentioned earlier. There are several advantages to formalizing EU–China trade liberalization through a bilateral free trade agreement (FTA). Such accords not only establish a sense of permanence in trade relations that provides the commercial sector with long-term predictability; they also create institutions under which bilateral trade relations can be improved and conflicts resolved.

Naturally, these possibilities already exist at the multilateral level through the WTO. Bilateral agreements can, however, be more easily honed to the contexts and requirements of the parties involved than multilateral agreements, and are much simpler to negotiate. They also allow trade partners to experiment with novel arrangements which, if successful, can be incorporated at the multilateral level. With time of the essence to avoid locking in high-carbon energy systems in China and the EU, an FTA could be an attractive option. Moreover, lowering barriers to trade in low-carbon goods and climate-adaptation technologies could set an example for WTO negotiations on liberalizing environmental goods and services (see Box 4.1).

Box 4.1: Enhancing trade and investment in climate adaptation technologies

China's 2007 National Climate Change Programme, published by the National Development and Reform Commission, highlights the following needs for international cooperation on climate change technologies:[a]

- **Technology needs for observation and monitoring.** Examples include technologies for the manufacture of advanced observation equipment, high-resolution and high-precision satellite technology, technology for satellite data acquirement and remote-sensing, and high-performance climate change simulation techniques;
- **Technology needs for adaptation.** This includes technologies for water saving in agricultural, industrial and household sectors; flood control; fertilizers, disease and pest control in the agricultural sector; cultivation of fast-growing and high-efficiency forestry species; recovery and reconstruction of wetland, mangrove and coral reef ecosystems; and pre-warning systems for extreme weather events.

Economic, market and technical barriers were cited as the major hurdles to technology transfer for China in a 2006 report published by the United Nations Framework Convention on Climate Change.[b] Such barriers include a lack of financial resources; high investment costs; incompatible prices, subsidies and tariffs; and a lack of incentives. A number of measures are available to overcome these barriers and to facilitate trade and investment in climate adaptation technologies between Europe and China. These include foreign direct investment, joint ventures, licences, temporary relocation of employees to help build local technical capacity, and international development aid.

Liberalizing trade in environmental goods and services is a second way to improve access to technologies by removing tariff and non-tariff barriers. While the discussions over environmental goods and services have reached an impasse within the Doha Round of the WTO negotiations, China and the EU could find a way round this by developing a bilateral agreement to eliminate tariffs and non-tariff barriers on monitoring, evaluation and assessment equipment and adaptation technologies.

[a] NDRC (2007a), pp. 60–61.
[b] UNFCCC (2006), p. 25.

The current political climate is unlikely to result in a formal bilateral FTA on low-carbon goods and services. Both China and the EU have expressed reluctance about moving forward in this area. The latter, for example, has effectively ruled out the possibility of an FTA with China for the time being, choosing instead to pursue deals with the more protected and less intimidating markets of India, Korea and ASEAN (Rollo, 2007; Thomsen, 2007). The European Commission's 2006 external trade strategy identifies China as 'the single most important challenge for EU trade policy' (European Commission, 2006h).

Although there is increasing concern that the proliferation of FTAs will undermine the multilateral trading system, there has not yet been a single trade accord devoted to low-carbon products, or even to sustainable development. China and the EU would even have ready-made guidelines for where such talks might start, from the different lists of environmental goods discussed at APEC

(Asia-Pacific Economic Cooperation) and the OECD. The negotiations on a new bilateral Partnership and Cooperation Agreement would also offer substantial scope for cooperation on standards for low-carbon products, smoothing the way for trade. In addition to energy-efficient products, these could include key adaptation technologies discussed in Box 4.1.

A low-carbon FTA would face potential technical and legal obstacles. Rules of origin would need to be fine-tuned to prevent external products from circumventing the FTA while not inhibiting the export of value-added products. Policy-makers in China and the EU would also have to be mindful of the need for FTAs to comply with the requirements of Article XXIV of GATT. It is difficult to discern with certainty the applicability of Article XXIV, since its wording is ambiguous: it calls for liberalization of 'substantially all' trade but does not define what this means; and there has been no definitive interpretation of it arising out of a WTO dispute. However, an FTA on low-carbon goods ought to strive in substance to be trade-creating, not trade-diverting. In addition to strengthening economic ties between China and the EU, it could help reinforce global approaches towards a low-carbon economy. This would be particularly valuable on the cusp of the vast low-carbon transition necessary to meet climate and energy security objectives.

An FTA should not be taken completely off the table, and could be placed on the agenda as a potential longer-term objective. Concluding such an agreement would clearly require strong political commitments by both the EU and China at a time when trade relations are characterized by acrimonious disputes over dumping and trade barriers. There is, however, hope that an FTA centred on low-carbon products and technologies to improve adaptive capacity could be less politically charged, as it would respond to concerns about climate change and energy security, involve trade gains for both parties, and incorporate high quality standards. Section 4.3.5 discusses the way such pioneering liberalization could be tested in the context of a low-carbon economic zone (LCZ).

4.3.2 Standards

Simpler than negotiating an FTA – and potentially more significant than tariff cuts in terms of market growth and carbon reduction – would be cooperation between the EU and China on performance standards relating to low-carbon products in order to influence trade and investment patterns.

The EU, as well as individual member states, have established such standards for a variety of environmental and health policy purposes. Many of these relate to climate change, such as energy efficiency standards, motivated in part by the EU's binding Kyoto emissions targets. These standards are often linked to product-labelling requirements. In addition to their implicit impact of promoting trade, high performance standards could also be part of a bilateral bargain in which tariffs for products meeting those standards are lowered.

For China and the EU to enhance low-carbon trade or cooperate on technological development, it is important to define what these high performance standards would entail. To achieve this, China and the EU could align their standards, including potentially by jointly defining some new standards.

Different analyses have pointed to EU standards acting as obstacles to Chinese exports. The Commission has called for expanding dialogues aimed at 'facilitating trade and improving market access'. Joint working groups or similar mechanisms could produce common approaches towards the development of new standards, which would not only enhance their credibility but also encourage domestic industry

Table 4.1: EU–China minimum energy performance standards

Technology type	EU	China
Lamps		
CFLs, self-ballasted		M
CFLs, separate ballast		M
LFLs		M
HID lamps		U
High pressure sodium lamps		M
Metal halide lamps		U
Ballasts/transformers		
LFLs	M	M
CFLs, separate ballast	M	M
Metal halide		U
High pressure sodium		M
Backlighting		
Televisions		V

Source: Adapted from IEA (2006a), page 310.
M = Mandatory, U = Under development, V = Voluntary. As of end of 2005.
HID = High intensity discharge; LFLs = linear fluorescent lamps.

in both places to meet the standards. Joint efforts could be bilateral, or they could be in the context of multilateral efforts, such as the compact fluorescent lamps (CFL) standards initiative.

Table 4.1 shows the difference in the application of minimum energy performance standards in China and the EU on energy-efficient lighting. Different standards between the EU and China on lighting are believed to act as obstacles to trade.

Where standards already exist in either China or the EU, such as the various building or energy efficiency standards under the Eco-Design Directive, the challenge will be to develop an integrated approach to drive larger-scale production of goods that qualify. This could also entail technical assistance for exports to make it feasible for them to meet those standards.

From a practical standpoint, promoting higher standards may be more feasible in the case of foreign-owned companies, where the home state is also the importing one. High standards may also stand a better chance of being accepted when they coincide with other public policy objectives, such as reducing the over-capacity in China's steel industry.

In some instances, even the development of standards on a unilateral basis can enhance trade. For example, the EU is modifying the Eco-Design Directive to promote more energy-efficient light bulbs. This will make Chinese CFL light bulbs more attractive, so long as European anti-dumping duties are removed. Such standards must comply with the WTO Agreement on Technical Barriers to Trade, which permits environmental standards, but sets out disciplines aimed at ensuring that they do not become a pretext for trade protectionism. Aligning these standards between China and the EU could smooth the way for exports and help alleviate the problem of technical standards being used as barriers to trade.

4.3.3 Services liberalization

Liberalizing services relating to low-carbon and energy-efficient activities could enhance the scale and quality of such activities for both China and the EU. For example, both would benefit from scaling up services trade relating to climate change adaptation (e.g. waste management, water services or pollution control) as well as mitigation (e.g. building design or energy efficiency). Professional services with specialized knowledge on low-carbon technologies, accounting and production know-how, such as engineers, architects, project managers and energy efficiency experts, may also be needed. These kinds of services liberalization could be part of a bilateral undertaking or occur in the context of multilateral commitments at the WTO.

As with environmental goods, there are two approaches to identifying environmental services for the purpose of liberalization. One is to establish a list of such services, which is the approach taken by the OECD and APEC. The other is to link the services with a particular project, as proposed by India, and supported by China, in the WTO. Project-based services liberalization may be attractive if linked to Clean Development Mechanism projects in China or sectoral energy-related initiatives. In fact, services liberalization could help make such projects more attractive for investors. This is consistent with the Stern Review's recommendation to link private-sector carbon finance to policies and programmes rather than to individual cases (Stern Review, 2006), and to place it within a context of national, regional or sectoral objectives for emissions reduction.

4.3.4 Investment

Increased investment is needed in both the EU and China to meet low-carbon objectives, especially in the energy sector. The EU has long been a proponent of liberalizing foreign investment, and China has been a popular destination for European investors.

China is becoming increasingly selective about the type of foreign investment it seeks. It has used various incentives, such as tax exemptions, to attract foreign investors in certain sectors. Table 4.2 shows a range of options potentially available to encourage investment into low-carbon projects.

Local content and local ownership requirements are currently perceived as an obstacle to investment in China. For example, 70% local ownership is required for new wind-power projects, although the majority of firms in that sector are foreign-owned. Although it is perhaps understandable that a host government seeks to use strategies used by many countries in the past to ensure that it maximizes the developmental benefits from foreign investment, a large body of economists assert that such performance requirements can be counterproductive. Such requirements may also violate the WTO Agreement on Trade-Related Investment Measures (TRIMs). A more flexible approach might be more effective, basing approval for foreign investment projects not on a fixed percentage, but rather on a totality of instruments that promote innovative collaboration between the investor and local firms (Steenblik, 2005). The LCZs outlined in section 4.3.5 could be a potential arena for testing policies to attract low-carbon foreign investments.

Other challenges to increasing investment over the long term relate to policy uncertainty, insufficient demand, pricing inflexibility, foreign ownership regulations, and high transaction costs. The

Table 4.2: Investment incentives for low-carbon projects

Fiscal incentives	Reductions in standard corporation tax for companies involved in low-carbon projects Tax holidays for low-carbon projects Accelerated depreciation allowances Duty exemptions for low-carbon projects Export tax exemptions for manufacture of low-carbon goods Reduced taxes for expatriates involved in low-carbon projects
Financial incentives	Investment grants for low-carbon projects Subsidized credits for low-carbon projects Credit guarantees for low-carbon projects
Other incentives	Subsidized service fees Subsidized designated infrastructure associated with low-carbon projects Preferential access to government contracts for low-carbon projects Closure of market to further entry or granting of monopoly rights for low-carbon projects Protection from import competition for manufacturing of low-carbon goods Geographical incentives – incentives offer to locate in certain areas

experience varies from sector to sector. Accordingly, the facilitation of foreign investment between the EU and China may need to be stepwise, driven by the identification of specific obstacles and the instruments to overcome them. Such instruments range from export credit and insurance programmes to subsidies for research and development and the facilitation of venture capital.

Formalizing investment arrangements between the EU and China would be complicated. Investment agreements are normally concluded by EU member states individually, rather than by the Commission, although the EU–ACP (African, Caribbean and Pacific) Economic Partnership Agreements appear to be an exception to this. By the same token, investment policies in both the EU and China would need to respect already existing agreements between China and many EU member states.

Box 4.2: Features of an EU–China bilateral investment agreement on efficient and clean energy projects

- Requiring environmental and social impact assessments prior to establishment
- Continuing commitment to high environmental standards after establishment
- Promotion of collaboration between foreign and local partners in research and development
- Host state obligations, such as procedural fairness and compensation in cases of expropriation
- Home state obligations, such as technical assistance and trade facilitation
- Dispute prevention and settlement procedures that are transparent, participatory, and designed to enables constructive solutions.

Figure 4.3: China's inward foreign investment by origin (US$100m)

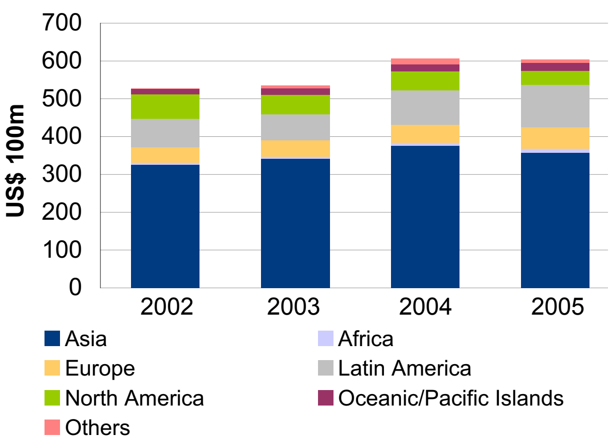
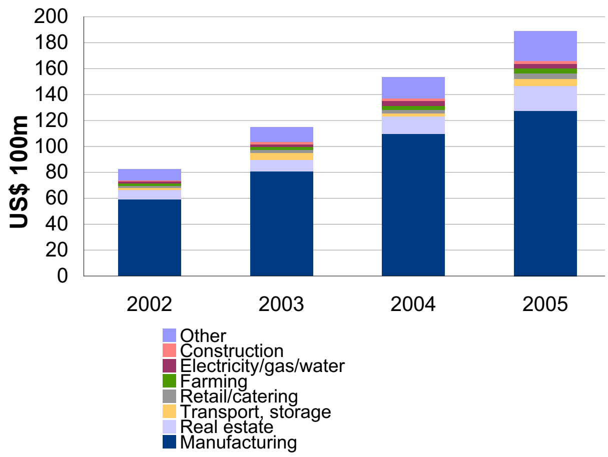


Figure 4.4: China's inward foreign investment by type (US$100m)



Source: China Statistical Yearbook.

Figure 4.5: China's outward foreign investment by destination (US$100m)

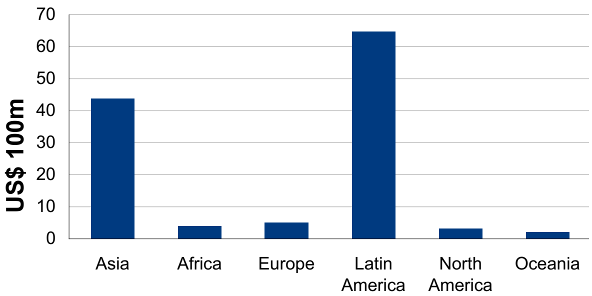
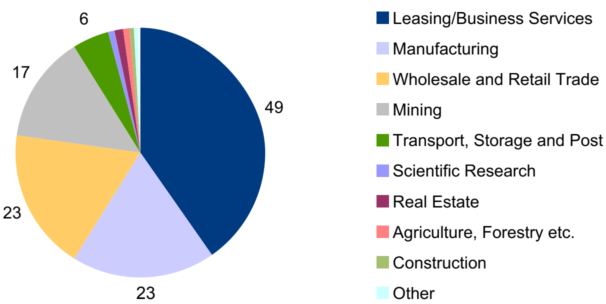


Figure 4.6: China's outward foreign investment by type (US$100m)



Source: China Statistical Yearbook.

Were the EU and China to consider concluding a specific bilateral investment agreement on low-carbon projects, they would need to decide on the appropriate balance of rights and responsibilities for investors (Peterson, 2007). This balance would seek to encourage investment that met low-carbon policy objectives. Box 4.2 outlines the potential elements of a bilateral investment agreement between the EU and China.

Initiatives to enhance low-carbon trade and investment between the EU and China will not face an easy road. But cooperation would serve the fundamental interests of both far better than the mistrust, irritation and fear that are lamentably in evidence today. This is perfectly illustrated by the perverse example of EU anti-dumping duties on emissions-saving energy-efficient light bulbs produced by a Chinese subsidiary of Philips.

4.3.5 Low-carbon economic zones (LCZs)

While the imperative for a sustainable energy future is clear, the transition is unlikely to be linear. Many policy-makers and businesses remain thwarted by the immediate costs of economic adjustment, despite the potential of lucrative new opportunities powered by this transition. As mentioned earlier in this report (see Chapter 1), markets for low-carbon energy products are likely to be worth at least $500 billion per year by 2050, and perhaps much more, according to the Stern Review (2006: Executive Summary). China alone will need $25 billion per year for investment in low-carbon technologies (Zhuang, 2007). Second, at a technical level, innovative products and services need time to be developed and refined prior to their adoption and diffusion. Key technologies and practices may come to commercial maturation at different times, making it difficult for policy-makers and businesses to commit to long-term investments. Third, even though there are already pilot projects and facilities and even cities to demonstrate specific or sets of technologies across the world, the effects of large-scale adoption of these new methods of production remain unknown.

In the early 1980s, the Chinese government 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 – were first established in Guangdong, Fujian, and Hainan provinces, most famously in Shenzhen. These were later expanded to larger geographical areas, paving the way for two decades of spectacular economic growth. In general, the term 'SEZ' covers a broad range of more specific zone types, including Free Trade Zones, Export Processing Zones, Free Zones, Industrial Estates, Free Ports, Urban Enterprise Zones and others.

Following the successes of the SEZs, policy-makers may wish to consider establishing 'low-carbon economic zones' in China. Just as the SEZs functioned as laboratories for liberal economic practices, these LCZs could become testing grounds for the large-sale economic transformation required for a low-carbon future. These zones at the regional or provincial level could pioneer on a large scale the demonstration of the transition to an efficient, low-carbon economy.

The key to the zones' success would be clear and active regional political leadership, endorsed at the national level, to set the regulatory and public investment framework to facilitate, support and accelerate transformative private investment.

The benefits of establishing LCZs are foreseen to be manifold. First, like the SEZs, they would provide a focus for attracting qualitative foreign investments away from simple processing, assembly and low-level manufacturing towards research and development, high-end design, modern logistics and other new areas. This is consistent with the vision of science-based development set out by the Chinese leaders at the 17th Party Congress in October 2007. This could apply to both light and heavy industries as well as both small- and larger-scale energy production.

Second, in addition to acting as testing grounds for new products, services and infrastructure, LCZs could become areas in which low-carbon technologies would thrive. Previously small-scale deployment could be scaled up, demonstrating the technologies' economic and environmental viability. This could also strengthen exports of key technologies and practices.

Third, these LCZs could become focal points for concessionary loans or aid efforts from public entities such as regional development banks or critical international partners such as the EU. European governments have diverse cooperation programmes with China to date, which are often ill-coordinated among member states. These investments often fail to make a transformative impact on the scale necessary to influence the pathway of China's development. To improve the impact of bilateral cooperation, European countries could agree to focus their assistance and cooperation on energy and climate change issues in these zones, so as to provide scale impacts and reduce transaction costs, and in particular to promote exchange of know-how and professional services in critical areas.

Fourth, these LCZs could enable experimentation on enabling conditions and progressive governance framework towards in the development of low-carbon economies. The range of push and pull mechanisms described in Chapter 3 of this report could serve as the starting point.

Fifth, these LCZs could serve as centres of excellence on climate change impacts and adaptation, where expertise on climate change impacts and understanding of the necessary technologies needed to adapt could be brought together and translated into joint ventures and policy solutions in order to boost China's adaptive capacity. (See Box 4.3)

More specific undertakings within these LCZs could include:

- Large-scale development, demonstration and manufacturing of state-of-the-art energy-efficient and low-carbon goods and services;
- Widespread construction of low- or zero-carbon new towns and infrastructure;
- Application of alternative transport modes over large areas and encompassing urban and rural requirements;
- Energy-efficient production methods for heavy industries;
- Testing of the necessary adaptation to climatic changes;
- Incubators for new technology companies, joint ventures and innovative practices.

Some preliminary policy options for these low-carbon economic zones could include:

- A clear regulatory structure aligned with the best international standards and regulations for driving the transition to an efficient, low-carbon economy;
- Incentives to encourage the right kind of foreign investment through financing incentives, including those that will enable the 'bundling' of financing for SMEs from larger financial institutions;

Box 4.3: Centres of excellence for climate adaptation

An additional role of the 'low-carbon zones' will be to establish centres of excellence on climate change impacts and adaptation. The LCZs will bring together Chinese and European experts from the fields of science, social science, technology and policy to undertake integrated research on climate impacts, vulnerability and adaptive capacities. The centres will enable expertise from different disciplines to be pooled in order to improve the adaptation planning process.

For example, both Europe and China have identified the need to more fully incorporate climate change adaptation planning into existing policies. The European Commission, in its 2007 Green Paper on Climate Change and Adaptation, has pinpointed European policies where climate change needs to be fully incorporated, ranging from the Common Agricultural Policy and the Water Framework Directive to the Sustainable Consumption and Production Plan and the Common Foreign and Security Policy.[a] China, in its National Climate Change Programme, has identified areas where climate change can be incorporated into other policy areas, including the Agriculture Law, Forest Law and the Marine Environment Protection Law.[b]

The aim of the centres of excellence will be to connect the science on climate change impacts and adaptation with the policy, in order to develop a range of options for government decision-makers which are underpinned by scientific, socio-economic and political analysis.

[a] European Commisison (2007a).
[b] NDRC (2007a).

- Incentives to promote and support inward investment in low-carbon products and services, including research and development;
- Facilitating higher value-added trade through removing barriers to trade in low-carbon goods and services such as zero tariffs for low-carbon goods and/or low-carbon services trade liberalization;
- Joint research and development programmes based in centres of excellence for low-carbon technologies, supported by public and private investment;
- Public investments in the large-scale demonstration of commercial technologies in return for licensing of key technologies for diffusion.

4.4 Looking forward

Trade and investment are important tools for China and the EU to generate win-win options in the shift to the low-carbon economy. Scaling up trade and investment in low-carbon goods and services will help meet energy and climate security goals, provided that the two can put aside their regular spats on tariffs and deficits.

This chapter has outlined several potential instruments to encourage low-carbon trade and investment, from targeted tariff cuts to cooperative standard-setting and investment incentives. One bold initiative that the Chinese government could consider would be to establish 'low-carbon economic zones' (discussed in section 4.3.5). Inspired by the 'special economic zones' in which China introduced liberal economic laws to such spectacular effect a generation ago, LCZs would be the testing grounds for policies aimed at promoting the economic transformation necessary for a low-carbon future.

The LCZs' focus on attracting investment in research and high-end manufacturing is consistent with the Chinese leadership's desire to shift away from simple processing and assembly, as recently articulated by 17th Party Congress in October 2007. LCZs could be to China's next industrial revolution what Shenzhen was to the current one – and a powerful demonstration of the viability of the low-carbon economy.

5

Mapping the Pathways: Strengthening EU–China Cooperation on Energy and Climate Security

To meet the twin challenges of preserving energy and climate security, the global energy sector will require significant innovation, new investment and restructuring over the next few decades. These challenges will particularly affect countries and regions that are large and expanding fossil fuel energy consumers and importers. With growing economic interdependence and shared risks from catastrophic climate change, it is in the interest of major economies to increase the scale and depth of cooperation in tackling these challenges. The power of globalization can be harnessed to assist in the drive to achieve an efficient, secure and low-carbon economy by:

- Aligning political opportunities;
- Capturing the economies of scale of production;
- Sharing the risk of developing new technologies; and
- Realizing the opportunities of combined markets and common standards.

Europe and China, as the world's largest market and the world's fastest-growing economy respectively, are ideally paced to pioneer such innovative collaboration. By taking joint leadership they will be able to define global standards for an efficient and low-carbon economy, and position themselves to benefit from the economic and technological opportunities it presents.

A transformative agenda for China and Europe

Today, there are great opportunities to forge a high-level, ambitious plan of action on energy and climate security. This report has assessed the common interests and interdependencies between Europe and China, and analysed opportunities for the two powers to work together to create added value in pursuit of their critical interests.

Opportunities for cooperation at both national and provincial/state levels are based around five shared strategic priorities:

1. **Avoiding lock-in to high-carbon and inefficient technologies** as both Europe and China will invest trillions of euros in the coming decades in long-lived power-sector, infrastructure and building investment.
2. **Reducing dependency on declining liquid fossil fuels** through combined efforts on low-carbon and sustainable alternative energy sources and modes, and increased efficiency standards.
3. **Improving the resilience of China and Europe to respond to the impacts of climate change**, by building up their strategic capability in preparation for future water stress, shifting agricultural zones, loss of ecosystem services and extreme weather events.

4. **Leading the technology race** by constructing linked innovation systems in Europe and China and placing innovation at the heart of energy policy, and energy policy at the heart of innovation.

5. **Capturing gains through trade and investment** by liberating and harnessing the market power of both regions to lower costs and widen markets for new technologies, and to set global standards for the new efficient and low-carbon energy economy.

Near-term opportunities

1. Building 'low-carbon economic zones' or 'bilateral efficient and clean economy transformation zones'. Just as the Special Economic Zones (SEZs) functioned as laboratories for liberal economic practices, the low-carbon economic zones (LCZs) could become testing grounds for the large-scale economic transformation required to achieve a low-carbon future in China. These zones at the regional or provincial level could pioneer on a large scale the demonstration of the transition to an efficient, low-carbon economy. The key to the zones' success would be clear and active regional political leadership, endorsed at the national level, to set the regulatory and public investment framework to facilitate, support and accelerate transformative private investment. Initially two zones could be established, one in the more prosperous east and one in the less developed west, to test the different environmental and industrial conditions and requirements. These zones could become the seedbed for mainstreaming energy and carbon accountancy into all aspects of economic life within the zones, facilitating cross-fertilization of ideas and practices. They could also demonstrate to other regions and countries the viability of the low-carbon economy.

Europe has diverse cooperation programmes with China, but these are often uncoordinated and fail to make a transformative impact on the scale of Chinese development. To improve the impact of bilateral cooperation, European countries could agree to focus their assistance and cooperation on energy and climate change issues in these zones, so as to provide scale impacts and reduce transaction costs, and in particular to promote exchange of know-how and professional services in critical areas. These low-carbon economic zones could also become established centres of excellence on climate change impacts and adaptation, where expertise on such impacts and understanding of the necessary technologies could be brought together and translated into joint ventures and policy solutions in order to build China's adaptive capacity.

2. Setting world-class standards for energy-efficient goods. Working together, China and Europe could set *de facto* global standards for energy efficiency. Over the coming years the European Union will set progressively tighter energy efficiency standards for major energy-using goods (e.g. electric motors, air conditioners) under the Eco-design Directive. China is a major supplier of these goods to European markets, and also has a strong interest in increasing its own efficiency in these areas. The EU could immediately establish a consultative committee with relevant Chinese industries to participate in the standard-setting process, allowing them to prepare for the new standards and suggest improvements. In parallel, the EU and China could begin intergovernmental discussions on harmonization of these product standards between their markets so as to reduce costs and increase market size.

3. Making coal more sustainable. Both the EU and China will depend on coal in the future. Both have much to gain from ensuring this is compatible with their environmental, health and safety objectives in coal production and consumption. Collaboration on these issues to date has been under-resourced and has failed to cover the full coal life-cycle. Current activities should be strengthened and expanded to deliver an agreed set of benchmarks and practices for improving efficiency and reducing the environmental impacts, based on joint learning from experience in the EU and China. This programme should include:

a. *Increasing life-cycle efficiency*: Strengthened cooperation on: improvements in mining and processing of coal resources; improved emissions management and control; greater recovery of coal-mining and coal bed methane; renovation and modernization of existing coal-fired power stations; development of higher efficiency pulverized coal and IGCC coal stations; electricity grid optimization and tri-generation (heating and cooling) power plants.

b. *Reducing the sustainable development impacts of coal*: Development of agreed targets and benchmarks to reduce the environmental and health impact of coal, across the whole of the fuel cycle and applications.

c. *Strengthening cooperation on carbon capture and storage*:

- Generating and agreeing upon a definition of 'capture ready' plants. The definition should address not only *in situ* engineering and financing concerns, but the availability of carbon disposal sites and impacts on the electricity grids.
- Enhancing the existing nZEC agreement by agreeing to develop a further number of commercial-size CCS demonstration facilities to be deployed in China, in parallel with those being envisioned under the EU CCS demonstration programme.

4. Establishing an EU–China ultra-efficiency building research platform. China and Europe both face daunting challenges in improving the energy efficiency of buildings, especially in regions with high cooling loads. Both face the critical challenge of scaling up existing experience gained in demonstration eco-house, town and city developments in a way that makes feasible a target of all new buildings being energy-neutral within a decade. Key to achieving this target is the development of approaches which reduce the enforcement burden of delivering these standards by reforming industry practice. Supported by the EU's 7th Framework Programme, China and the EU should establish an ultra-efficiency building research platform, involving industry, research institutes and government to drive rapid progress in new materials, construction techniques, business approaches, supply chain organization and standards, which will enable mass diffusion of energy efficiency technologies; greater use of prefabrication would be one example.

Joint study areas to develop future opportunities

5. Exploring an EU–China low-carbon free trade agreement. The EU and China would both benefit from increased trade in high-efficiency and low-carbon products. A joint China–EU working group could be established to develop a framework for such an agreement. This would cover: core principles for trade in low-carbon goods, including the use of trade-related environmental instruments; framework standards for defining low-carbon goods, especially for new and innovative products, as the first step in defining the scope of an EU–China free trade agreement; and measures to facilitate trade in low-carbon goods, such as mutual standards recognition, enhanced certification and testing regimes and compatible labelling. The group would assess the opportunity to remove all tariff barriers to trade in areas such as energy-efficient electrical goods and on climate monitoring, evaluation and assessment equipment and adaptation technologies. By promoting a liberal approach to developing low-carbon markets, the EU and China would establish a global precedent for the treatment of zero-emission renewable energy, energy efficiency and climate adaptation technologies which could be extended to other markets.

6. Pioneering sectoral approaches to climate change. The potential competitiveness impacts of climate change policies on a small number of energy-intensive sectors (cement, aluminium, iron and steel) have prompted interest in agreeing global sectoral standards in these areas. Such agreements would aim to avoid the relocation of production as a result of climate change policies by improving the efficiency of production around energy-intensive products such as cement through sectoral standards and benchmarks. Europe and China should agree immediately to develop a model sectoral agreement, starting with the cement sector, which would help drive efficiency and reduced emissions in both regions. This agreement would contribute to global discussions and would provide important practical experience for the potential extension of the existing Clean Development Mechanism to a programmatic or sectoral approach.

7. Tackling global supply constraints on renewable energy. Both China and the EU have very ambitious targets on deploying renewable energy technology over the next decade. However, the affordability and feasibility of reaching these targets is being undermined by cost increases in basic equipment, driven by supply chain shortages and material cost increases. As the two largest consumers of renewable technologies, China and the EU should immediately establish a high-level joint commission to:

a. *Tackle production bottlenecks*: review the engineering, manufacturing, distribution and other constraints that the escalating Chinese and EU programmes could create, and recommend immediate measures to reduce supply chain bottlenecks and upward pressure on prices.

b. *Facilitate advanced investment*: recommend innovative approaches to encourage joint ventures, technology licensing and increased investment between the two regions so as to increase cooperation in technological development and develop economies of scale.

Medium-term opportunities

8. Reducing dependency on imported oil. China and Europe both face increasing dependency on imported oil from unstable regions, and are seeing carbon emissions from the transport sector rise at dramatic rates, cancelling out efficiency gains in other areas. In China more than 80% of vehicles are manufactured through joint venture companies, many of which have European partners. This offers an opportunity to harmonize the growing number of energy efficiency and pollution standards. Changing either country's liquid fuel transport infrastructure will take decades, and it will reduce transition costs if immediate cooperation is undertaken to address these issues jointly by:

- cooperating to introduce incentives for ultra-efficient vehicles by aligning average vehicle efficiency standards and agreeing a technology-forcing joint market share target for ultra-efficient vehicles;
- jointly developing standards for alternative transport fuels, e.g. sustainable low-carbon biofuels;
- launching a joint initiative, linked with the low-carbon economic zones, on modal shifts towards mass rapid transit systems in cities.

9. Developing a low-carbon investment regime. Europe and China both wish to see the rapid diffusion of efficient and low-carbon technologies globally and also have industrial and innovation policies to promote the competitiveness of their domestic businesses in these sectors. They also have a need to improve foreign direct investment and joint ventures in adaptation technologies. There are intrinsic tensions between these policy objectives over the treatment of inward investment and services, access to research programmes, government procurement and intellectual property rights. The effectiveness of expanded global carbon markets in addressing climate change will be hampered by any economic restrictions in these areas, which will raise costs and deter inward investors. Europe and China should explore the potential for a special reciprocal investment agreement which relaxes Chinese restrictions on establishment, foreign ownership or local content requirements in return for access to carbon finance and enhanced technology cooperation, including fair use of patented technologies at reasonable prices.

10. Increasing efficient and low-carbon technology cooperation. Private-sector cooperation on research and development between Europe and China has grown far faster than public-sector cooperation. Given mutual interests in the energy and climate security area, there are many opportunities to increase such cooperation. These include:

a. A China–EU climate technologies prize fund to promote innovation in energy-efficient and environmental products. This fund could function as a patent pool and/or a repository for cross-licensing of technologies.

b. The interaction between technical standards, intellectual property rights and legal enforcement capacity needs to be addressed directly as part of the necessary framework for low-carbon innovation and diffusion. The EU and China could agree on practical steps to address structural issues in low-carbon technology cooperation around intellectual property rights – with a focus on practical mechanisms such as conditional or compulsory licensing, fair use rights, and guidelines for standardization – to enhance the diffusion of key technologies.

c. China and the EU could consider requiring compulsory licensing as a precondition for public-sector assistance in deploying key climate technologies at scale. For example, a condition for state funding of CCS could be a requirement to enter into joint ventures or issue licences in third countries that are party to EU clean coal agreements.

ANNEX 1

Chinese Energy Policy

China adopts Five-Year Plans that outline anticipated developmental paths for a wide range of sectors. The 11th Five-Year Plan covers the period 2006–10, and it notes the achievements made in the development of the energy sector through meeting the demands of the economy and social development. This should not be underestimated as a 50% increase in energy consumption in China has been recorded since the 10th Five-Year Plan. The 11th plan also states that 'China's energy industry is now at a new historical starting point' (NDRC, 2007b).

The plan envisages that energy demand will grow by 4% per year until 2010, representing a significant reduction from the growth rates for 2005 and 2006.

Energy efficiency is a priority, and the plan foresees a 20% increase in energy efficiency over the five-year period, with a further 40% increase by 2020. This will require the enforcement of energy-saving and environmental protection measures, the development of high-tech industry, and shifting more economic activity to the less energy-intensive services sector. The plan includes specific energy efficiency targets for the large energy users – metal, construction and the railways – as well as demand-side improvements for household and office equipment.

The plan also calls for improvements in the dominant coal sector, with supply-side efficiency targets to be achieved by the introduction of larger and more efficient coal stations, including IGCC (Integrated Gasification Combined Cycle) plants, to meet rising demand and to compensate for the closure of the less efficient plants. Similarly, it provides for accelerating the construction of larger mines along with pithead power stations that would obviate the need to transport coal (which accounts for up to 50% of all railway traffic). Further efforts are proposed to increase the movement of coal by ship. Currently coal provides 66% of the country's energy, but the objective is to reduce this to below 60% by 2020.

Pilot plans are also being developed for the use of CCS (carbon capture and storage), with a demonstration plant being built by GreenGen scheduled to start operation in 2015.

Oil and gas are imported in ever-increasing volumes as domestic reserves are unable to keep up with rising demand. To facilitate this, in the longer term, it is envisaged that further pipelines will be built, in particular to run from the west to the east and from the northeast to the south. In addition more ports are to be developed to import liquid natural gas and oil. To enhance oil security it is envisaged that China will conform to the International Energy Agency's oil stock reserve requirement in 2020.

Plans are being developed to diversify liquid transport fuels, both through the development of coal-to-liquids technology and through the greater use of biofuels. Although a small tentative target for ethanol has been suggested by 2010, more widespread development of this sector is not expected until after 2010, as with the coal-to-liquids sector.

The rise in biofuel production worldwide has caused a surge in corn prices. Wheat prices have also soared, as farmers shift to corn plantations. An increasing concern with food security led the

State Council to reject the Five-Year Plan on biofuels development. The National Development and Reform Commission (NDRC) suspended all new grain-based biofuel projects (although it did not ban new investment in biodiesel projects). According to an analysis of Chinese policy by the United States Department of Agriculture, although the old production target was scrapped, no new objectives have been set. The report states that 'a realistic goal given the new constraints on the sector has been suggested to be between 3 and 4 million MT by the 2010 target' (USDA, 2006, p. 3).

Hydropower is a major energy source in China. The plan envisages expanding the sector, both small- and large-scale. Longer-term plans have been put forward to see 200–240 GW of large hydro by 2020. This will require an annual increase of 7–9 GW, with an additional 60–70 GW provided by smaller units. Hydropower is the major part of the plans to boost the share of renewable energy by up to 15% by 2020 (excluding traditional biomass). The use of wind power is also expected to increase significantly, with up to 20 GW by 2020, as is the increased use of biomass for electricity production. Traditional biomass is already a significant contributor to heat generation.

The use of nuclear power is expected to increase significantly in the medium term, with up to 40 GW to be operational by 2020. This will require a significant increase from the current level of 8 GW. The Chinese government is also a partner in the international programmes for the development of the next generation of fission and fusion research.

Sectoral legislation will be introduced and passed, including on coal, electricity and energy, and energy conservation. It is envisaged that the power market regulation system will be improved and a fair competition market environment be created. Further plans are being developed to 'unbundle' and separate generation from the power grids, along with the introduction of regional power markets. This will be accompanied by pilot projects on direct trading between large users and power generation companies, and by reform of the power tariff. Market measures to assist the introduction of renewables will also be developed.

ANNEX 2

EU Energy Policy

The European Union's 2007 spring summit was a milestone for the development of a common energy policy. The headline agreements were that the EU should adopt binding or indicative targets that would see a 20% increase in energy efficiency by 2020, along with a 20% reduction in greenhouse gas emissions (30% if there was an international agreement). These would be accompanied by a requirement for 20% of energy to come from renewable sources, including a 10% biofuel requirement for liquid transport fuels.

Also important was the summit's agreement to directly link future EU energy policy with action to stop climate change, and to give the EU a much greater potential role in addressing energy in external affairs. These measures, along with others addressing research, trans-European networks, nuclear power and fossil fuels, were described by European Commission President José Manuel Barroso as 'a step change for the European Union. Energy policy was a core area at the start of the European project. We must now return it to centre stage.' The Energy Commissioner Andris Piebalgs hailed the proposals as part of 'a new industrial revolution' (European Commission, 2007c).

Some of the European targets agreed by the heads of government have still to be defined for member states, with Commission proposals expected in January 2008. They will then need to be agreed and transposed into national legislation, a process which will take a few years.

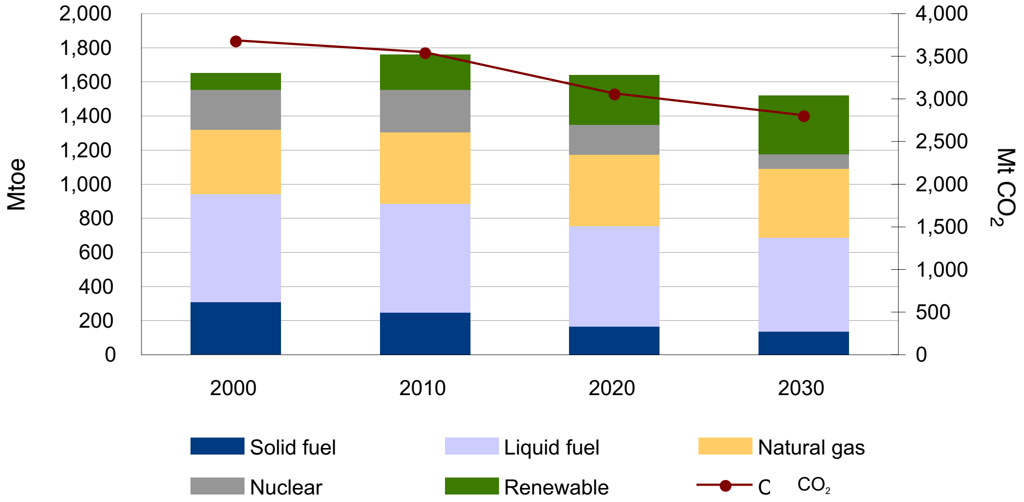
Despite the claim by the Commission and EU member states that energy efficiency should be 'a if not the' priority, the efficiency target is only indicative, and stems from the October 2006 Energy Efficiency Action Plan. If implemented by 2020, a 20% increase in energy efficiency would reduce the EU's overall energy consumption by 13%, while saving €100 billion and 780 billion tonnes of CO_2 each year. This is a truly win-win scenario. Moreover, it should be seen only as a first step: even using existing technology, a 40% increase in efficiency is possible.

In 2004, renewable energy accounted for 6% of EU energy consumption (13% of electricity). The summit proposed that the 20% of energy from renewable energy sources should be a binding target. This is not a common target for each member state, as both resources and the extent to which renewables are already used vary significantly – Austria and Sweden, for instance, already exceed the 20% target. In January 2008 the European Commission will propose targets for each member state, which will then allocate sector-specific (electricity, transport, heat and cooling) targets. The EU, other than for biofuels (for which the 10% target has been proposed) will not set sector targets. However, the European Parliament has called for EU-wide sector targets in its report on the draft legislation.

If the energy efficiency and renewable energy objectives were achieved, the EU would already exceed its current greenhouse gas reduction target, as these policy measures could lead to a 24% reduction in CO_2 (see Figure A2.1).

Notably, under this scenario the role of nuclear power declines significantly, with a 23% decline by 2020 and a 59% decline by 2030.

Figure A2.1: The EU's 20% by 2020 renewable and energy efficiency targets



Source: European Commission (2006i), Table 1-4.1.

The European Commission has emphasized that if fossil fuels are to be used in the future, emissions from their use will have to be reduced. As part of this plan it has put forward the objective of having 12 large-scale carbon capture and storage demonstration facilities in operation by 2015 (either in the EU or elsewhere with EU cooperation). Furthermore, the Commission believes that by 2020 all new coal-fired power stations should, *if possible*, be built with CCS. Existing plants should then be progressively retrofitted. The Commission will substantially increase funding for energy R&D, making the demonstration of sustainable fossil fuels technologies one of the priorities for 2007–13.

As for natural gas, the Commission is calling for member states to diversify sources, to set up hubs in central Europe and to make better use of strategic storage, while also developing liquefied natural gas (LNG) terminals.

EU oil policy calls for the development of alternative fuels, in particular biofuels; exploiting energy efficiency; more effective reporting on oil stocks; deepening relations with key energy producing and transit countries; and enhancing relations with other major energy consumers.

In order to help member states meet the demands of the 2003 Biofuels Directive, which set targets for biofuel use and encouraged the substitution of petrol and diesel for transport, the EU in 2006 adopted a Strategy for Biofuels. However, an assessment of the 2003 directive carried out in 2007 (European Commission, 2007f) showed that the targets for the end of the decade were unlikely to be met. Member states have adopted a variety of production-based and consumption-based incentives to encourage the use of biofuels.

Owing to strong divisions within member states, the European Commission is formally 'agnostic' on the issue of nuclear power. But it does actively support research on nuclear technologies. Nuclear fusion receives the largest share of any energy source in EU research and development budgets.

The Commission and some individual EU member states are partners in international technology development for future nuclear research, the ITER for fusion and for the next design series of fission nuclear power. In 2007, the Commission set up a Sustainable Nuclear Energy Technology Platform (SNETP) to address concerns about the environmental sustainability and economic competitiveness of the industry.

The EU is using a separate Strategic Energy Technology Platform to further harmonize Europe's energy research in order to 'address the mismatch between the sheer magnitude of the challenges and the underlying research and innovation effort' (European Commission, 2007g, p. 6).

The EU has significantly increased its annual energy and nuclear research and development budgets significantly, from €574 million for 2002–06 to €886 million over the next five years.

A key objective for the EU's spring summit in 2008 will be for member states to agree on the role of technology in shaping EU energy policy and on the focusing of existing and novel instruments.

The EU is also planning to introduce further unbundling measures for the energy and gas market and to remove the direct linkage between the grid operators and the generators/retailers. Additional measures are being proposed to improve regional coordination of the energy markets and to increase the powers of regulators when addressing cross-border issues.

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