China Council for International Cooperation on Environment and Development (CCICED)

China's Low Carbon Industrialization Strategy

CCICED Task Force Report

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SUMMARY

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High and volatile resource prices as well as climate-related concerns have called into question the carbon-dependent development model across the world. This, together with the resurgence of interest in manufacturing in developed countries, has changed the global competition landscape for emerging economies. The imperative of delivering alternative growth strategies is clearer than ever.

A Low Carbon Industrialization Strategy (LCIS) can address many of the critical challenges facing China – from employment, resource scarcities, energy security and climate change to demographic pressures. The LCIS will drive an evolution from the current investment-driven growth strategy in China towards innovation-led development.

Low carbon industrialization will play a central and decisive role in achieving the national carbon intensity target for 2020. Of the needed reduction in carbon intensity, 95% will come from action in the industrial sectors: 42% from energy efficiency, 29% from structural change in the energy industry, 21% from changes in industrial structure and 3% from more efficient use of resources.

In the short to medium term, seven traditional industrial sectors – electricity, steel, building materials, petrochemicals, non-ferrous metals, textiles and paper and pulp – can avoid 16.08 $GtCO_2$ between 2005 and 2020 through setting sectoral targets. There should be specific energy-intensity and conservation targets for each of these sectors.

Seven emerging pillar industries also have a key role to play in catalysing low carbon industrialization in China: energy conservation and environment protection; low carbon energy technologies; low carbon energy vehicles; biotechnology; information technology; advanced materials; and equipment manufacturing. These provide support – whether in terms of technology or systems integration – to the movement of traditional sectors towards lower carbon growth. For example, by 2020 low carbon energy can help avoid emissions of 1.8 $GtCO_2$. China has already succeeded in industrializing and exporting some of the relevant technologies, contributing to a price reduction for renewable technologies in the global market.

Innovation lies at the heart of any large-scale industrial transformation and is critical to delivering sustainable growth to 2020 and beyond. As well as investments in research and development (R&D), a comprehensive upgrade of the whole innovation eco-system is needed, with active hubs facilitating exchanges between different sectors, between public and private actors, and between China and the rest of the world.

The government can send strong and stable signals to the market through regulations and standard-setting for industries (such as Japan's Top-Runner Program). Enforcement of regulation is key, as is meeting the need for monitoring and auditing. These measures should be combined with market-based mechanisms including price reform, carbon taxation and trade, as well as innovative finance to improve efficiency, internalize externalities and minimize costs.

Box 0-1: The Low Carbon Industrialization Strategy Task Force

This report was produced by the Low Carbon Industrialization Strategy (LCIS) Task Force of the China Council for International Cooperation on Environment and Development (CCICED).

The goal of the LCIS Task Force, established in 2010, is to provide a 10-year plan to promote the transition to low carbon industrialization (LCI) in China by 2020, together with a longer-term industrial vision for the country. These goals are designed to support China's scientific development strategy, help to optimize its existing industrial base, promote the development of emerging industries and reinforce wider economic transformation towards low carbon production systems. The Task Force has also considered the regional strategy for and implications of LCI, reflecting the range of development characteristics and needs across China.

In parallel with the LCIS Task Force, a separate CCICED Task Force on the Green Economy (GE) has developed a strategic framework and priorities for greening the economy at the national policy level in China. The GE Task Force has a wider scope, assessing environmental opportunities and challenges throughout the economy, while the LCIS Task Force focuses on the role of industry in delivering a low carbon economy. The conclusions of the LCIS Task Force (see Chapter 5) are highly consistent with the headline messages from the GE Task Force: China requires a fundamental change in values and perspectives on wealth and how it is created; a transformation of the role of the government so that it can lead and facilitate a well-functioning market; and a range of mechanisms, capacities and skills to support innovation and encourage green production, investment and consumption.

The LCIS Task Force builds on a previous Task Force on China's Low Carbon Economy (LCE), which reported in 2009 and proposed that, amongst other recommendations, China should adopt carbon intensity improvement targets. It also highlighted the vital role of China's industry in meeting its LCE goals.

Many of China's overall goals for 2020, such as its target to improve the carbon intensity of the economy by 40–45% relative to 2005, were set out in or prior to the 12th Five Year Plan (FYP). The LCIS Task Force is focused on the contribution of individual sectors – and their interactions – in the delivery of these goals, rather than revisiting the overall emissions and energy pathways.

Report Structure

Chapter 1 sets out the trends that will help define the global landscape over the next 10 to 20 years, the critical period for China's low carbon industrialization. A resurgence of manufacturing and focus on low carbon industries in key markets makes this a vital area for China's future competitiveness. There is considerable international experience in promoting low carbon industries, especially in the past two decades. Strengthening China's innovation capacity and promoting an open and inclusive approach are key to a successful transition.

Chapter 2 provides an overview of China's industrial and energy situation, highlighting the strong foundation for taking a lead on low carbon industry but also the challenges that need to be addressed.

Chapter 3 explains that low carbon industrialization is central to meeting China's broader objectives on the low carbon economy. The key dimensions are energy efficiency in industrial sectors, industrial restructuring and reorganization, and the emergence of new pillar industries. In each area, innovation will become increasingly important over time.

Chapter 4 provides a detailed explanation of the role of seven energy intensive industries in low carbon industrialization, underpinned by detailed technical analysis.

Chapter 5 assesses the potential of the seven emerging industries, including their role in supporting improvements in heavy industry and more fundamental restructuring of the energy and economic systems.

Chapter 6 presents specific policies and recommendations for China's low carbon industrialization.

1 INTRODUCTION AND INTERNATIONAL CONTEXT

Rapid industrialization is integral to the growth strategies of many developing countries. Guided public and private investment into primary and secondary production – whether in steel, shipbuilding or metals processing – is also pursued by many other emerging economies today. However, environmental and resource constraints will make it increasingly difficult for the emerging economies to follow this 'traditional' pathway. As a result, the transition to a low-carbon economy presents unique challenges and opportunities for developing countries.

China is very much at the forefront of this search for a new, more sustainable model of industrialization. As made clear by senior leaders in China, moving to a low carbon economy is of critical strategic importance as China evolves its development model, adjusts its economic structure, reinforces its technological base and strengthens future growth potential. Sustainable industrialization is a critical dimension of China's prospect for achieving future growth.

According to the International Energy Agency, one-third of the world's energy consumption and 36% of carbon dioxide (CO_2) emissions are attributable to manufacturing industries. The large primary materials industries – chemical, petrochemicals, iron and steel, cement, paper and pulp, and other minerals and metals – account for more than two-thirds of this amount. Overall, global industry's use of energy has grown by 61% between 1971 and 2004, albeit with rapidly growing energy demand in developing countries and stagnating energy demand in OECD countries. Despite their high emissions profile, global demand for hard-to-substitute goods like steel and petrochemicals is unlikely to fall rapidly over the next decades - the decisive period in the global response to climate change.

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

Industrial energy consumption is roughly 70% of China's rapidly expanding economy, accounting for a large share of total greenhouse gas emissions today. These heavy industries have great potential to improve energy efficiency and are the key to delivering China's important commitments on energy and carbon intensity in the next decade. Meanwhile the global picture for competitiveness is changing: Chinese firms hope to meet burgeoning global demand for low carbon technologies, such as renewable energies, electric vehicles and green information and communications

systems (ICT). China's 12th FYP shows that in the next ten years these low carbon sectors have the potential to become pillar industries, playing a central role in the economy. Meeting this goal depends on refocusing China's industrial assets and upgrading its capacities for technology innovation. Finally, shifting China's economic growth pattern and accelerating the process of economic restructuring is set to be an important strategic theme in the coming years. Green growth and low carbon industrial transition must be a key part of the solution.

Achieving the goal of industrial re-structuring is no mean feat, especially in the wake of the global economic downturn and increasingly volatile energy prices. Today, China's energy-intensive industries remain the pillars of the national economy. Employment pressures make it harder to speed up structural adjustment in the short-term and close inefficient production capacity.

Across the globe, governments and businesses increasingly recognize that those who are moving fastest on low carbon transition will gain significant competitive advantage. According to HSBC, the low carbon energy market reached USD 0.7 billion in 2009 and is set to grow to between USD 1.5 to USD 2.7 trillion in 2020.[1] By this time it may well exceed global military expenditure, which was at USD 1.6 trillion in 2010.[2] The key policy question is how states and markets can harness their industrial assets towards stimulating genuine opportunities in low carbon economic activities and energy efficiency investments across the globe.

The financial crisis of 2008 unleashed many questions for the future of the global economy. Perhaps more significantly, in the eyes of many, the crisis reaffirmed a global trend in the making over the past decade – that of shifting economic power across the globe and the rise of several countries as major geo-economic actors. In 2010, China overtook Japan as the world's second largest economy in terms of nominal GDP, although its per capita GDP (USD 3,678) remains still only one-tenth of Japan's. This trend is accompanied by the growing role of governments in managing economic affairs following the economic crisis.

1.1 A changing global economic landscape

Trends in today's global economy will influence China's industrialization pathway to 2020 and beyond. Since late 2008, governments across the world have engaged in comprehensive efforts to mitigate the near-term threats posed by a slow and uncertain global economic recovery, along with the longer-term threats posed by climate change, ecological pressures and higher resource costs. These developments are radically changing the context for development and growth for emerging economies.

China has emerged as a global player at a time of great uncertainty. Competitive advantages are shifting globally, in turn affecting how investment, industry, technologies and regions should be prioritized. The importance of manufacturing as a key driver of economic growth in the wake of the global downturn is cementing into a longer term trend, with low carbon technologies and services constituting some of the most promising markets. Indeed, the scale of investment and technology deployment required to meet international goals on climate and energy security strongly suggest that low carbon technologies will be decisive in shaping future competitiveness.

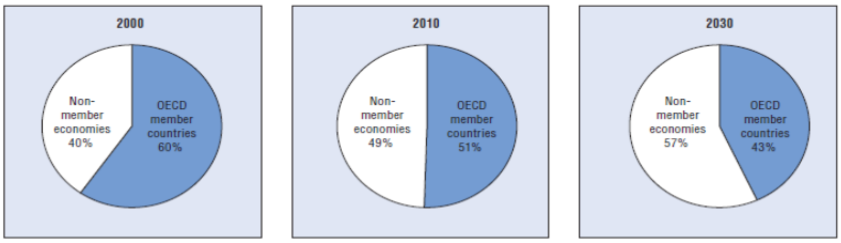
1.1.1 Shifting global economic trends

The developing economies are continuing their role as the driving force behind global growth since the financial crisis. Overall, these economies have weathered the recession - most countries posted only mild losses or escaped recession altogether. By the end of 2009, initial losses had been almost entirely recovered and these emerging economies continued to surge forward in 2010.

That this recovery was achieved under far more adverse external conditions is testament not only to the increased resilience of these economies, but also to the role of China as a regional life-saver. Although China suffered just as much from the drying up of world trade (in early 2009, Chinese exports were down 25% from previous year levels), its enormous room for fiscal manoeuvre allowed it to enact the (proportionally) largest stimulus plan in the world, fuelling a massive credit expansion which kept domestic demand growth high. This meant that the Chinese economy recorded yet another year of outstanding growth: 8.7%. On a regional level, Chinese demand kept imports from its Asian trading partners high. This effect was not just limited to Asia: China jumped to being Brazil's largest single trading partner over the course of 2009.

Emerging Asian economies have doubled their share of global output in the past two decades. According to Development Centre forecasts based on Maddison (2007 and 2010), non-OECD member countries as a group could account for as much as 57% of global GDP on a purchasing-power parity basis by 2030.[3] This shift of global economic wealth is not a transitory phenomenon, but one of global historic significance.[4]

Figure 1-1: Share of global economy in purchasing power parity term



Note: These data apply Maddison's long-term growth projections to his historical PPP-based estimates for 29 OECD member countries and 129 non-member economies.
Source: Authors' calculations based on Maddison (2007) and Maddison (2010).
StatLink http://dx.doi.org/10.1787/888932287957

Source: OECD (2010)

According to the OECD, a number of factors underpin this realignment. First, the opening of the large, formerly closed, economies of China, India and the former Soviet Union brought an additional 1.5 billion workers to the open market-oriented economy in the 1990s, creating a supply shock. This reduced the cost of many traded goods and services. It also created the condition for economic take-off in Asia. The growth in these countries also stimulated demand for many commodities like fossil fuels and industrial metals, transferring wealth to exporters in Africa, the Americas and the Middle East. As these economies grew, they moved from being net debtors to net creditors, which kept US and global interest rates lower than they might otherwise have been.[5]

However, according to Nomura, the assumption that Asian economies are decoupled from developments in the more advanced world seems to have been misplaced, notwithstanding the decades-long boom in Asian trade.[6] Nearly 40% of goods produced in Asia are destined for US, EU and Japan, and a collapse in demand from

advanced economies can be felt throughout Asia. Indeed, one of the main casualties of the financial downturn was global trade. World trade loss amounted to USD 3-4 trillion in 2009, as compared to global GDP loss of USD 1-2 trillion.

In the near term there is the risk of a return to protectionist policies, which has been high on the international agenda since the financial crisis broke in 2008. The strong rhetoric at the G20 on fighting protectionist tendencies has not always been reflected in the actions of individual countries and the risk of an escalation in trade disputes remains. Analysis by Global Trade Alert suggests that nearly 1400 protectionist measures have been implemented since the G20 in November 2008.[7] WTO agreements, it says, have encouraged countries to channel protectionist pressures into policies not well covered by enforceable rules.[8]

China's economy remains heavily dependent on global trade and investment flows, something which was highlighted in 2008 when the global slump forced thousands of factories to close. Rebalancing the economy toward domestic consumption and accelerating the transformation of China's economic development model is a top priority for the 12th FYP.

In the absence of a comprehensive global deal on climate change, links between trade and climate change have been brought into focus in the debate over the potential for border adjustment measures (BAM). In the US and to a lesser extent the EU, carbon price adjustment at the border for imported goods is now being considered seriously as part of a broader climate policy package, although this has retreated in the US with the failure of major legislative proposals for cap and trade. Viewed narrowly as a response to competitiveness and carbon leakage concerns caused by carbon mitigation policies, BAMs make intuitive sense.[1] However, moves in this direction are highly controversial, especially in developing countries which regard them as discriminatory. In principle, BAMs would be imposed on sectors in countries perceived to have failed to introduce carbon policies that are "at least as stringent" as the US, for example. In absolute terms, China would be the developing country most affected by such an approach. A BAM policy in the US or EU is likely to result in economic impacts that are significantly greater than the scale of recent trade disputes.[9] There is a risk that the political pressure resulting from a BAM could lead other countries to consider retaliatory trade measures.

1.1.2 The resurgence of manufacturing as a strategic interest

The state of manufacturing has become a key indicator of success for developed countries while their governments seek to stimulate economic recovery. The sector is perceived to be critical to long-term prosperity, growth and competitiveness. There is, therefore, a renewed focus on the role of governments in creating the conditions for a thriving manufacturing sector.

Many developed countries have bolstered their industrial policies and are pursuing more interventionist strategies. For example, the US launched *A Strategy for American Innovation: Driving Towards Sustainable Growth and Quality Jobs* in September 2009[10], The EU adopted *Europe 2020: A strategy for smart, sustainable and inclusive growth* in June 2010[11] and Japan announced details of its *New growth strategy by 2020* in June 2010[12] (see Box 1-1).

Box 1-1: Japan: New Growth strategy[13]

In mid-2010 the Japanese Government announced 21 National Strategic Projects for the revitalization of Japan for the 21st Century. These projects affected a wide variety of sectors: the energy sector, transport, urban construction, manufacturing and healthcare, to name but a few. Under the subheading of Green Innovation, three specific projects have been proposed:

Expansion of Japan's renewable energy market:

- Expand the purchase of renewables through the feed-in tariff system
- Introduce smart grids to make the system more efficient and enable the greater integration of renewables
- Promote the construction of renewables, through the creation of implementation zones
- Provide financial assistance to strengthen finance mechanisms
- Create renewable heat demand

Future Cities Initiative:

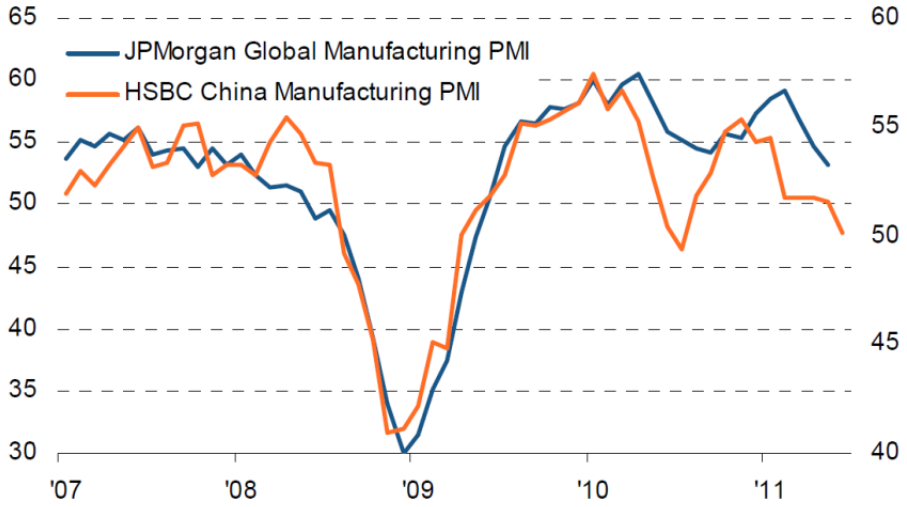
- Create a world leading 'future city' through future-orientated technologies, schemes and services
- A comprehensive package of policy measures, including regulations, tax incentives and focus of budgetary support for key technologies
- Spread the initiative throughout Asia

Forest and forestry revitalization plan:

- Raise the timber self-sufficiency to 50% and, therefore, help to revitalise the localised economies
- Promote sustainable forestry practices

Bolstered government support for manufacturing combined with an improving global economic outlook appears to have had a positive impact on the sector. In the US, UK and the Euro area, private sector confidence in the manufacturing sector collapsed during 2008 but returned to pre-crisis levels by early 2010. However, the middle of 2011 was marked by a slowdown in the expansion of Chinese manufacturing (see Figure 1-2).

Figure 1-2: The Recovery of Global and Chinese Manufacturing



Source: Markit, 2011

Emerging economies have maintained and accelerated support for manufacturing during the global economic downturn. Brazil's development bank – BNDES – financed 40% of investment in infrastructure and manufacturing in the country in 2009[14] and South Africa launched a revised Industrial Policy Framework Action Plan in February 2010. China has many initiatives to support manufacturing, from support for R&D to training of engineers. China's foreign investment has also increased from USD 9.11 billion in 2005 to USD 63.87 billion in 2009, mostly in energy, metals, and chemicals, as well as transportation and communications – the key inputs into the manufacturing processes.[15] National and regional governments also supported the development of special economic zones or industrial parks in China, Korea and beyond.

The World Bank also shifted its position away from non-interventionist Washington Consensus principals, noting that while industrial policy has often failed, "the historical record also indicates that in all successful economies, the state has always played an important role in facilitating structural change and helping the private sector sustain it across time"[16]. Creating optimal conditions for strong, sustainable and resilient economic growth in developing countries will require reform and transformation across a number of interlinked and mutually reinforcing key areas, including: infrastructure, private investment and job creation, education and skills, trade, knowledge-sharing and inclusive growth.

A study by Deloitte and the US Council on Competitiveness pointed to what it described as a 'new world order for manufacturing competitiveness' in less than a decade, along with a tectonic shift in regional manufacturing competence. Deloitte's Global Manufacturing Competitiveness Index (GMCI) highlights the rise in the manufacturing competitiveness of three countries in particular – China, India and the Republic of Korea – which appears to parallel the rapidly growing Asian market.[17] According to the GMCI, US, Japan and Germany, the dominant manufacturing superpowers of yore, are now lagging behind these three.

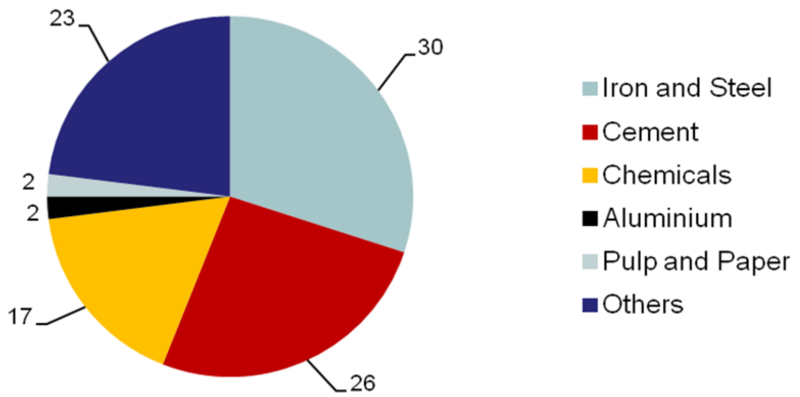
1.2 Industry and the global low carbon economy

The carbon footprint of a country's industrialization, and its long-term energy and environmental destiny, depends on four tightly linked factors: the resource-intensity of urbanization, the energy-intensity of urban life, the carbon-intensity of energy production and the nature and pace of economic growth.

This was brought home in China in recent years thanks to a surge in investment in infrastructure and the heavy industry that supplies it. Between 1980 and 2000, China did a remarkable job of growing an economy while restraining energy consumption: as the economy expanded six-fold, the country's energy needs grew at less than half that rate. However, in 2001 that trend began to reverse and China moved in a much more resource-intensive direction. Over the past six years, energy demand has grown at an average annual rate of 11%, faster than growth in the economy overall.

At the global level, industrial and manufacturing activities together account for over 35% of CO_2 emissions (not including the energy sector). The large primary material industries, such as chemical, petrochemicals, iron and steel, cement, paper and pulp, and other minerals and metals, account for more than two-thirds of this amount. The top three emitting sectors in China (steel, cement and petrochemicals) have been interlinked with China's industrial development strategy.

Figure 1-3: Contribution of Global Industrial CO_2 Production by Industry



Source: IEA, 2009[18]

There are many serious dilemmas and questions. First, how to de-link growth strategies from heavy industrialization in emerging economies? Is there always a correlation between growth and investment in heavy industries (for example, shipbuilding, steel making, metals processing and cement) for countries at early stages of development? Second, how much of emissions-heavy production is due to outsourcing from developed countries? Or, are they re-located to developing countries because the trend is to move production closer to sources of materials and/or markets? Third, are the material needs for developing countries – infrastructure, building, transport systems – dictating the future demand for emission-intensive production patterns?

The current economic crisis provides an opportunity for both China and other countries to find a new model for industrialization. Awash with liquidity over the past several years, there have been fewer incentives for urban planners and project developers to take a thoughtful approach to resource use when designing and building cities. This created a surge in demand for energy-intensive goods that was met by the

most readily available source, regardless of environmental impact. The energy required to produce such goods was growing so quickly that China was forced to rely on the most proven and accessible sources of supply: coal and coal-fired electricity.

The Chinese government has recognized that to return to a more sustainable, low-carbon model of economic growth, China will need to find a new approach to both urbanization and industrialization. This will require:

1. *Changing the way urbanization is planned and funded.* Over the past decade, rapid capital accumulation has allowed for rapid construction of new highways, bridges and buildings. This growth in infrastructure, housing stock and office space has enabled millions of Chinese citizens to seek economic opportunity in the cities. However, the way in which this urbanization has occurred is creating near-term energy challenges and limiting the ability of the country to manage its energy future. Three decades of rapid economic growth has boosted income to Chinese households. Much of this income has been saved, providing state-owned companies and local governments with a relatively unlimited supply of capital to build-out new cities. As is painfully evident today in the West, excess liquidity makes for more resource-intensive construction than would otherwise occur. Officials will need both smart urban planning and smart financial management.

2. *Changing the mix of what China makes for itself and what it buys from abroad.* Good planning and a healthy capital system can reduce the amount of steel, cement, glass and aluminium required for China's urbanization. However, beyond this, achieving low-carbon growth will require the purchase of these materials from the least carbon-intensive producers. As a country rich in labour and relatively poor in natural resources, heavy industry doesn't play to China's strengths and falls short in delivering the types of employment gains the country requires. The five most energy-intensive industries in China consume nearly half of the country's energy resources, but only employ 14 million people out of a labour force of 800 million. Purchasing these basic materials from other countries with a less carbon-intensive energy mix would both free up resources in China for more labour-intensive activities and help the world meet China's development needs in a more environmentally friendly manner.

3. *Lower the carbon-intensity of energy supply and increase the efficiency of energy use.* While rebalancing Chinese growth away from heavy industry towards light industry and services will no doubt help China find a more sustainable development pathway, low-carbon growth will still require a reduction of the carbon-intensity of the energy system. This means switching to lower-carbon sources of supply and improving the efficiency with which energy is consumed. China has already made important steps in this area and, as a newly emerging economy, has access to low-carbon alternatives that were not available when the West went through its industrialization.

Delivering on energy efficiency in particular will have a significant impact on Chinese and global emissions. Table 1-1 shows how large scale savings can be achieved by improving practices and technology in specific sectors.

Table 1-1: Energy and CO_2 Saving Potential

	World Saving Potential (EJ/yr)	*Chinese Saving Potential (EJ/yr)*	*World Average saving potential (GJ/T)*	*Chinese Average saving potential (GJ/T)*	*World CO_2 Saving Potential (Mt CO_2/yr)*
Chemicals and Petrochemicals	*5.2*	*0.7*	*N/A*	*N/A*	*300*
Iron and Steel	*4.7*	*2.5*	*4.1*	*6.2*	*350*
Cement	*2.5*	*1.1*	*1.0*	*0.9*	*450*
Pulp and Paper	*1.4*	*0.1*	*2.5*	*0.9*	*80*
Aluminium	*0.4*	*0.12*	*N/A*	*N/A*	*45*

Source: IEA 2009[19]

Fuel switching has usually entailed a shift from relatively low-energy-density (e.g. wood, coal) to high-energy-density fuels (e.g. oil), driven primarily by technological developments not income growth. However, it should be noted that cause and effect are difficult to disentangle, and changes in the pattern of demand for goods and services may also have played a role.

Energy innovation and diffusion has been driven largely by inherent advantages in cost, convenience and suitability for powering new products. In some circumstances, local environmental concerns, such as smog in London or Los Angeles, have also played a role. Given the current state of knowledge, alternative technologies do not appear, on balance, to have the inherent advantages over fossil-fuel technologies (e.g. in cost, energy density or suitability for use in transport) necessary for decarbonisation to be brought about purely by private commercial decisions. Strong policy will, therefore, be needed to provide the necessary incentives.

Technical progress in the energy sector and increased energy efficiency are also likely to moderate emissions growth. One study has found that innovations embodied in information technology and electrical equipment capital stocks have played a key part in reducing energy intensity over the long term. However, in the absence of appropriate policy, incremental improvements in efficiency alone will not overwhelm the income effect.

1.2.1 The role of industrial policy in the OECD

The strength and type of industrial policies deployed in the OECD has varied considerably across different countries and timescales, shaped by factors such as the extent of liberalisation and privatisation, local resource endowment, economic structure, the political influence of industrial sectors and the nature of the particular sector or industry seeking support. Some countries, such as the UK, pursued a relatively non-interventionist approach in the two decades prior to the financial crisis, while others, such as Germany and France, have always maintained greater state involvement in industry.

In recent decades the governments of Japan, Korea and France have not only supported priority industries but also extensively used measures to support domestic firms with regards to R&D expenditure, access to skills, international trade and access to finance. Compared to other developed countries the state played a particularly important role in these three cases. Korea followed a centralized approach with publicly-funded large-scale R&D projects in key areas, government-owned research institutes, as well as the establishment of large SOEs and direct control of the banking

sector to ensure access to finance. Japan put a stronger emphasis on general R&D incentives such as loans, subsidies, tax incentives and the creation of regional R&D clusters. They also involved the private sector in the policy making process regarding the support of priority industries and secured access to finance with more moderate measures than Korea, for example the establishment of special banks for long-term industrial financing. France started with a very centralized top-down support of R&D, funding of selected grand projects and the establishment of SOEs, but subsequently moved the focus to bottom-up research grant schemes and cluster support programs.

With respect to access to skills, Japan and Korea put a stronger emphasis on technology imports. In comparison, French efforts focused on the local generation of knowledge and domestic technology dissemination, for example by fostering cooperation between companies, research centres and universities. Nevertheless, as far as measures regarding international trade and investment are concerned, all three countries restricted imports to varying degrees and supported their export industries with subsidies, tax incentives or preferential tariffs.

In contrast, Germany and the UK did not put a special emphasis on trade and investment measures. Although both countries used instruments from the other four areas, a distinction can still be made with regards to the support of priority industries and access to skills and finance. The set-up of specialized industry associations and chambers of commerce and industry in Germany in particular indicates a stronger commitment to the targeted support of key sectors. The UK government pursued a more limited approach, including occasional investment into priority sectors and loan guarantees, but not the establishment of specific institutions. Germany was also more active in the improvement of access to skills and capital. For example, the public vocational training system with its comprehensive system of training standards and active support of public savings and cooperative banks to ensure the banking system's capacity to supply long-term finance stand out here. In contrast, the UK's industrial policy in these areas is characterized by 'softer' measures with a focus on grants and advisory services respectively.

US industrial policy was certainly even less selective in R&D expenditure and access to skills and capital. Most of the measures were based on incentives (e.g. R&D tax credits, competitive university funding and investment capital initiatives) and targeting was only pursued to support SMEs in general, not specific sectors (e.g. technology transfer, sponsored research, technical assistance and credit guarantees). Indeed, SME support is a measure for comparison between Japan, Korea and France's active support of mostly large-scale industrial endeavours on the one hand with Germany, the UK and the USA's support for SME's on the other. However, what stands out in particular is the fact that the US government did not put any special emphasis on the support of priority industries, but mostly concentrated on trade policies. Supporting local SMEs with regards to export financing, global marketing and the integration into global value chains was accompanied by promoting free trade initiatives within WTO and through bilateral agreements. In addition, anti-dumping duties, import quotas and foreign ownership restrictions further supported the development of local firms in selected industries. This suggests that cushioning from international competition dominated the US government's concern for domestic firms.

Table 1-2: Industrial policies in developed countries

Measures	Japan	Korea	France	Germany	UK	USA
R & D expenditure	• R&D loans and subsidies • Special R&D cost deductions • Tax incentives • Large-scale research contracts • Public research organizations & national R&D projects • Promotion of basic research in priority areas • Creation of regional R&D clusters	• National R&D projects • Government-Funded Research Institutes & science parks • Technology Diffusion Institutes • R&D tax credits • Public investment in basic research	• Public R&D financing in key sectors • Bottom-up driven grants by national research agency • Long-term industrial technology programmes • Research tax credit scheme • R&D subsidies	• Large projects on key technologies first • Public institutes between basic and industrial R&D • Steering of co-funded research • Financial R&D incentives for SMEs • Support programmes for specific kinds of innovations • Support of industry-public research cooperation	• Provision of funds for private R&D activities • Fixed minimum budget quota for commissioning of SME related research • R&D tax credits • Innovation management advisory to companies • Collaborative R&D projects	• R&D tax credit for companies • SME technology transfer and R&D funding • Funding of R&D by government agencies & universities • Programs to create networks between firms and research institutions • Sponsored research projects for SMEs
Access to skills	• Technology imports • Royalties for techn. licensing • Bargaining with foreign technology suppliers • Hiring foreign technical advisors • Enhancement of industry-university collaboration • Diffusion of R&D outcomes	• Promotion of technology imports • Creation of demand-oriented technology development system • Extensive technical training • Development and acquisition of top-level scientists & engineers	• Dedicated support of high-tech skills for SMEs • Fostering companies, research centres & universities cooperation • Support of assimilation and dissemination of high technologies • Employment aid schemes	• Set-up of prof. associations • Technology transfer & advisory services • Public vocational training system • Apprenticeship training standards • Easing the access of highly qualified migrants • Short-term work subsidies	• Government funded advisory • Knowledge transfer, training, recruitment & development of skilled personnel • Promotion of manufacturing in schools • Support of business-academia partnerships • Support of apprenticeships	• Competitive process for university funding • Technical support to upgrade technological efficiency • Technical assistance for SMEs • Support of SME manufacturing/business expertise • Technical education grants
International exposure	• Import controls • Inward FDI controls • Foreign exchange controls • Export subsidies • Tariff rebate on imports	• Export targets & penalties • Export promotion • Exemption from import duties • Tax incentives • Trade protection • Non-pecuniary awards	• Export support • Prevention of foreign entries • Import rationing and licenses • Preferential tariffs			• Export financing, global marketing support for SMEs • Bilateral & WTO free trade initiatives • Anti-dumping & countervailing duties • Import quotas • Tax credit for exporters • Foreign owner restrictions
Access to finance	• Off-budget finance • Special banks for long-term industrial financing • Direct subsidies • Subsidized credit • Special depreciation provisions • Etc.	• Direct credit rationing by government • Institutions for large-scale project financing • Instruction of private banks • Preferential access for exporters • Special depreciation allowances • Etc.	• Subsidized loans • Loan guarantees for SMEs • Financial incentives for entrepreneurs • Support of equity financing by SMEs	• Low interest loans and loan guarantees for restructuring of eastern Germany • Active support of banking system's capacity to supply long-term finance • Support of public savings and cooperative banks for SME lending • Financial incentives for entrepreneurs	• Selective investment grant schemes	• Investment capital initiatives • Tax credits for business angels • Loans & credit guarantees for SMEs
Support to priority industries	• Tax preferences • Focused tariff protection • Government subsidies • Partial tolerance of cartels • Deliberation councils for policy making in key sectors • Informal administrative guidance	• Establishment of SOEs & firm nationalisation • Extensive tax incentives • Bail-out guarantees • Reduced electricity and transport prices • Etc.	• Extensive support of grand projects (oil, power, telecom, transport, etc.) • SOEs in key sectors • Dedicated cluster support • Sectoral aid schemes • Reduced VAT rates	• Set-up of industry associations & chambers of commerce and industry • Funding of cluster programmes • Targeted support of environmentally friendly technologies • Sectoral aid schemes	• Occasional investment into priority sectors (e.g. electric cars and civil aerospace) • Limited loan guarantees	

Source: UNIDO, 2011

1.2.2 Reducing Resource Dependency

The movement towards a more resource efficient economy is now as strong as the development of a low carbon economy. This results from increased concern over the impact of higher and fluctuating resource prices on individual sectors and the wider economy. However, it is not a case of either a low carbon economy or a resource efficient economy: their respective development need to go hand-in-hand.

The transition to a low carbon economy will require large volumes of (potentially new) resources in the medium term, as is described in section 2. Resource efficiency and recycling will be critical to reducing exposure to volatile resource prices for materials including iron and steel, lithium and rare earth elements (REEs). Over time, countries can also reduce the impact of high resource prices by diversifying economies into higher value-added, less resource-intensive goods. The EU's recent 'flagship initiative on resource efficiency' puts competitiveness front and centre, as described in Box 1-3.

Box 1-2: EU flagship initiative on resource efficiency

In January 2011, the European Commission published a so-called Flagship Initiative on the creation of a resource efficient EU. This has included a timetable of new initiatives in this area and activities under three main pillars:

1. Fair and sustainable supply of raw materials from international markets: The EU will actively pursue a "raw materials diplomacy" with a view to securing access to raw materials through strategic partnerships and policy dialogues. For example, it will seek the inclusion of binding disciplines on trade and investment measures related to raw materials (e.g. regarding export duties) in trade negotiations; tackle trade barriers through dialogue but also other tools including WTO dispute settlements and market access partnerships; and finally raise awareness and support awareness-raising in international fora. This follows on from 2008 Raw Materials Initiative[20].

2. Fostering sustainable supply within the EU. This aims to ensure that mineral resources are exploited in an economically viable way, harmonised with other national policies, based on sustainable development principles and including a commitment to provide an appropriate legal and information framework. This pillar also focuses on spreading best practices in land use planning and administrative conditions for exploration and extraction. Efforts will be made to improve the EU's knowledge database of mineral deposits through better networking of national geological surveys; optimal use of the satellite-based information system; and a sustained promotion by the EU of research projects that focus on the extraction and processing of raw materials.

3. Boosting resource efficiency and promoting recycling. The European Commission has published a Raw Materials Initiative strategy document aimed at improving the function of recycling markets through the development of best practices in collection and treatment of waste, improvement in the availability of certain statistics on waste and materials flows, and support for research on economic incentives for recycling.[21]

Within the EU rules are in place to increase the recovery and reuse/recycling targets for vehicles which will rise to 95% and 85%, respectively, by 2015. This means the amount of waste being disposed of in landfills would fall from the current figure of about 25% to less than 5%.[22] Such a target is unlikely to be difficult to meet: for example, Volvo claims that it had already reached this target by 2002. Similarly, targets have been set for the electrical industry through the Waste Electrical and Electronic Equipment directives. Under these EU laws collection targets equal to 65% of the average weight of electrical and electronic equipment placed on the market over the two previous years in each Member State[23]. These directives have lead to changing practises in industries, both in relation to the recyclability and reuse of components, and in the level of recycled goods that are included in their products. For example, HP has developed an HP Scanjet scanner component made from 25% recycled inkjet cartridge plastic and 75% recycled plastic bottles, in addition to reductions in the different types of plastic used in its equipment[24].

To ensure competitiveness, countries and companies are also looking to increase the resilience and flexibility of manufacturing. This makes the possibility of substitution a priority for innovation. There is much discussion, for example, around whether: magnets in large wind turbines can be produced without REEs;[25] buildings can be constructed with smaller amounts of steel; resources other than lithium carbonate can be used in the mass production of electric vehicle batteries; and whether plants can replace oil products as the feedstock for petrochemicals and plastics. Biofuels are another example of resource input substitution, although to date Brazil is the only major economy to have decisively reduced its dependence on fossil fuels in the transport sector.

China's "new materials" pillar industry is of central importance to its wider low carbon industrialization. The potential of nanotechnology to greatly enhance the novel properties of certain critical minerals and open up entirely new avenues for alternative product designs is a key question at present. For example, nano-sized rare earth compounds are already being considered in green technologies such as magnets, batteries, fuel cells, H2-storage and catalysts.

Scientists at the National Institute of Advanced Industrial Science and Technology (AIST), Japan, have developed an advanced composite material partly consisting of multi-walled carbon nanotubes which, when used in dye-sensitised solar cells, exhibit photoelectric conversion efficiency as high as that of the conventionally used platinum.[26] The United States Department of Energy National Laboratory views nano-structured permanent magnets as a key strategy to lowering the REE content in permanent magnets [27].

The recent concern over access to REEs highlights the importance of perceived scarcity as a driver for innovation. Increasing awareness over the need for REEs has already triggered rapid supply responses, from the re-birth of the metals recycling in Kosaka, Japan to plans to reopen or establish new rare earth mines in South Africa, Australia, Canada, the United States and Vietnam, amongst others.[28] REEs are used in permanent motors of hybrid electric vehicles and electric vehicles. Commercially available alternatives already include a number of asynchronous motor designs, however ongoing research hints at alternatives to pure Neodymium permanent motors. Most low carbon energy efficient lighting systems contain REEs. There is now a focus on innovative technologies that can dramatically reduce or eliminate the REEs content in phosphors used for light emitting diode (LED) and compact florescent (CFL) lighting solutions.

The introduction of novel information and communications technologies (ICT) and systems has the potential to reduce the overall material demands in society. These technologies are already improving the design and operation of industries to make them more efficient. For example, wind power is heavily dependent on ICT technology for site selection, wind farm optimisation, prediction of availability, error detection and security. Factories also use supervisory control and data acquisition systems (SCADA) to optimise their manufacturing processes to track energy and other resource use along supply chains.

More broadly, ICT are challenging existing technology systems by reducing the need for travel (via videoconferencing and online working environments), accelerating innovation via collaborative approaches, and by bringing producers into a dynamic relationship with consumers. As the sector grows, there are also significant savings to be made by greening ICT systems themselves: the efficiency of servers, low carbon cooling systems and via system-level changes, for example a shift to 'cloud computing'.

The full potential and impact of virtualisation and ICT more generally will become clear over time as this is a rapidly evolving field. What is clear is that it has the potential to drive rapid transformation in many areas of society and the economy. ICT plays two key roles in the shift from heavy industry to services. First, it can reduce growth in demand for additional roads and buildings through smarter cities and logistics. Secondly, ICT enables the growth of knowledge-intensive service industries that rely on education, information and connectivity.[29] A number of recent international studies have made efforts to quantify the potential ICT offers, for

example the SMART 2020 report estimates there is a potential abatement of 7.8 $GtCO_2$ in the total BAU emissions in 2020 (51.9 $GtCO_2$).[30]

WWF and China Mobile have published a study focused on China.[31] Focusing largely on the impacts of transport substitution and dematerialization, the study estimates a total of 0.6 $GtCO_2$ could be saved by 2020. The study was based on a detailed examination of the CO_2 savings associated with 14 dematerialization services already offered by China mobile in Chongqing and a less detailed assessment of the potential savings from a larger group of applications. The bottom line concludes that, with the right policies, there is potential to reduce emissions by 615 mt in 2020 and by 1298 mt in 2030.

1.2.3 Knowledge assets

The low carbon economy will require, not only transformations in specific sectors, but systemic change across the whole of society. Innovation at the system level will depend on leveraging the knowledge assets held across the economy and on cooperation along supply chains and across national and sectoral borders. As part of an integrated vision, every pillar industry will play a key role in driving this wider transition. This includes the traditional heavy industries as well as the more disruptive new pillars such as renewable energy, electric vehicles and ICT. Box 1-3 and Figure 1-4 describe how one example of China's emerging pillar industries - electric vehicles - is highly interconnected with a range of other sectors and technologies, including the energy system, materials sciences and energy efficiency. It also demonstrates the extent to which the 8 emerging pillars identified in the 12th FYP are interdependent of each other's development. Failure to move forward in any one sector will potentially have a detrimental impact on a much wider group of technologies, through reducing the technology specifications and/or creating supply-chain bottlenecks.

Box 1-3: Electric Vehicles – links with other emerging industries

Manufacturing of electric vehicles will require the development of a variety of technologies from across the traditional and new pillar industries.
New and Renewable Energy Source: The wider use of lower carbon electricity sources will lower the average emissions per km. Without such measures net emissions from the transport sector will not decrease.

New Materials: Technology and performance gaps still exist when comparing electric vehicles (EVs) to ICE: new products need to be developed, in particular as they relate to electricity storage. These developments will have a wide variety of other uses, for example in mobile telephones and computers.

High-end Equipment: More resilient and often smaller components will improve the efficiency and durability of EVs. The development of these processes and supply chain will have benefits for a wide variety of other sectors and in non-EV transport systems.

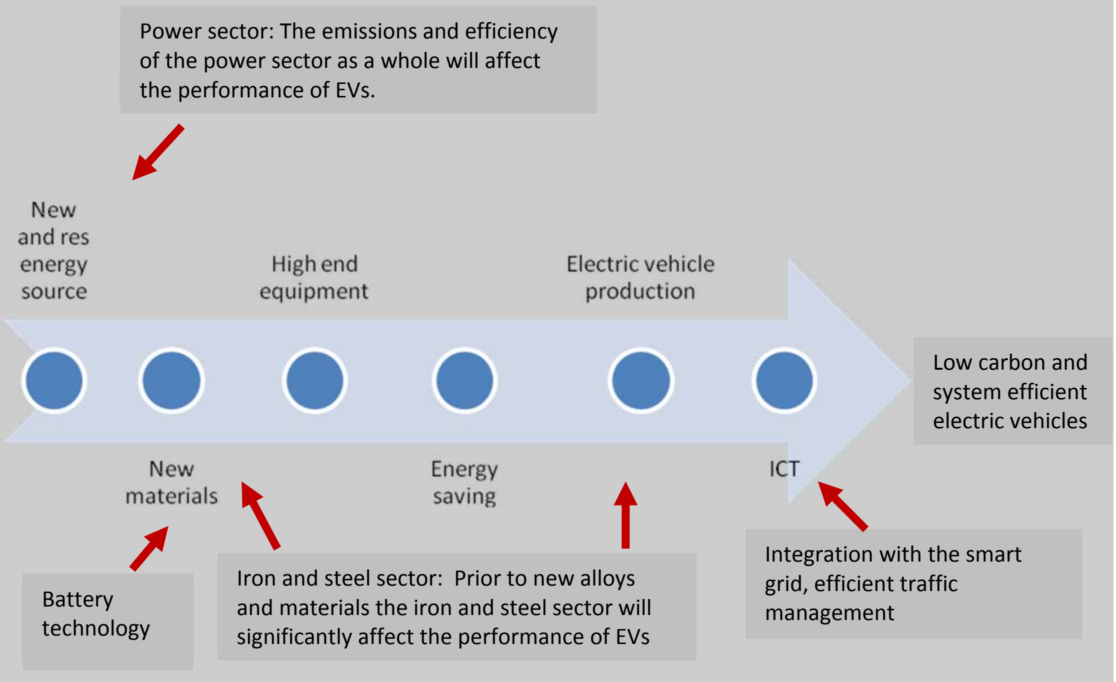
Energy Efficiency: Lower energy-using equipment, higher conversion factors and lower weight materials are all necessary for the wide utilisation of EVs. These technologies will be deployable in ICEs and other electrical appliances and transport modes (train, bikes etc).

EV Production: Creating efficient and functioning supply chains and manufacturing processes will have benefits for other electric appliances and non-EV transport systems.

ICT: A large-scale, fully functioning EV system will require the roll out of charging systems which will require the integration of ICT. Large-scale penetration EV systems envisage the utilisation of the storage capabilities of the vehicles for grid balancing (especially with systems with high renewable penetration) which will not function without integrating the EV and utility systems.

The traditional pillar sectors will also be engaged in the production of EVs and their associated infrastructure, in particular the power sector, iron and steel industries and the traditional automobile companies.

Figure 1-4: The integration of electric vehicles with other emerging pillar industries



Just as important are the links between traditional heavy industries and these new low carbon pillars. Until recently, it was energy intensive heavy industries that were seen as the bedrock of growth and development. They have often been the first port of call for countries bent on climbing the value addition ladder. China is the recent case where heavy industrialization effectively powered the export-led growth since 2002. In more advanced economies, citizens increasingly question the environmental legacy and the movement of these industries to emerging economies. This has resulted in bifurcation between developed and developing economies as regards the role of the heavy industrial sectors. The reality is that heavy industries are often the most potent industrial assets for many developing countries. In industrial regions, they tend to dominate the economic landscape. These industries are so integrated into the local economy and society that they are unlikely to be displaced soon, even with the expected explosive growth in low carbon industries.

The key question is how to utilise the assets held by high carbon industries in progress towards low carbon development. Existing technological assets will determine the

short-term options for low carbon development in a given area and heavy industries in industrialising countries tend to be among the strongest in terms of knowledge assets. This makes heavy industry a potentially important catalyst for driving low carbon industrialization, even though energy intensive companies may have short-term interests in maintaining the status quo. The evidence for this is clear in China's efforts to propel BYD from a battery manufacturer to an electric car pioneer, and in industrial giant Tata's pivotal role in wind and electric vehicles in India. There are examples from developed countries too – the electronics firm Nokia has its roots in the paper and pulp and cable manufacturing industries.

The knowledge assets held by heavy industry give them a particular importance in accelerating local technology innovation in industrialising countries. For example, local university research capacity is often geared to support these historically important industries and will work closely with the companies themselves. Large industrial enterprises also have major advantages in distribution networks and logistics capacity, particularly in the transport and retail of fossil fuels. These assets will, for example, play a key role in deploying biofuels and perhaps hydrogen in future. The power sector will play a key role in providing the infrastructure for electric vehicle charging. Heavy industries are also some of the largest companies in developing countries. This gives them access to finance and longer term investment options. While they are not always known for risk-taking, they do have the capacity to invest in large-scale pilots focused on capitalising on the linkages with low carbon growth opportunities.

Heavy industries are interconnected with many parts of the economy since they provide the fundamental materials used in the production of many products. This is particularly the case for intermediate products such as steel and petrochemicals. The quality and type of these products produced by heavy industry will be critical in the decarbonisation of all sectors, enabling lightweight materials and advanced applications.

1.3 International experience of low carbon industrialization policies

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

While long-term targets set the overall context, midterm targets are used to drive short-term action. For example, the South African government has announced that its GHG emissions will stop growing at the latest by 2020-2025, stabilise for up to ten years and then decline in absolute terms.[32]

This section reviews international experiences in some of the key policy areas for low carbon industrialization, including fiscal tools, market based instruments and technical standards.

1.3.1 Energy pricing, subsidies and carbon taxation

The IEA estimates that fossil fuel related consumption subsidies amounted to USD 557 billion in 2008. Based on its analysis, if these subsidies were phased out by 2020 it would result in a reduction in primary energy demand at the global level of 5.8% and a fall in energy-related carbon-dioxide emissions of 6.9%, compared with a

baseline in which subsidy rates remain unchanged. Furthermore, subsidies provided to producers of fossil fuels may be in the order of USD 100 billion per year. The total order of magnitude of subsidies to consumers and producers – almost USD 700 billion a year - is roughly equivalent to 1% of world GDP. In parallel, OECD countries have been raising taxes on energy - mainly fossil transport fuels - in amounts exceeding USD 400 billion per year between 2003 and 2008. These taxes significantly affect relative end-use prices for fuels. Subsidies to other non-fossil fuel energy are considerable and have been increasing over time. A rough estimate by the Global Subsidies Initiative (GSI) indicates around USD 100 billion per year are spent to subsidize alternatives to fossil fuels.[33]

At the G20 meeting in Pittsburgh in September 2009, leaders agreed to phase out and rationalize over the medium term inefficient fossil fuel subsidies, while providing targeted support for the poorest, noting that 'inefficient fossil fuel subsidies encourage wasteful consumption, reduce our energy security, impede investment in low carbon energy sources and undermine efforts to deal with the threat of climate change'.[34] To deliver on their commitment in Pittsburgh, G20 countries have developed strategies and timeframes for implementing national-level policies to rationalize and phase out inefficient fossil fuel subsidies. Measures proposed for phase out by some countries include preferential tax incentives for oil production, financial support for domestic coal industries and direct subsidies for general fuel consumption. However, Achim Steiner, head of the United Nations Environment Program, told Reuters in 2011 that despite some progress, countries were not moving fast enough and there is no collective implementation.[35]

Table 1-3: Country strategies for removal of energy subsidies

Country	**Summary of Implementation Strategy**
Argentina	Proposes to reduce household subsidy for propane gas consumption as natural gas access is expanded.
Australia	No inefficient fossil fuel subsidies.
Brazil	No inefficient fossil fuel subsidies. Lists several government measures in the energy sector related to the production or consumption of fossil fuels
Canada	Proposes to implement recently released draft legislation to phase out the accelerated capital cost allowance for oil sands assets over the 2011-15 period. Previously phased out other tax incentives applying to fossil fuel producers.
China	Proposes to gradually reduce the urban land use tax relief for fossil fuel producers.
France	No inefficient fossil fuel subsidies. Previously reformed subsidies for hard coal mining.
Germany	Proposes to discontinue subsidized coal mining in a socially acceptable manner by the end of 2018.
India	Proposes to work out implementation strategies and timetables for rationalizing and phasing out inefficient fossil fuel subsidies based on the recommendation of the Empowered Group of Ministers that has been constituted.
Indonesia	Proposes to phase out inefficient fossil fuel subsidies in a gradual manner in parallel through managing the demand side by adopting measures that will reduce fossil fuel energy consumption and by gradually narrowing the gap between domestic and international prices.
Italy	Proposes to continue with planned expiration of subsidy for certain cogeneration plants, and negotiate on a voluntary basis with private operators of these plants on the timing of their recess from the subsidy scheme.
Japan	No inefficient fossil fuel subsidies.
Korea	Proposes to phase out subsidies to anthracite coal and briquette producers.
Mexico	By continuing current policies and based on current market conditions, subsidies to gasoline, diesel and LP gas are expected to disappear in the medium term.

Russia	Proposes to implement the commitment to rationalize and phase out inefficient fossil fuel subsidies through national economic and energy policy, within the framework of its Energy Strategy 2030 and the Concept of Long-Term Social and Economic Development, as well as in the context of its joining the WTO.
Saudi Arabia	No inefficient fossil fuel subsidies. Saudi Arabia has a long-standing energy policy to improve the utilization of economic resources with emphasis on rationalization.
South Africa	No inefficient fossil fuel subsidies. Noting recently introduced electricity tax that applies to electricity generated from non-renewables as well as other relevant tax measures and incentives to reduce wasteful consumption and encourage low carbon energy development.
Spain	Proposes to implement current coal industry restructuring plan until 2012 when further restructuring will be considered.
Turkey	Proposes to work on a restructuring plan to rationalize the inefficient producer subsidies transferred to a stated-owned hard coal producing enterprise.
United Kingdom	No inefficient fossil fuel subsidies. Previously reformed subsidies for hard coal mining.
United States	Proposes to pass legislation to eliminate twelve preferential tax provisions related to the production of coal, oil, and natural gas.

Source: G20, 2010[36]

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

Several European countries, however, have introduced new carbon taxes as part of a broader trend of environmental tax reform. In 1991, Norway implemented a carbon tax of approximately USD 50 per tonne of CO_2, covering about 60% of national emissions. Other notable examples in the EU are Sweden, Finland, the Netherlands, Denmark, Germany and the United Kingdom. A recent study concluded that the introduction of carbon or energy taxes with revenue recycling in most of these countries had a positive effect on GDP compared with the counterfactual reference case of no environmental tax reform, with a neutral effect in the United Kingdom.[37] Table 1-4 shows the level of carbon taxation in selected countries.

Table 1-4: Carbon Tax Policies

Country/ Jurisdiction	Start Date	Tax Rate ($USD unless noted otherwise)	Annual Revenue	Revenue Distribution
Finland	1990	$30/metric ton CO_2 (€20)	$750 million (€500 million)	Government budget; accompanied by independent cuts in income taxes
Netherlands	1990	~$20/metric ton CO_2 in 1996	$4.819 billion[a] (€3.213 billion)	Reductions in other taxes; Climate mitigation programs
Norway	1991	$15.93 to $61.76/metric ton CO_2 (NOK 89 to NOK 345)	$900 million (1994 estimate)	Government budget
Sweden	1991	Standard rate: $104.83/metric ton CO_2 (910 SEK) Industry rate: ~$23.04/metric ton CO_2 (~200 SEK)	$3.665 billion (25 billion SEK)	Government budget
Denmark	1992	$16.41/metric ton CO_2 (90 DKK)	$905 million	Environmental subsidies and returned to industry
United Kingdom	2001	$0.0078/kWh for electricity; $0.0027/kWh for natural gas provided by gas utility; $0.0175/kg for liquefied petroleum gas or other gaseous hydrocarbons supplied in a liquid state; and $0.0213/kg for solid fuel	$1.191 billion (£714 million)	Reductions in other taxes
Boulder, CO	2007	$12-13 per metric ton CO_2	$846,885	Climate mitigation programs
Quebec	2007	$3.20 per metric ton of CO_2 (C$3.50)	$191 million (C$200 million)	Climate mitigation programs
British Columbia	2008	$9.55 per metric ton of CO_2 in 2008 (C$10), increasing $4.77 (C$5) annually to $28.64 (C$30) in 2012	$292 million (C$306 million)	Reductions in other taxes
BAAQMD, California	2008	$0.045 per metric ton of CO_2e[b]	$1.1 million (expected)	Climate mitigation programs
France	proposed	$24.74 per metric ton of CO_2 (€17)	$4.499 billion (€3 billion) expected	Reductions in other taxes
CARB, California	proposed	$0.155 per metric ton CO_2e in FY 2010-11, dropping to $0.09 per metric ton CO_2e in 2014	$63.1 million 2010-2013; $36.2 million starting in 2014, expected	Climate mitigation programs

[a] Revenue in the Netherlands is from all environmentally related taxes, of which carbon taxes are the clear majority.
[b] CO_2e is carbon dioxide equivalent.

Source: NREL, 2009[38]

1.3.2 Emissions trading

Cap and trade systems play a significant role in international experience of low carbon transition. Two key reasons are that they create a national cap of emissions in key sectors that can be reduced over time and that through trading they set a price for carbon. This has created huge new global markets in low carbon alternatives and made carbon-intensive options less attractive. Currently, the global market is dominated by trading in Europe, but plans to introduce emissions trading schemes in South Korea, New Zealand, Australia and perhaps South Africa and Japan indicate a global trend. The major outlier is the United States, where proposals for cap and trade legislation have been repeatedly rejected by Congress. New Carbon Finance suggested that, depending on the design, the value of the carbon market in the US

could be in the order of USD 1 trillion per year by 2020, but for the time being there is little prospect of a scheme being introduced.

Experience of international emissions trading is by far dominated by the European Emissions Trading Scheme (EUETS). After 5 consecutive years of robust growth, the total value of the global carbon market remained stable in 2010 at about USD 142 billion. The EUETS market accounted for 85 % of global carbon market value. This share rises to 97 % if the value of the secondary 'Clean Development Mechanism' transactions is also taken into account.[39]

The design of the EUETS is somewhat particular to the existing governance structures in Europe, but the scheme also displays several classical features of emissions trading schemes. As the largest and most mature carbon market in the world, it provides very valuable lessons when thinking about the potential for a wider global role of carbon markets. A detailed description is beyond the scope of this paper, and has been summarised elsewhere in the literature to a great extent (see Ellerman and Buckner, 2007[40]). Nevertheless, because of its importance, some features are worth describing here. The scope of the EU ETS currently covers annual emissions of around 3000 $mtCO_2$ from large stationary combustion sources over 50 $MW_{thermal}$. This includes most of the industrial sector (including refineries), all of the power generation sector and the offshore energy sector. Each company in the scheme is required to keep sufficient allowances in an electronic registry account to cover every tonne of CO_2 they emit each year. If companies fail to hold sufficient allowances to cover their independently verified annual emissions, they pay a fine of €100/tCO_2, and then have to subsequently cover the shortfall in the subsequent year.

In the first two phases of the scheme, companies were given a large proportion of their required allowances for free. New entrants to the scheme (e.g. new plants) have also been allocated free allowances, despite the lack of economic justification on the grounds of stranded capital. Companies can sell any surplus allowances, and any shortfall must be purchased from the carbon market. Third party traders and brokers are also allowed to trade, and the market comprises a mixture of over-the-counter trades and carbon exchanges. Considering the high degree of free allocation, liquidity in the first two phases has been relatively good. It should become significantly better in Phase III as the scheme moves towards predominantly auctioning of allowances.

An important feature driving the price of the EU allowances so far has been the rules concerning banking and borrowing of allowances. The scheme does not allow borrowing of allowances from future periods to be used in the current trading period. In the first phase of the scheme (2005-2007), no banking of allowances from this period into the subsequent 2008-2012 period was allowed either. This meant that surplus allowances left over at the end of 2007 were essentially worthless, and the price of carbon dropped to zero. Currently, banking of allowances from one trading period to another is allowed, which should help prevent a repeat of the price collapse that occurred in Phase I, as long as there is an expectation of scarcity of allowances in the long-run. Borrowing is still not allowed, so in principle the price spiking at the end of trading periods is still possible. In practice, companies will probably hedge against this risk by abating and/or purchasing more allowances than necessary and banking these surplus allowances to create a safety net.

The day-to-day behaviour of the allowance price in Phase I prior to the price collapse was linked to the marginal cost of switching from existing coal-fired to gas-fired power generation. As the gas-coal price differential increases, the price of carbon

required to incentivise this switch also rises and vice versa. In the longer run as the generation mix in the EU finds a new equilibrium factoring in the existence of a carbon price, and taking account of the retirement of significant amounts of coal in Europe as a result of the Large Combustion Plant Directive[41], other abatement options will come into the equation. In early stages of Phase II, prices showed signs of responding to other factors such as expectations of the future cost of carbon capture storage (CCS)[42].

As a mandatory regulatory instrument, the EUETS is likely to be very stable. What is less certain is the ambition level of the cap which has perhaps the most important impact on the carbon price. The EU and national governments are caught in the middle of conflicting priorities in this regard. On the one-hand, predictability and transparency in policy-making processes are important to investors, suggesting the need for target setting to be specifically focused on the needs of the EU carbon market (Gross 2007). On the other hand, the same national governments are involved in international negotiations in which political economy and gaming considerations become predominant. In this context the EU (like many other parties to the UNFCCC) set targets that are contingent on the commitments of other parties in order to avoid commitments becoming too far out of line with economic partners. The EU target was for a 20% or a 30% reduction in emissions by 2020 relative to 1990. Whilst this contingency may make sense from the point of view of strategic bargaining within the UNFCCC context, it does not help create stable investment conditions for domestic industry. The EU is currently negotiating an internal target consistent with the UNFCCC pledge.

In 2011, the European Commission produced a roadmap to 2050[43] setting out key milestones and policy actions required to meet long-term goals. This roadmap adds two important things to EU policy. Firstly, it begins to resolve the EU's dilemma over 20% vs. 30% emissions reductions target by 2020. Secondly, it helps to bridge the gap between the hard regulatory targets for 2020, and the softer aspirational targets for 2050. Both of these are good news for carbon markets, which have been left weakened by a lack of stringent targets. A contingent target for 2020 means that policy becomes hostage to the decisions of others. A 20% reduction doesn't put the EU on a path to its long-term target, whilst the EU's conditions look unlikely to be met for increasing the target to 30% in response to similar targets being taken on by other major economies. The suggested target for 2020 in the roadmap is a 25% reduction in emissions to be achieved domestically within the EU. Adjusting for the use of offsets, this comes quite close to the original 30% emission reduction target for the EU.

Just as significant for carbon markets would be a move towards providing targets for 2030, as suggested in the Commission's roadmap. Carbon prices are determined not by the balance of supply and demand now but in the future, due to the possibility to bank allowances for sale in future periods. Again, the roadmap looks to be tightening longer-term expectations. The implied emission reductions for 2030 relative to 2005 under current policy for the EUETS is a 30%-48%[44] reduction, whereas the roadmap increases this to 38%-50%. However, the targets for the EUETS in 2020 and 2030 have still not been clearly stated.

Tightening the caps will lead to higher carbon prices, but will also help to reduce policy risk in the carbon market according to recent analysis by Chatham House and London Business School[45]. This research shows that when caps are weak, carbon

price variations are dominated by policy risks which companies generally find more difficult to manage than market risks. Conversely, with strong caps in place, carbon price risk mainly arises from market-based risks (e.g. fuel price variations), which companies are in a better position to hedge and manage. Another consequence of a tighter 30% cap is that revenues accruing to Member States from auctions of EUETS allowances would increase significantly to €42 billion compared to €22 billion under a 20% in 2020. The revenues would also be a lot more certain under a 30% cap. Under a 20% cap (without the prospect of tighter caps in subsequent periods), there is a significant probability of very low or even zero revenues accruing from allowance auctions due to a collapse in the carbon price. Box 1-4 below sets out EU plans for allocating a share of this revenue to climate change-related investments.

The impact of the emissions cap is obviously crucial to the EUETS. By comparison, in macroeconomic terms, the way in which emissions allowances are allocated has very little effect on the overall economic and environmental efficiency of an emissions trading scheme. However, from the point of view of individual companies, the method used to allocate allowances can have a very significant effect on cash-flow.

The early stages of the EUETS (as with other major emissions trading schemes such as the US SO_2 program) were characterised by a high degree of free allocation to incumbent companies. This represented a significant wealth transfer from the public sector to the private sector with allowances representing assets worth over €150 billion, with ownership transferred to companies covered by the scheme. The transfer was justified on the grounds that the operating costs for these companies would be increasing as a result of the additional costs of carbon created by the EUETS. However, in many cases the degree of free allocation significantly over-compensated companies. This was particularly the case in the electricity sector, where electricity prices generally increased to cover the additional running costs, such that the carbon price was effectively passed on to the consumer. The value of the free allowances therefore effectively accrued to the power companies as windfall profits. Such effects also occurred but to a lesser extent in industrial and manufacturing sectors.

These issues led to a redesign in the third phase of the EUETS, such that there is a progressive move towards almost full auctioning of allowances by the end of Phase III. The power sector will see a particularly rapid move towards full auctioning during the early part of the third phase. This move marks a significant centralisation of allowance allocation across the EU. In earlier phases, allocation to different sectors was left up to individual Member States, with the role of the EU limited to an oversight function ensuring that individual plans added up to a sufficient level of environmental improvement across the EU as a whole. In Phase III, the total number of allowances to be created is determined for the EU as a whole. These are then divided between Member States who may hold their own individual auctions, and retain the income from these auctions.

Allowances are divided between Member States according to a politically agreed formula, resulting from a negotiating process between Member States. This represents a significantly better defined process than under the earlier phases of the scheme. In phases I and II, Member States also had a politically negotiated agreement defining emissions limits, but these had been negotiated in the context of the Kyoto targets for the period 2008-2012, and covered total emissions of greenhouse gases at the national level. Member States were able to define their own (free) allocations of CO_2 allowances to companies in the EUETS, as long as they could show that these

allocations were in line with the national greenhouse gas targets. These plans were laid out in so-called National Allocation Plans written by each country. This system was significantly less robust because the political economy at national level encouraged each Member State to tend towards over-allocation. Although the plans were vetted by the EU, and reductions in allocation levels were consequently made, the system was subject to political pressure to weaken the environmental integrity of the scheme.

This centralisation has made the target setting process more transparent and robust, and has led to better coordination of supply and demand across the trading system. These measures should help remove competitive distortions between Member States since all companies would have equal access to allowances at the same price, and improve the efficiency of the mechanism. Nevertheless, centralising decision-making in relation to any form of taxation in the EU is difficult politically because of the sovereignty of Member States to raise taxes over which the EU does not have jurisdiction. Auction revenues accruing to Member States, could be in the region of €30-60 billion per year depending on the carbon price. However, there is some tension over the use of these auction revenues: Member States would generally like to maintain the maximum amount of flexibility over how the funds are spent to meet their own domestic political agendas, whereas the EU would prefer to ensure that a significant fraction of the revenues are spent on environmental improvements so as to help ensure the environmental effectiveness of EU policy.

The increased transparency in the target-setting process does not, however, make political agreement on what the target should actually be any easier. As discussed above, there is still ongoing negotiation over what target to set for 2020 within the EUETS. Nevertheless, the EUETS provides useful lessons for China when thinking about how targets would be set and allowances allocated. Free allocation of allowances can certainly help to overcome the resistance of companies to a change in regulatory regime in the scheme's early stages. However, the complexities of determining exactly what level of allowances each company should get soon start to outweigh the benefits and policy-makers should plan for a relatively rapid transition towards auctioning of allowances rather than free allocation.

Auctioning has many benefits in terms of ensuring a level playing field for all companies in the trading scheme and creates much clearer investment signals for companies to help start the process of decarbonisation. Auctioning allowances also avoids the competitive distortions that can arise between sectors and regions from allocation schemes that are based on politically negotiated target-setting processes. A centralised auctioning mechanism creates a single price for all companies; it also creates the possibility to raise significant amounts of revenue and agreement on how to spend these revenues needs to be reached. For example, how these revenues should be divided between central and regional governments, and how much should be earmarked for environmental improvements.

Box 1-4: Auction revenues from the EU Emissions Trading Scheme

Auction revenues from the EUETS could be in the region of €30-60 billion per year by 2020. This is a significant amount: over the period to 2020, the total income could be over €300 billion, giving the EU a low-carbon 'war chest' almost an order of magnitude larger than the amount allocated to green energy in the US stimulus package. The Directive has been amended to require Member States to spend at least 50% of these revenues (or an equivalent amount from the central budget) on one or more of the following climate-related areas:

- To reduce greenhouse gas emissions, including by contributing to the Global Energy Efficiency and Renewable Energy Fund and to the Adaptation Fund as operationalised by UNFCCC COP 14 in Poznan; to adapt to the impacts of climate change and fund R&D; to fund demonstration projects for reducing emissions and adaptation , including participation in initiatives within the framework of the European Strategic Energy Technology Plan and the European Technology Platforms
- To develop renewable energies to meet the EC's commitment of using 20% renewable energies by 2020; to develop other technologies contributing to the transition to a safe and sustainable low-carbon economy; and to help meet the EC's commitment to increase energy efficiency by 20% by 2020
- For measures to avoid deforestation and increase afforestation and reforestation in developing countries that have ratified the future international agreement; to transfer technologies and to facilitate adaptation to the adverse effects of climate change in these countries
- For forestry sequestration in the EU
- For the environmentally safe capture and geological storage of CO_2, in particular from solid fossil fuel power stations and a range of industrial sectors and sub-sectors, including in third countries
- To encourage a shift to low emission and public forms of transport
- To finance R&D in energy efficiency and clean technologies in the sectors covered by the scope of the directive
- For measures such as those intended to increase energy efficiency and insulation or to provide financial support in order to address social aspects in lower and middle income households;
- To cover administrative expenses of the management of the Community scheme.

One problem with such earmarking is that the income from both emissions trading schemes and taxes are uncertain. In the case of trading schemes, the quantity of allowances to be auctioned is known but their price is uncertain, whereas in the case of a tax, the price is known but the emissions level is uncertain. Governments will, therefore, need to identify who bears the risk of these uncertainties when they commit funds to long-term programs such as R&D or adaptation where secure financing will be important.

Another issue that affects the possible design of a Chinese emissions trading scheme is the type of target that would be defined for the participating companies. The EUETS sets targets in terms of an absolute level of CO_2 emissions during the compliance period. Other emissions trading schemes may be based on a relative target, which could relate emissions to some measure of activity such as emissions per unit of output. Relative targets may provide more flexibility and be perceived as having lower economic risk for participating companies, as they might appear to be less constraining of economic growth. Clearly, the total amount of effort required by any particular company would depend on the stringency of the targets under either an absolute or relative target system.

There is less experience of full-scale trading schemes using relative targets. One of the complications of such a scheme is that the final allocation of allowances to a company can only take place once the final figure for the company's output during the compliance period is known (although some initial allocation could be made with ex-post adjustments). The risk of expanding the total number of allowances in the system as a result of economic (and hence emissions) growth has led to caution in the use of these mechanisms. One example occurred in the UK emissions trading scheme where one set of participants had absolute CO_2 targets, and another set of participants had intensity-based targets. Trading between the two groups was constrained by a 'gateway' which limited the flow of allowances from the intensity-based group, to ensure that there was no devaluation of the carbon 'currency' in the trading system. The mechanism proved relatively complex to administer, and the UK-ETS was superseded by the EUETS.

Nevertheless, designing an emissions trading scheme around intensity-based targets is possible, as long as robust systems can be put in place to measure the output quantity sufficiently accurately to allow calculation of performance against targets (relative to a business-as-usual pathway – itself challenging to define). It is also important to recognise that the targets will have to show a steeper decline over time than absolute targets in order to achieve the same environmental effectiveness in a context of economic growth.

Linking an ex-post allocation system to the EUETS is in principle possible, as long as there are clear rules regarding the status of allowances in relation to any allowances that were issued prior to final ex-post adjustments. Linking of emissions trading schemes can lead to economic benefits for companies in both schemes, as it encourages investment in the lowest cost abatement options in the two regions covered by the linked schemes. The political, economic and environmental benefits of linking depend on the wider policy framework in place governing the accounting of emissions at a national level. Linkages between two countries which themselves have absolute targets would appear to be more politically acceptable, since any additional environmental impacts created by faster-than-expected economic growth in the trading scheme would have to be offset by the government (e.g. by achieving greater emission reductions in other sectors outside the trading scheme, or by buying international emissions offsets). However, in practice, it seems unlikely in the near future that the EU would agree to link the EUETS to an intensity-based scheme because of the additional complexities and environmental uncertainties involved.

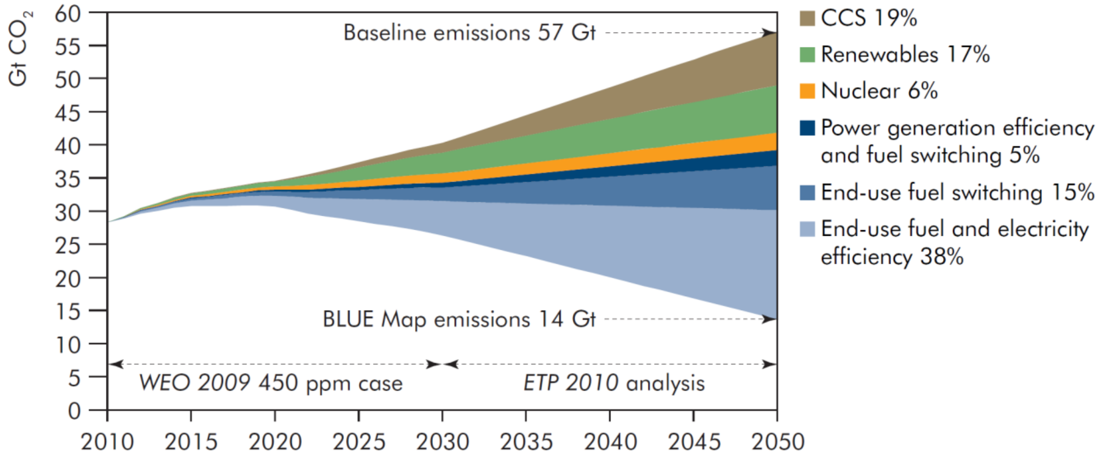
Another interesting aspect of the recent changes to the EUETS is the increased coverage of the scheme to include new sectors, most notably the aviation sector. Clearly, aviation is an international business and unilateral action risks creating competitive disadvantages for EU-based flight routes which could affect European airlines and airports. This competitiveness effect was the reason why an international deal had been sought through the International Civil Aviation Organisation as a parallel to the Kyoto Protocol, but no international solution appeared to be forthcoming. The fact that the EU has managed to agree to bring aviation within the scope of the EUETS shows that it is possible for regions that are sufficiently large to take unilateral action in the absence of adequate international measures. It remains to be seen what the actual competitiveness effects will be. It also remains to be seen whether inclusion of aviation in a regional scheme leads to increased pressure from companies to create a level playing field by pushing for a more harmonised international approach to aviation emissions.

1.3.3 Energy efficiency in industry

According to both the IPCC and the IEA, cost-effective energy efficiency improvements could contribute to half the potential emissions reductions by 2020 and beyond. Furthermore, energy efficiency addresses all aspects of energy policy, environmental sustainability, security of supply and competitiveness largely at a lower cost than new supply options.

Figure 1.3 below, from the IEA's Energy Technology Perspectives, illustrates the potential role of energy efficiency in meeting CO_2 emissions reduction targets. End-use fuel efficiency and end-use electricity efficiency could provide 38% of the emissions savings by 2050. As the IPCC said in its Fourth Assessment Report, it is often more cost-effective to invest in end-use energy efficiency improvement than in increasing energy supply to satisfy demand for energy services.

Figure 1.3: the potential role of energy efficiency in meeting CO_2 emissions reduction targets



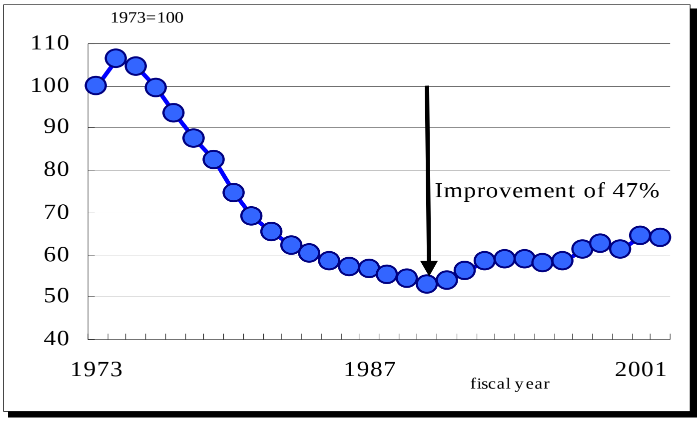
Source: IEA 2010[46]

The EU energy efficiency action plan proposes a 20% improvement in energy efficiency by 2020. This is already resulting in a dramatic increase in attention paid to energy efficiency across the EU. If successful, this would mean the EU would use approximately 13% less energy than today by 2020, saving €100 billion and around 780 mtCO_2 each year.

A number of EU Member States including Ireland and the UK have proposed bans on the use of inefficient lighting systems, in line with the objectives of countries like Australia and regions like California. Significantly, the European Commission has been asked by the Member States to examine areas where economic instruments, including VAT rates, can have a role to play to increase the use of energy-efficient goods and energy-saving materials.

Due to low resource endowment Japan has always been aware of the importance of security of supply. Concerns were heightened in the 1970s with the oil shock and led to the introduction of strong domestic programs, which resulted in the Japanese economy becoming one of the most energy efficient in the world. Figure 1-5 below demonstrates the extent to which these policies were successful in driving down the energy intensity of the country’s economy.

Figure 1-5: Manufacturing Industry in Japan: energy consumption per production

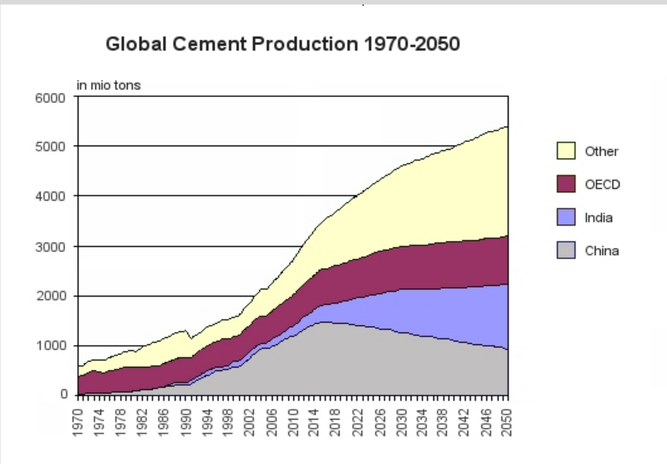


Source: IEEJ-EDMC, Handbook of energy & economic statistics in Japan

In response to energy challenges, Japan addressed energy use across all sectors of society. These policies include setting of standards for boilers, promotion of energy efficient appliances and lighting, and the use of intelligent transport systems. However, in recent years improvements in energy efficiency have stagnated. To further stimulate improvements, new initiatives being put forward. Specifically, the 'Top Runner' program was developed in 1999 to set targets by product category, for example for cars, TVs or air conditioners. In each category, the most efficient model currently on the market is used to set the standard to be attained within four to eight years.

By the target year, each manufacturer must ensure that the weighted average of the efficiency of all its products in that particular category is at least equal to that of the top runner model. This approach eliminates the need to ban specific inefficient models from the market. At the same time, manufacturers are made accountable and, perhaps most importantly, they are stimulated to voluntarily develop products with an even higher efficiency than the top runner model.

Box 1-5: The case of cement



Source: International Energy Agency (IEA)

The cement industry contributes about 5% to global CO_2 emissions and around 18% of GHG emissions produced by industry. Under a business-as-usual scenario these emissions are expected to rise from around 2 Gt today to just under 5 Gt in 2050[47]. Production is energy intensive, primarily using coal;

energy consumption by the industry is around 2% of global energy consumption and 5% of industrial consumption.

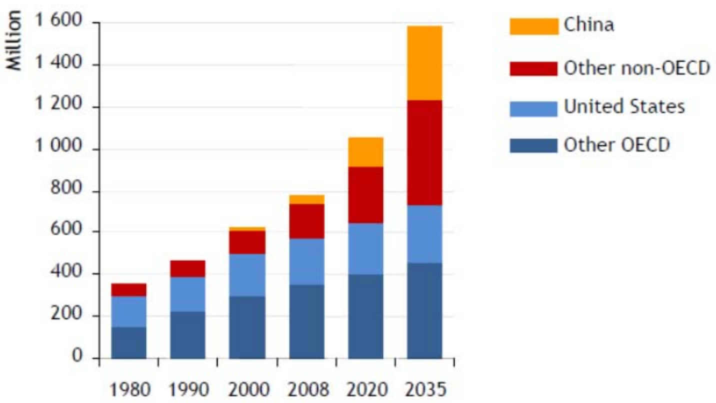
Of the top twelve producers of cement in the world (around 81% of the world total) only three have experienced negative growth since 1999: the EU, Japan and Turkey. The cement industry continues to grow most rapidly in developing countries as it responds to demand for infrastructure and housing; this is especially true for China, India and a number of Middle Eastern countries. Yet some of the cleanest cement plants are located in these rising economies due to newly built facilities; the older, least efficient plants tend to be in US. Whilst cement emissions in Europe, Australia and Japan are declining or stagnant, they have risen in East and South Asia, South America, the USA and the Middle East.

The WBCSD estimates that 80% of the future emissions from cement plants will take place in emerging economies such as China and India. China accounts for 50% of the global market in terms of both production and consumption of cement - a figure widely predicted to rise[48] and with an important impact on China's energy use and CO_2 emissions. Yet the international trade volume of Chinese cement is very limited, suggesting a strong correlation between Chinese growth and high levels of consumption in the cement sector driven by domestic infrastructure needs.

1.3.4 Efficient vehicles

Global automobile demand is set to grow rapidly, largely driven by increasing car ownership in developing countries as incomes rise. In IEA's baseline scenario, the total stock increases from about 750 million in 2007 to more than 2.2 billion by 2050. This represents a major area of potential growth in greenhouse gas emissions.

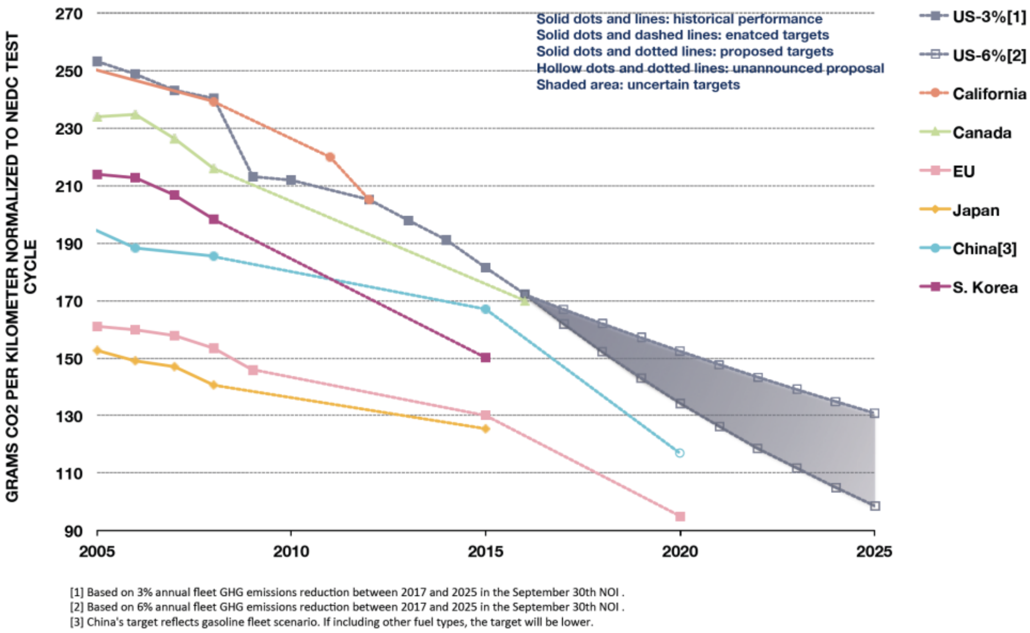
Figure 1-6: Passenger vehicles in the IEA's New Policies Scenario



Source: IEA 2010

The three main options for reducing automobile emissions are to: encourage modal shift to alternative forms of transport; improve the efficiency of internal combustion engines; or switch to lower carbon fuels. The International Council on Clean Transportation provides a comparison of global vehicle efficiency standards. Figure 1-7 shows the global standards normalized to NEDC cycle (in gCO_2/km). Japan has had the toughest targets since the 1970s, but the EU has closed the gap in recent years. Japan is now in the process of determining a standard for passenger car fuel economy for 2020 and a formal proposal is expected by the end of 2011.[49] There is a significant lag between the introduction of targets and the impact on the total vehicle fleet. For example, in the EU new passenger cars are about twice as efficient as the average for the whole car fleet.[50]

Figure 1-7: Evolution in vehicle emissions standards



Source: ICCT, 2011

In the EU, an ambitious compromise deal was agreed in December 2008, despite industrial pressures caused by the financial crisis. This will gradually limit CO_2 emissions to 120g/km for 65% of new cars in 2012, 75% in 2013, 80% in 2014 and 100% in 2015 (2004, 161g/km). A target of 130g/km is to be reached by improvements in vehicle motor technology; a further 10g/km reduction should be obtained by other technical improvements, such as better tyres or the use of biofuels. Between 2012 and 2018, the fine for non-compliance will be as follows: €5 for the first gram of CO_2, €15 for the second gram, €25 for the third and €95 from the fourth gram of CO_2 onwards. From 2019, manufacturers will have to pay €95 per gram exceeding the target.

The Global Fuel Economy Initiative has proposed a target of 50% fuel economy improvement worldwide by 2050, with interim targets. It argues that the benefits are large and greatly exceed the expected costs of improved fuel economy. Cutting global average automotive fuel consumption (l/100 km) by 50% would reduce emissions of CO_2 by over 1 gigatonne (Gt) a year by 2025 and over 2 gigatonnes (Gt) by 2050, and result in savings in annual oil import bills alone worth over USD 300 billion in 2025 and 600 billion in 2050 (based on an oil price of USD 100/bbl).[51]

Further emissions savings can be made by substituting petrol and diesel for sustainable biofuels in internal combustion engines. However, biofuels are at the centre of an often heated international debate involving questions of energy security, climate change, food prices, biodiversity conservation and social development.[52] Government policies to support the production and use of biofuels are motivated by their potential to reduce greenhouse gas emissions as an alternative to fossil fuels. But the record price spikes for food commodities in 2008, for example, have been blamed in part on the diversion of food crops for biofuel production. Other analysis has suggested that estimates of biofuels-related carbon benefits generally fail to include emissions from land-use changes.[53] The World Bank has drawn attention to the

economic viability of current biofuel programs, including upward pressure on food prices as well as intensified competition for land and water.[54] Other critics have also raised concerns over social problems related to land use, often exacerbated by the lack of clear tenure rights. Growing criticism of biofuels has put many governments under pressure to rethink their policies. The EU, while retaining its target of 10% biofuel requirement by 2020, has opted to include some sustainability criteria. The challenge for governments will be to provide this support in a way that is backed up by evidence and is sufficiently neutral to move towards the most promising biofuels. Second generation biofuels technology focuses on breaking down lignin and cellulose from woody substances to release sugars that can then be fermented in a process similar to first generation biofuels. This has the potential to greatly increase the volume of available material without competing with food crops and can achieve far higher greenhouse gas reductions. However the main technologies are not yet scaled up commercially and technical challenges remain. The impact of growing second generation biofuels on soil quality is also under consideration.

In the last few years electric vehicles have increasingly been considered as the most promising alternative to the internal combustion engine. Many developed countries and China have made commitments to deploy electric vehicles (see Table 1.5) The EV20 alliance of companies announced in September 2010 that its members would add one million EVs to the roads by 2015 compared with targets already announced by companies.

Table 1-5: EV targets

Austria	*2020: 100,000 EVs deployed*
Australia	*2012: first cars on road, 2018: mass deployment, 2050: up to 65% of car stock*
Canada	*2018: 500,000 EVs deployed*
China	*2015: 1,000,000 annual production of EVs*
Denmark	*2020: 200,000 EVs*
France	*2020: 2,000,000 EVs*
Germany	*2020: 1,000,000 EVs deployed*
Ireland	*2020: 10% EV market share*
Israel	*2011: 40,000 EVs, 2012: 40,000 to 100,000 EVs annually*
Japan	*2020: 50% market share of next generation vehicles*
New Zealand	*2020: 5% market share, 2040: 60% market share*
Spain	*2014: 1,000,000 EVs deployed*
Sweden	*2020: 600,000 EVs deployed*
United Kingdom	*No target figures, but policy to support EVs*
United States	*2015: 1,000,000 PHEV stock*

Source: Foley et al, 2010[55]

1.3.5 Renewable energies

The growth in the global renewable energy industry has been rapid in recent years. Direct investment in new renewable capacity rose from USD 8 billion in 1997 to USD 30 billion by 2004[56] and in 2010 totalled over USD 120 billion.[57] This level of growth far exceeds the growth of the more traditional energy sector: from 2007 onwards wind energy attracted more annual investment on a global scale than nuclear or hydro power.

Europe continues to have the largest investment in low carbon energy for any region in the world: in 2010, new investment including mergers and acquisitions totalled

USD 94.4 billion. In the same year, wind accounted for more new generation capacity in Europe than any other power source. The main reason for this level of investment is the clear, and now binding, requirement of Member States to increase the contribution of renewable energy. The introduction of a target calling for 20% of the EU's energy to come from renewable energy sources by 2020 is undoubtedly extremely ambitious as it will require a more than 3 fold increase from current levels. Experience in some Member States, in particular Denmark, Germany and Spain, shows that the right policies - those that create market certainty in the medium and long term - can rapidly drive the diffusion of technology.

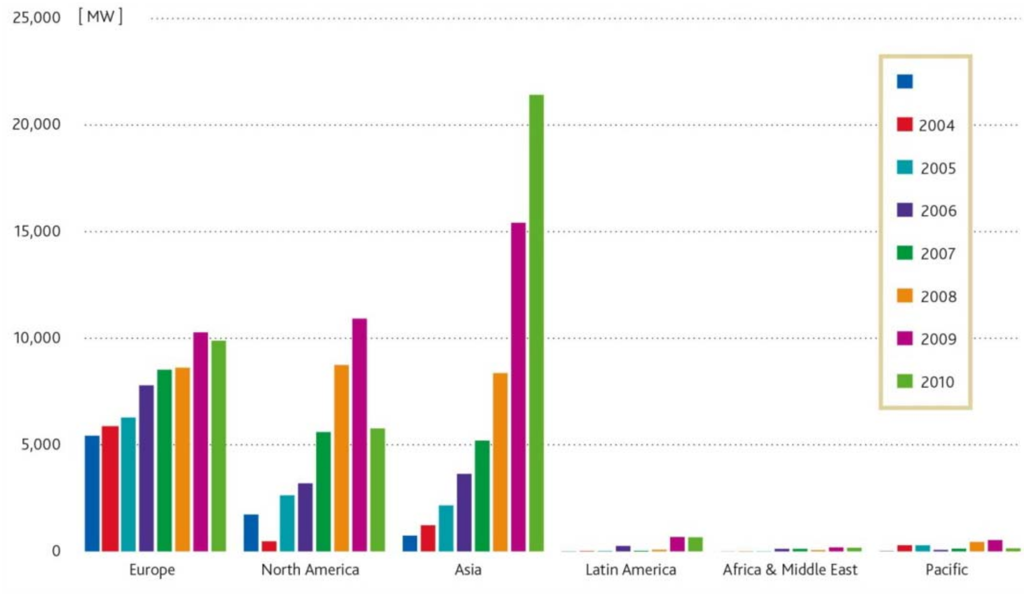
Across the United States, states, municipalities and utilities are putting in place mechanisms and targets to increase the use of renewable energy. The DSIRE web site list 37 states in which action has been taken to create specific targets for the use of renewable energy. In Florida for example, the state utility is required to produce 7.5% of its electricity from renewable energy sources by 2015; elsewhere, in Massachusetts all electricity retailers must produce 4% of their electricity from renewable sources by 2010. At a federal level, the US provides investment and production tax credits for renewable energy which has helped encourage development of wind power in particular in recent years. The US leads the world in new wind power installations, accounting a quarter of the global total in 2007.

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

In India, the government has set a target for 10% of the country's energy to come from renewable energy by 2032. In order to achieve this, specific targets have been put in place for the electricity and transport sectors. The growth in the wind sector is the most notable, with a proposal to move from 7.8 GW to nearly 20 GW by 2012. In 2007, 1.7 GW of new capacity was added. However, to many this is just the beginning and Low Carbon Energy Finance predicts that by 2020, 42 GW is possible. Currently, the Indian Wind Turbine Manufactures Association estimate that the potential is in the order of 65 GW. In global terms, India is the fourth largest wind energy generator with a major turbine manufacturing base. The industry's products are used for both domestic and export markets, and the sector provides around 10,000 jobs.

However, Asia - and China, in particular - is rapidly increasing its manufacturing and deployment of wind power. Figure 1-8 shows how, in 2009/10, Asia overtook both Europe and American annual deployment rates. The graphic also highlights the degree to which certain large markets, such as the Middle East, are yet to deploy wind power on any scale. This suggests that a considerable global market is still to emerge.

Figure 1-8: Growth in Global Wind By Region



Source: Global Wind Energy Council 2011[58]

1.3.6 Carbon footprint

A 'carbon footprint' measures the total greenhouse gas emissions caused directly and indirectly by a person, organisation, event or product.[59] This allows individuals, companies and potentially countries to calculate the greenhouse gases released as a result of their activities. It is also a way to assess the emissions associated with a specific product along the supply chain, enabling consumers to make more informed choices.

Over 50% of an average corporation's carbon emissions are typically from the supply chain rather than within an organisation's direct activities and transport.[60] A major challenge lies in developing a consistent and comparable approach to carbon footprinting, given the methodological issues associated with, for example, defining system boundaries. Adding a carbon label to a product is a complex and often costly process that involves tracing its ingredients back up their respective supply chains and through their manufacturing processes to work out their associated emissions.[61] Nonetheless, there is growing pressure on the private sector to assess and address emissions as part of corporate good practice. According to the Carbon Disclosure Project, 534 institutional investors controlling USD 64 trillion in assets request disclosure from listed companies in whom they invest.[62] The expectation is that the cost of carbon will be increasingly internalised by companies, even while regulation remains patchy across the globe and despite the absence of a global binding agreement on climate change. By acting early they position themselves well for future low carbon markets and avoid unnecessary costs.

Since 2007, carbon footprinting activities in the UK and France have helped shape the two global standards that may provide the basis for a consistent international approach: ISO 14067, being drawn up by the International Organisation for Standardisation, and the GHG Protocol, a project backed by two environmental groups - the World Resources Institute and the World Business Council for Sustainable Development.[63]

The debate over how and where greenhouse gas emissions should be quantified has been rising up the policy agenda in recent years as part of discussions over the future of international climate policy post 2012 and the end of the Kyoto Protocol's Phase II. The primary question is whether emissions should be allocated to the country where the emissions have been released (a production-based approach), as is the case at present, or where the end products have been consumed (a consumption-based approach).

Proponents of consumption-based approaches make several arguments, for example: that consumers should be responsible for the full cost of their environmental impact; that consumption-based approaches would require policy makers in developed countries to focus more on addressing the emissions embedded in high carbon traded commodities, thus having a greater environmental impact; and that it would improve the prospects for a global binding agreement on climate change, by encouraging the participation of energy intensive exporters. Proponents of the current system argue that in a global cap-and-trade system with given emission caps, switching from a production- to a consumption-based accounting system has neither efficiency nor distributive effects. Which countries would benefit from a switch depends on the precise structure of arrangements in the meantime, which is likely to complicate rather than simplify negotiations. They also argue that it introduces considerable methodological uncertainty (with a detrimental impact on environmental efficacy), as well as significant transaction costs.[64]

Irrespective of the approach used in the global climate regime, the use of consumption-based numbers can be useful to decision makers and the general public in understanding the environmental consequences of their policies. For example, recent analysis by Glen Peters et al.[65] shows that most developed countries have increased their consumption-based emissions faster than their territorial emissions, with non–energy-intensive manufacturing playing a key role in emission transfers. The net emission transfers via international trade from developing to developed countries increased from 0.4 Gt CO_2 in 1990 to 1.6 Gt CO_2 in 2008, which exceeds the Kyoto Protocol emission reductions.

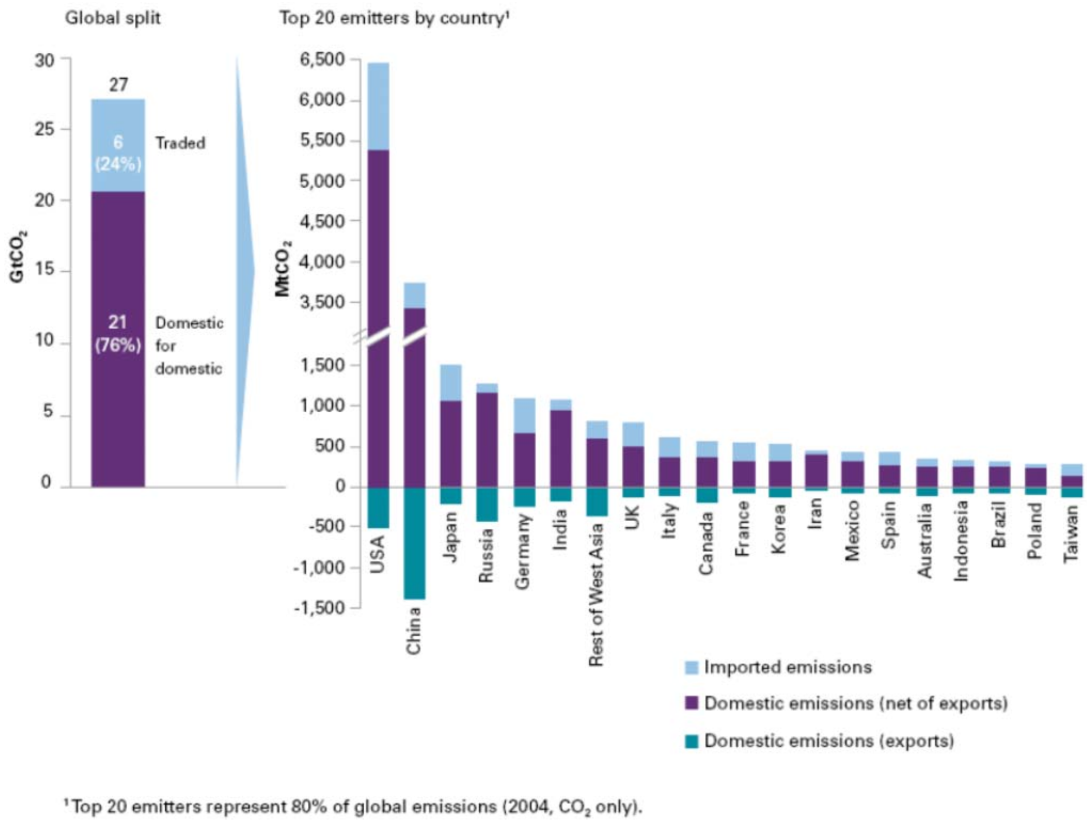
Another recent study by the UK's Carbon Trust provided the following conclusions:

- **Embodied carbon flows are large and growing:** approximately 25% of all CO_2 emissions from human activities 'flow' (i.e. are imported or exported) from one country to another.
- **Embodied carbon imports are significant for many developed economies:** major developed economies are typically net importers of embodied CO_2 emissions. UK consumption emissions are 34% higher than production emissions; Germany (29%), Japan (19%) and the USA (13%) are also significant net importers of embodied emissions. For some economies with very carbon efficient production processes, the relative importance of imported carbon is even greater. The high levels of net imports in France (43%) and Sweden (61%) reflect in part the low carbon intensity of their energy systems.
- **Many developing countries export embodied emissions in international trade:** developing countries are generally net exporters of CO_2 emissions. For

example, in 2004 China exported around 23% of all its domestically produced CO_2.

- **Embodied carbon flows in both commodities and final products:** the flow of carbon is comprised of roughly 50% emissions associated with trade in commodities such as steel, cement, and chemicals, and 50% in semi-finished/finished products, such as motor vehicles, clothing or industrial machinery and equipment.[66]

Figure 1-9: Production of CO_2 emissions by country, and the import and export of CO_2 emissions embodied in trade

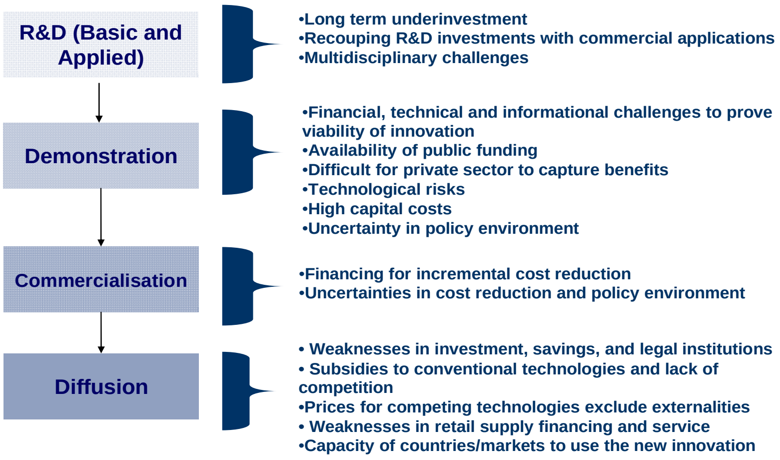


Source: Carbon Trust Analysis; CICERO / SEI / CMU GTAP7 EEBT Model (2004)

1.4 Accelerating innovation

Innovation is recognized across the G20 as central to future growth and competitiveness, especially in the context of the resurgence of global manufacturing. The focus is now often on green, efficient technologies – such as in energy, transport and buildings. Yet despite broad agreement on the importance of low carbon energy technology, there has been slow progress on developing and implementing a practical and effective innovation system of incentives to drive the transition to a low carbon economy at scale. Furthermore, there are barriers to innovation which can prevent or slow technological development anywhere from the early R&D phase through to the rolling out of the technologies. As Figure 1-10 shows, these barriers can occur at multiple points in the innovation chain (this is a simplification as in practice these elements interact in a dynamic fashion).[67]

Figure 1-10: Understanding barriers along the innovation chain



Source: UNDP (2000); OECD (2006); Chatham House and E3G (2007-08)

Overcoming these barriers and delivering low carbon technological options at scale is no mean feat at a time of volatile energy prices and the global economic downturn. A careful balance between private interests versus the delivery of global public goods is also critical, as are the needs of developing countries.

The race for low carbon technology solutions offers genuine opportunities for developed and developing countries to embrace new models of technological cooperation, whether at the domestic, bilateral or multilateral level. For developing economies, it can provide an opportunity to increase their share of value addition through the production of low carbon goods and services. This will enhance the prospect of de-linking their economic growth from environmental harm. The size of emerging economies' markets and their potential manufacturing power also offers some economically viable pathways to drive down the costs of the energy transition, while building new markets for low-carbon goods and services.

While the traditional concept of 'technology transfer' implies a process through which a piece of equipment or blueprint is transferred to a recipient company or country, this is only half the story. Moving up the technology ladder is as much about access to the physical hardware as it is about acquiring the knowledge and know-how to use it effectively. Technological innovation is needed across a broad range of areas, encompassing high technology, materials, industrial process, consumer products and business practice

Box 1-6: Japanese-Indian Joint initiative on Smart Communities[68]

In January 2011 a consortium of five heavy industrial companies (Mitsubishi Heavy Industries, Ltd. (MHI), Mitsubishi Electric Corporation, Mitsubishi Corporation, Mitsubishi Research Institute, Inc. and the Electric Power Development Co., Ltd. (J-POWER)) signed a Memorandum of Understanding with the State Government of Gujarat to promote the development of a Smart Community. This aims to create energy-conserving, low-carbon, next-generation urban infrastructure through the introduction of advanced energy-saving technologies and urban transportation systems. This is a part of the larger Delhi Mumbai Industrial Corridor development, which is connecting industrial parks, power plants, airports, ports, railways, roads and commercial facilities. The partnership will target business development opportunities in high-efficiency power generation systems leveraging natural gas and power generation systems using renewable energies, such as solar thermal, as well as promoting electrification in the transportation sector.

It is critical not to overlook the range of substantive gains to be achieved through the diffusion of incremental technologies, such as improved insulation and furnace technologies, and of 'soft' practices, for example congestion charges, industrial process optimisation training, lean manufacturing and quality management, and SCADA systems. These soft practices and incremental improvements have different barriers to implementation than large-scale capital investment in horizon technologies. While many of the critical technologies have already been developed, it is important to pursue the high-tech and 'disruptive' technologies (important in many energy scenarios) to move onto a low-carbon path,

The development of energy technologies rarely follows a linear logic or evolves within the boundaries of individual economic sectors. Many breakthrough innovations occur when different fields interact. For example, innovation in solar PV technologies has benefited from developments in consumer and industrial electronics, and advances in CSP derive from aerospace and satellite technologies.

Innovation in the supporting infrastructure for low carbon technology deployment will also play a vital role, for example the charging network for electric vehicles and grid extensions to connect dispersed renewable energy generation. There has been considerable interest in "smart grid" innovation in recent years as a more flexible model for electricity would allow for greater penetration of renewables and better demand management. This would spread demand so that less generating capacity is needed at peak times. Box 1-7 explains the trends on smart grid innovation in key countries.

Box 1-7: Smart Grids

A rapid rise in the market size of smart grids has been forecast by an array of studies. However, as well as the usual uncertainties that exist with market predictions, looking to the future for smart grids has additional problems, namely:

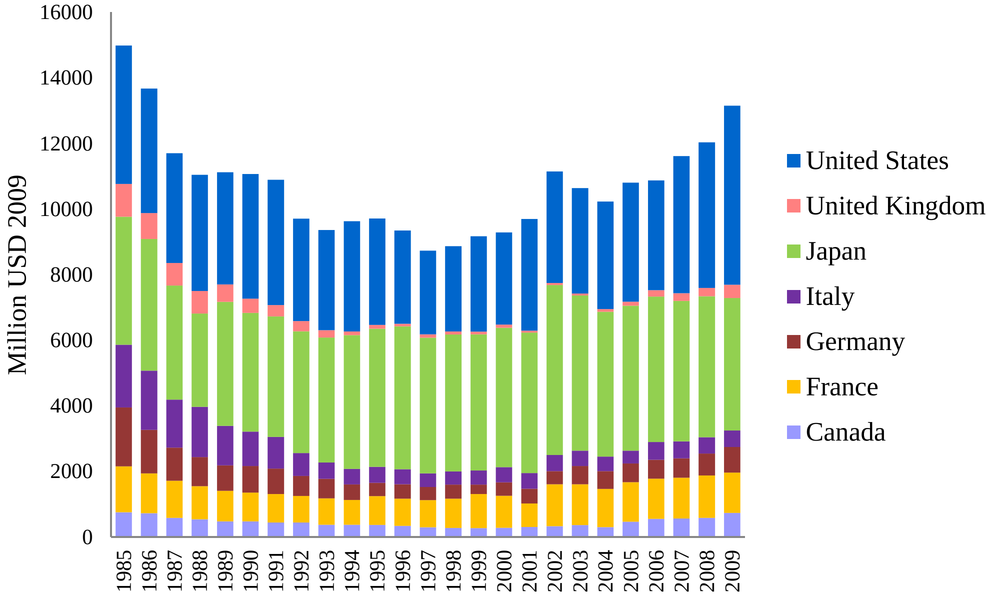
- Many of the technologies are relatively new and the production costs of global diffusion less certain
- There will be significant costs associated with the installing of new equipment
- There is no universal definition of a 'smart grid' and therefore no benchmark by which cost comparisons can be made
- Many investment costs, either for the necessary upgrading of transmission and distribution equipment or the installation of new systems, may be defined as 'smart'.
- The mixture of public and private finance expected in the smart grid will help shape investment patterns and definitions. In the US the market is expected to grow to USD 9.6 billion by 2015, assisted by USD 3.4 billion in federal stimulus grants[69].

1.4.1 Building capacity on R&D

Even though global R&D investment is mostly undertaken in the private sector and is increasingly global in nature[70], government action and public policy can help leverage the power of private markets to solve low carbon innovation challenges.

While public spending on overall R&D increased by 50% between 1988 and 2004, public energy-related R&D declined by 20% over the same period of time. However, in recent years, partly due to the stimulus packages, energy expenditure has increased in a number of countries, while overall private sector R&D in energy has decreased.[71] The other trends to note are that there is a strong bias towards certain technologies. Nuclear power (both fission and fusion) has received over half of all state R&D budgets from the G7 countries over the last two decades, more than five times the combined energy efficiency budgets. Innovation in climate mitigation technologies is concentrated in a few countries: Japan (42% of total patents), Germany (13%), US (12%), China (6%), South Korea (5%) and Russia (4%).[72]

Figure 1-11: Public energy-related R&D spending in G-7 countries, 1985-2009 (Million USD 2009)



Source: IEA database of R&D, 2011[73]

In 2005, businesses accounted for almost 63% of R&D funding in OECD countries. The private sector funds three-quarters of R&D in Japan and 65% in the United States, but only 54% in the European Union. However, governments remain the major source of R&D funding in almost one in four OECD countries. On average around 7% of R&D performed is financed by direct government funds. This is primarily due to trends of increasing adoption of other policy instruments to stimulate innovation, such as R&D tax incentives.

Box 1-8: Alternatives to high carbon products and approaches

Innovation will play a critical role in improving the products and technologies that are already part of our daily experience, from cars to electronic goods and buildings to more efficient coal power plants. However, given the scale of the climate change challenge and concerns about resource constraints, China's vision of low carbon industrialization in the 2020s needs to consider the role of alternatives to existing products, materials and industrial methods. Could there, for example, be an alternative to cement or steel in construction?

A new market for sustainable products and low carbon commercial vehicles are at the forefront of this trend. There is evidence that consumer demands are shifting in favour of sustainable products shown, for example, by the rise in sales of hybrid cars (2,200% since 2000 in the US alone). Despite fears that the current economic climate will discourage demand for more costly, sustainable products, consumer understanding of environmental performance is on the increase. Furthermore, in some products, such as hybrid cars and energy efficient light bulbs, there is recognition that resource efficiency reduces expenditure. These new developments, particularly apparent in the automotive industry, are creating momentum for a sustainable, low carbon economy and adding to expectations and challenges of corporate roles, particularly in the developing world.

Insufficient attention has been paid to developing alternatives to these highly emissive goods, despite the fact that this would significantly improve efficiency and produce sustainable products that are both less vulnerable to resource scarcity and appealing to the changing consumer market.

Bridging the gap between the R&D phase to full-scale commercialisation represents a significant limiting factor in the uptake of new technologies. The size and complexity of demonstrating these new technologies, which often includes intricate planning and infrastructural support, makes it difficult for the private sector to independently

finance them. This is particularly the case with large scale or unproven technologies, such as CCS and biorefineries. Public funding, public-private partnerships and joint ventures are an effective way of raising the necessary capital and for pooling expertise essential to getting a new project off the ground.

The collaborative project between pulping giant Weyerhaeuser, the Swedish company Chemrec and the US Department of Energy saw the piloting of the first full-scale high-temperature, black liquor gasifier at the North Carolina facility [74]. This technology made it possible to achieve higher overall energy efficiency in the paper-pulping process by recovering energy-rich syngas from the pulping by-products. More recently, Chemtec attracted EU funding for the development of a demonstration plant for the production of bio-methanol and other biofuels from black-liquor pulp mill residue.[75] The project is expected to generate important external benefits, contributing in particular to knowledge spill-over, environmental protection and regional development, as well as enhancing the subsequent industrial uptake of the new technology with a significantly lower level of risk.

Innovation is becoming increasingly international both in terms of finance and actual research. The average R&D intensity of affiliates under foreign control is higher than the R&D intensity of domestically controlled firms in most countries.[76]

In 2005, China became the third largest R&D spender worldwide (in purchasing power parity terms) after the United States and Japan. Emerging economy firms are also increasingly investment in developed countries. A recent study showed that Chinese firms alone set up 37 R&D units abroad, of which 26 are based in developed countries (11 in the USA and 11 in the EU)[77]. Emerging economy firms have also acquired developed country firms in order to gain access to their intellectual property and markets.

Environmental and resource constraints will make it increasingly difficult for emerging economies to follow the 'traditional' pathway to industrialization. Stating the unsustainability of the traditional industrialization model, however, is insufficient to trigger a sea-change in approach. It is, therefore, crucial that both developed and developing countries actively pursue an alternative strategy for growth by encouraging and collaborating on low carbon innovation. Furthermore, that they demonstrate how and why the effects of decarbonisation could be positive overall for industrial development, applicable to key industries and implemented without compromising efforts to deliver infrastructure.

A substantial strengthening in the innovation base is the best way for China to position itself. There is little alternative for China but to generate a range of options and flexibility in order to thrive in future years. Research, development, deployment and associated infrastructure, as well as continued investment in key sectors, will play a key part. China must also look more broadly, building up education and human capital at all levels and stimulating a culture of innovation across society.

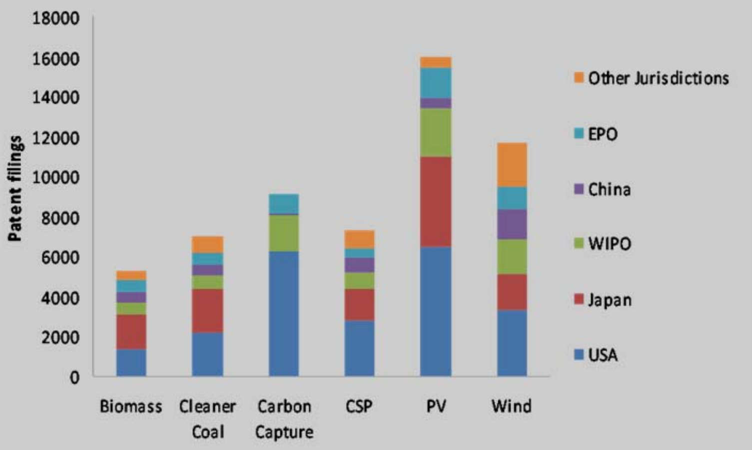
There is no doubt that China has the capacity and the need to become a global leader in sustainable development and innovation in environmental technology and Chinese leaders have long recognized that a more sustainable model of development is required given constraints on resources and environmental impacts.[78] However, no one country will hold the keys to the low carbon economy: collaboration on the development and supply chains of key technologies will be vitally important. China

must maintain a vision of open innovation and investment to ensure the flexibility that is necessary for a prosperous future.

Box 1-9: China and low carbon energy innovation

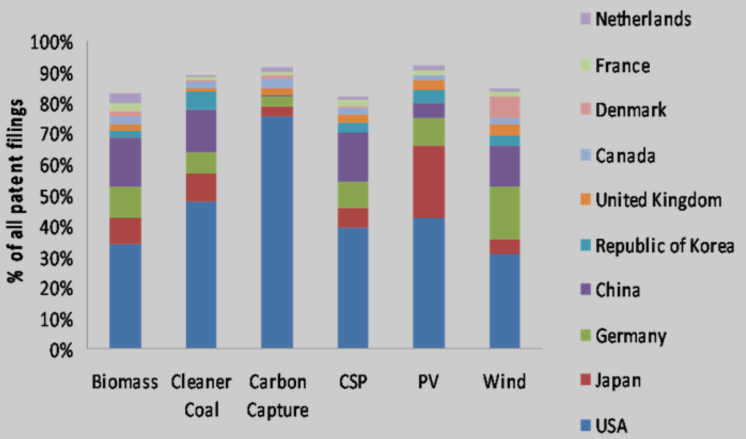
The geographical distribution of patenting and how this changes over time provides an indication of innovative activity and trends. China is increasingly popular as a destination for patent filing, which reflects an intention to invest, sell or license a technology. This is not surprising given of the size of the potential markets in China.

Patent Filing Locations for Six Energy Technologies



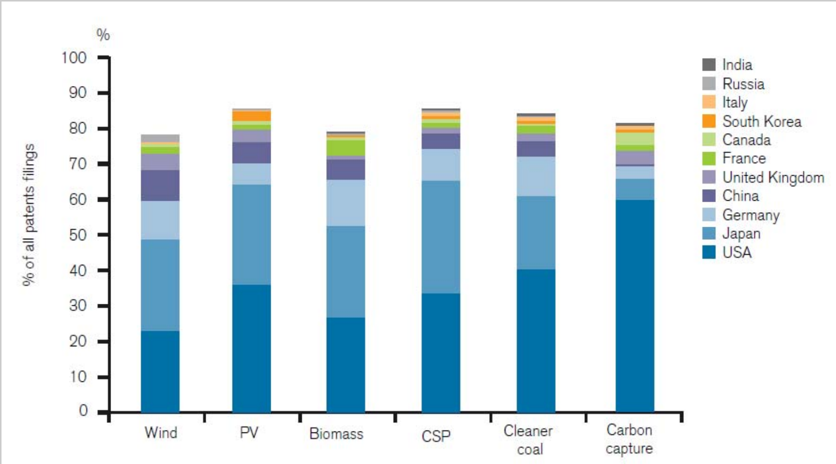
The origins of the patenting organisation show where R&D activity is taking place. The US is far ahead by this measure, but China has recently joined Japan and Germany in the next tier down:

Patent Assignee Origins



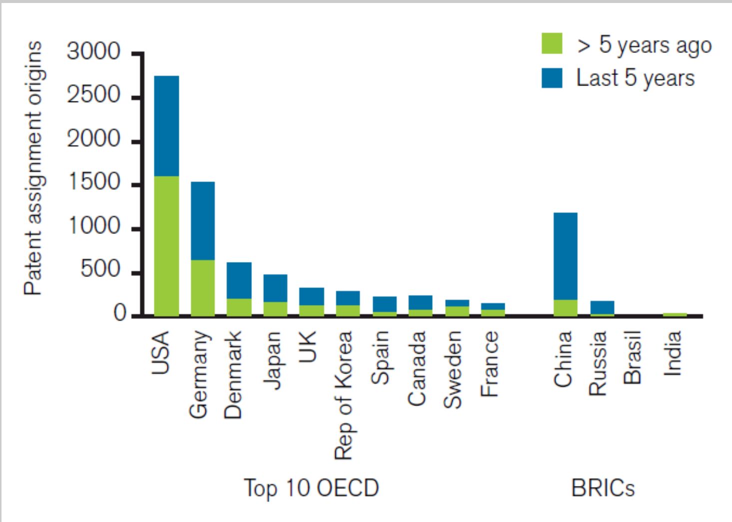
Innovation is still dominated by OECD actors, who will determine the diffusion speed of the most advanced energy technologies in the next decade. The next chart shows the geographical origin by parent company. Here, China lags further behind the US, Germany and Japan. This is because many companies that record their "origin" as China are in fact local subsidiaries of Japanese and US firms.

Patent Assignee Origins (parent companies)
(firms with more than 4 patents only)



However, China is catching up fast, as the example of wind power demonstrates. In the last five years, firms based in China have registered more patents than anywhere outside the US:

Patent Assignee Origins – Wind Power



Source: Chatham House, 2009

1.4.2 Managing new resource risks

The development of low carbon energy resources, as with the conventional resources that they seek to displace, comes with new material and environmental risks. These risks include:

- Access to the materials or fuels needed for the manufacture or use of the low carbon energy source
- The resource use, particularly if there is an impact on water or land use
- Use of equipment, materials or fuels for military means - dual use capabilities

For example, rare earth metals (REEs) are a group of 17 elements (atomic numbers 57-71, plus Scandium and Yttrium) whose unique properties make them indispensable in a wide variety of advanced technologies. They are an important example of material scarcity and the ‘third energy revolution’.

China's accelerating consumption of its own rare earth resources risks leaving the rest of the world without a viable alternative source. Today, access to REEs for low carbon energy production is already creating trade tensions between China and the US. However, REEs are not the only elements needed for low carbon energy technologies. Table 1-6 below shows a range of other materials that will be needed in significantly greater volumes.

Table 1-6: Material Use for Low Carbon Energy Sources

	Raw materials (application)
Fuel cells	Platinum Palladium Rare earth metals Cobalt
Hybrid cars	Samarium (permanent magnets) Neodymium (high performance magnets) Silver (advanced electromotor generator) Platinum group metals (catalysts)
Alternative energies	Silicon (solar cells) Gallium (solar cells) Silver (solar cells, energy collection/transmission, high performance mirrors) Gold (high performance mirrors)
Energy storage	Lithium (rechargeable batteries) Zinc (rechargeable batteries) Tantalum (rechargeable batteries} Cobalt (rechargeable batteries)

Source: Materials Innovation Institute, November 2009[79]

The production of energy can compete with resources previously destined for other uses. The best-known example relates to the production of first generation biofuels and the development of coal to liquids, both being developed primarily to combat oil supply security concerns.

The widespread availability of coal has encouraged some countries, for example Australia, China, India and United States, to develop its use as a liquid transport fuel. However, despite the abundance of coal in these regions there are environmental constraints, particularly concerning water. Such use necessitates water requirements in the order of 5-10 litres for every litre of fuel output. This has already had an impact on the development of the sector, with plans rejected for the construction of such projects in China[80].

Facing possible scarcities of REEs due to supply-side constraints has driven research into discovering adequate substitutes, as well as the redesigning of products to avoid use altogether.

REEs are used in permanent motors of hybrid electric vehicles and electric vehicles. Already, a number of commercially available alternatives exist, including asynchronous motor designs, though ongoing research hints at alternatives to pure Neodymium permanent motors. The German government, for example, included research on reluctance motors offering greater performance and lower Neodymium content in its National Development Plan for e-Mobility.[81] More broadly, Germany's €500 million allocation for electric vehicles is aimed at stimulating research in a

multitude of key technologies and addressing all the subsystems required to support the larger electric vehicle network. This includes battery development and integration, energy management and new materials research. The Federal Government aims to have 1 million EVs on the road by 2020 and gain a world leading manufacturing status.

Another emerging trend within this realm of scientific research is the potential of nanotechnology to greatly enhance the novel properties of certain critical minerals and open up entirely new avenues for alternative product designs. The application of nano-sized rare earth compounds are being considered in green technologies such as magnets, batteries, fuel cells, H2-storage and catalysts.

Scientists at the National Institute of Advanced Industrial Science and Technology (AIST), Japan, have developed an advanced composite material partly consisting of multi-walled carbon nanotubes. This material, when used in dye-sensitised solar cells, exhibits photoelectric conversion efficiency as high as that of the conventionally used platinum.[82] The United States Department of Energy's National Laboratory sees nano-structured permanent magnets as a key strategy to lowering the rare-earth content in permanent magnets. The DOE, through its Advanced Research Projects Agency-Energy (ARPA-E) fund, supports both low-risk, evolutionary projects and high-risk, high-payoff experiments. One ARPA-E project has funded General Electric Global Research (GE) in developing next-generation permanent magnets with a lower content of critical rare earth materials. As part of this USD 2.2 million project, GE is developing bulk nano-structured magnetic materials with a dramatic increase in performance relative to state-of-the-art magnets. These new magnets will increase the efficiency and power density of electric machines, while decreasing dependence on REEs. If successful, this project will lead to technologies for scaled manufacturing of low-cost, reduced rare earth-content, high energy density PMs.[83]

2 <u>THE FOUNDATION OF AND CHALLENGES FOR CHINA'S LOW CARBON INDUSTRIAL TRANSFORMATION</u>

2.1 Domestic Background

2.1.1 China is in the medium term of industrialization.

According to China's Industrialization Report (2008) by the Chinese Academy of Social Sciences, China had already entered the second half of industrialized metaphase in general. However, results showed the situation varied by district:

- Beijing and Shanghai had already achieved industrialization;
- Tianjin and Guangdong were in the second half of the latter period of industrialization;
- Zhejiang, Jiangsu and Shandong were in the first half of the latter period of industrialisation;
- Liaoning and Fujian were in the second half of the industrial metaphase
- 10 provinces and districts, including Shanxi and Inner Mongolia, were in the first half of the industrial metaphase;
- 10 provinces, including Henan and Hunan, were in the second half of the initial phase;

- Guizhou was in the first half of the initial phase;
- Tibet is in the pro-industrialization phase.

China has already established itself as the largest energy consumer and 2nd largest economic body in the world. Table 2-1 shows the main indicators of China's energy and economy:

Table 2-1: Main Indicators of China's Energy and Economy

	1990	2000	2005	2006	2007	2008	2009	2010
Population/million	1143.3	1267.4	1307.6	1314.5	1321.3	1328.0	1334.7	1339.2
GDP/RMB 100 million	18668	99215	184937	216314	265810	314045	3400983	397983
Economic Structure/%								
Primary Industry	27.1	15.1	12.1	11.1	10.8	10.7	10.3	10.2
Secondary Industry	41.3	45.9	47.4	47.9	47.3	47.5	46.3	46.8
Tertiary industry	31.6	39.0	40.5	40.9	41.9	41.8	43.4	43.0
Per Capita GDP/USD/Person	344	949	1808	2070	2652	3414	3748	4396
Primary Energy Consumption /Mtce	987.0	1455.3	2360.0	2586.8	2805.1	2914.5	3066.5	3250.0
Dependence on oil imports /%	-18.4	26.4	36.4	39.7	43.2	46.9	51.7	54.5
Per Capita Energy Consumption /kgce	864	1148	1805	1968	2123	2195	2297	2424
Power Generation/TWh	621.2	1355.6	2500.3	2865.7	3281.6	3495.8	3714.7	4206.5
Steel Output/Mt	66.4	128.5	353.2	419.2	489.3	503.1	572.2	626.96
Cement Production/Mt	209.7	597.0	1068.9	1235.0	1361.2	1423.6	1644.0	1806
Total Export Value/100 million USD	621	2492	7620	9689	12178	14307	12015	15779
Total Import Value/100 million USD	534	2251	6600	7915	9560	11326	10059	13948
Average Exchange Rate (CNY/USD)	4.7832	8.2785	8.1943	7.9734	7.6075	6.9444	6.8310	6.7695

Source: National Bureau of Statistics (NBS)

China’s economy and energy consumption differs in districts, with great gaps between rural and urban areas, and between rich and poor. In 2008, the area with the highest

per capita GDP was 9.4 times above that of the lowest per capita GDP, and the highest average per capita family income in urban areas was 65 times higher than that of the lowest in rural areas (Wang Xiaolu, 2010).

Power consumption gaps are large, with the highest individual power consumption 11 times that of the lowest. Survey data from the State Grid Corporation shows that the poorest families use as little as 1.1 kWh/month on average, while families in large villas (over 500m^2 of floor space) use 2000 kWh of electricity per month. According to International Standard, there was still an impoverished population of 150 million. This is a reflection of unbalanced, incoherent and unsustainable social development.

2.1.2 Urbanization propels heavy industrialization.

In 2010, China's primary energy consumption reached 3250Mtce, an increase of 125% from 2000. The acceleration of urbanization is the main reason for the upsurge of energy need. Urbanization and an increase in citizens' disposable incomes have led to significant changes in the structure of consumption: the need for houses, cars and domestic appliances is showing unprecedented growth.

From 2000 to 2010, China's urbanization rate rose from 36.2% to 49.7% and there was an increase in the urban population of 206.5 million. According to data provided by NBS, the Agricultural Department and survey data in 2007, the energy consumption of urban citizens was 3.7 times and per capita power consumption 4.6 greater than that of rural residents,

Over the same period, the disposable income of urban citizens grew from RMB 6280 to RMB 19109; a 1.7 times increase. The net per capita income of rural residents was RMB 5919; 30% that of the urban citizens in 2010. The per capita housing area increased from 20.3m^2 in 2000 to 31.6m^2 in 2010. Average car ownership increased from 0.5 to 13.1 per 100 families; air conditioner ownership from 30.8 to 112.1; and refrigerators from 80.1 to 96.6.

As Table 2-2: shows, urbanization was accompanied by consumption structure upgrading, driving a new round of heavy industrialization. The output value of heavy industry accounted for 52.7% of the total industrial output value in 1995, 60.2% in 2000 and 70.5% in 2009. The energy consumption of heavy industry per unit of output value is about 4 times that of light industry. High energy consumption products, such as steel and cement, developed at full speed. From 2000 to 2010, raw steel production increased from 128.5 Mt to 627.0 Mt and cement from 597.0 Mt to 1880.0 Mt.

Table 2-2: China's Urbanization and Energy Consumption

	2000	2005	2008	2009	2010
Urban Population/million	459.1	562.1	606.7	621.9	665.6
Urbanization Rate /%	36.2	43.0	45.7	46.6	49.7
Amount of Cities with Prefectural level and above		286	287	287	
>4million (population)		13	13	14	
2-4million (population)		25	28	28	

1-2million (population)		75	81	82	
Urban Per Capita Disposable Income/ RMB	6280	10493	15781	17175	19109
Urban Per Capita Housing Construction Area/m^2	20.3	26.1	30.6*	31.3*	31.6*
Urban Family Cars Popularizing Rate/Amount/100 families	0.5	3.4	8.8	10.9	13.1
Urban Family Air Conditioner Popularizing Rate/Amount/100 families	30.8	80.7	100.3	106.8	112.1
Urban Family Refrigerator Popularizing Rate/Amount/100 families	80.1	90.7	93.6	95.4	96.6
Urban Central Heating Area/100 million m^2	11.1	25.2	34.9	35.6	
Urban Per Capita Electricity Consumption /kWh	217	306	397	429	445

*Number with * is based on evaluation.*

Sources: NBS, China Electricity Council and Housing and City and Countryside Ministry of Construction

In 2009, China's construction industry consumed 284Mt of steel. This makes up 50.8% of the total steel consumption, of which housing construction took up 36.1%, infrastructure 14.7%, cars 3.1% and domestic appliances 1.5%. China's steel consumption in the construction industry alone is responsible for one quarter of global steel consumption. Cement consumption in the industry reached about 1460Mt, accounting for 90% of domestic total consumption and half of the global cement consumption.

China is at the peak of residential construction and there is also much room for growth in cars and domestic energy consumption equipment. These three factors are driving the rapid growth of heavy industries, notably steel, building materials, electricity, engineering machinery, power equipment and the automobile industry.

China's heavy phase of industrialization is set to last for at least another 10 years. The output of the high energy consumption products is expected to peak around 2020, with peak steel output of 1 Gt (Chen Kesi, 2010; Yu Huabin, 2010).

2.1.3 The Prospects of China's Manufacturing Industry

China's secondary industry accounted for 46.9% of the total GDP in 2010, of which industry covered 40.2% and construction 6.6%. In 2007, that number was 22.4% in USA; 30.1% in Japan and Germany; 29% in India; and a world average of 28.0% (World Bank). China's secondary industry proportion remained high for an extended period, highlighting an unbalanced industrial structure. To get out of this means to mainly rely on the growth model of manufacturing.

Chinese statistics distinguish between 'light' and 'heavy' industry. However, some light industries are high energy consumers: for example paper making, synthetic fiber, domestic glassware and audio-visual equipment. Equally, some industries are categorised as 'heavy' but have an energy consumption per unit of value added that is only 4% of the steel industry – these include communications equipment

1. China's Large-Scale Manufacturing Industry

China's manufacturing industry is characterised by large scale and rapid development. At the end of 2008, there were 1.8 million manufacturing business entities, with a labour force of 103.6 million (see Table 2-3). In 2010, China's manufacturing output value was 19.8% of the global total, exceeding the USA (19.4% and listed occupying first place) (IHS Global Insight, 2011).

Table 2-3: China's Energy and High Energy Consumption Enterprises (2008)

	Business Entities Amount /10,000	Employees/10,000	Total Profits (10 million RMB)
Industrial Total	190.3	11738.3	33854.3
Coal Mining and Washing	2.1	570.7	2490.4
Petroleum and Natural Gas Exploration	0.1	110.8	4605.2
Manufacturing	175.3	10359.3	24486.5
Petroleum Processing, Coking and Nuclear Fuel Processing	0.6	91.4	-990.7
Chemical Material and Chemical Products Manufacturing	9.3	557.0	2058.4
Non-metallic minerals mining products	20.6	932.9	1987.7
Ferrous Metal Smelt and Extension Processing	1.8	329.7	1604.8
Non-ferrous metal Smelt and Extension Processing	2.1	202.5	873.6
Electric and Heating Power Production and Supplies	3.7	311.2	569.6
Gas Production and Supplies	0.3	22.4	126.3

Source: NBS, the 2nd National Economic Census Main Data Bulletin, released in December 25, 2009.

2. China's industry takes up a relatively large share of energy consumption

According to international energy balance definition and calculating methods, in 2009 China's industrial sector energy consumption made up 57.3% of the nation's total terminal energy consumption (see Table 2-4). This was much higher than that of global average level in 2008 - 27.9% (see Table 2-5) – and is about same as that of Japan in the early 1970s.

Table 2-4: Consumption and Structure of Terminal Energy in China Sub-Sector

	1980		2000		2005		2009	
	Mtce	%	Mtce	%	Mtce	%	Mtce	%
Agriculture	31.4	6.9	40.2	4.9	57.5	4.0	56.1	3.4
Industry	277.0	61.4	489.2	59.2	905.7	62.7	1210.8	62.8

Communications and Transportation	36.0	8.0	134.8	16.3	198.7	13.7	295.4	15.4
Civil, Business and Others	107.3	23.7	170.9	19.6	383.3	19.6	352.2	18.4
Total	451.7	100.0	871.7	100.0	1445.2	100.0	1590.8	100.0

Notes:

1. Table 2-4 is based on China's Overall Energy Balance Table and calculated by international energy balance definition and methods. Terminal Energy Consumption is equal to Primary Energy Consumption minus Energy Consumed in Processing, Transforming, Storage and Industrial Consumption. These figures exclude energy used in raw materials.

2. The proportion of energy consumed by the industrial sectors other than energy used as raw materials is 57.3% in 2009.

Table 2-5 Global Terminal Energy Consumption Structure (2008) Unit: Mtoe

	Total Consumption Amount	Sub-sector Consumption			
		Industry (%)	Transportation (%)	Civil/Business/Agriculture (%)	Non-energy use (%)
China	1379	657(47.8)	156(11.3)	426(30.9)	139(10.0)
USA	1542	295(19.1)	609(39.0)	491(31.8)	155(10.1)
EU（27）	1219	295(24.2)	330(27.1)	455(37.3)	139(11.4)
Japan	320	87(27.3)	78(24.5)	113(35.4)	41(12.8)
OECD	3696	849(23.0)	1191(32.2)	1229(33.2)	427(11.6)
Global Total	8423	2351(27.9)	2297(27.3)	2850(33.8)	923(11.0)

Sources: Institute of Energy Economics Japan, Japan Energy and Economic Statistics Brochure 2010

3. Prospects for China's Manufacturing Industry

China is the world's biggest producer and consumer of energy intensive products. Table 2-6 displays the production of energy intensive products and products with a high final energy demand. Table 2-7 shows that in 2009 China's production of steel, cement, plate glass, architectural ceramics, chemical fertilizer, chemical fibers and automobiles took up 47%, 60%, 50%, 65%, 35%, 57% and 25% of the global total respectively.

Table 2-6: High Energy Consuming Products and the Production of Terminal Energy Consumption Equipment

	1990	2000	2005	2006	2007	2008	2009	2010
Energy intensive products								
Raw Steel /Mt	66.4	128.5	353.2	419.2	489.3	503.1	572.2	626.96
Cement/Mt	209.7	597.0	1068.9	1236.8	1361.2	1423.6	1644.0	1880.0
Electrolytic Aluminium /Mt	0.85	2.79	7.79	9.27	12.34	13.17	12.89	15.65
Ethylene /Mt	1.57	4.70	7.56	9.41	10.48	9.88	10.73	14.19
Farm-oriented Chemical Fertilizer /Mt	18.80	31.86	51.78	53.45	58.25	60.28	63.85	67.41
Products with high final energy demand / Million units								
Auto	0.51	2.07	5.71	7.28	8.89	9.31	13.80	18.27
Refrigerators	4.63	12.79	29.87	35.31	43.97	48.00	59.30	73.01
Color TV	10.33	39.36	82.83	83.75	84.78	91.87	98.79	118.30
Air Conditioners	0.24	18.27	67.65	68.49	80.14	81.47	80.78	108.99

Source: NBS

Table 2-7 Global Share of China's Energy and Energy Consumption Products Market (2009)

		% global
Population	1.3 billion	19.5
GDP	4985 billion USD	8.5
Primary Energy Consumption	3066 Mtce	19.5
Petrol Consumption	384 Mt	10.4
Coal	2973Mt	43.3
Electricity Generation	3714.7 TWh	18.5
Steel	57.2 Mt	46.6
Cement	1.6 Gt	60
Plate Glass	58.6 million weight cases	50
Architectural Ceramics	6.8 billion m2	65
Chemical Fertilizers	63.9 Mt	35
Auto	13.80 million units	25
Yarn	23.94 Mt	46
Chemical Fibers	27.3 Mt	57
Air Conditioners	80.78 million	70

Refrigerator s	59.3 million	60
Colour TVs	98.79 million	48
Microwaves	60.38 million	70
Microcomputers	18.2 million	60
Mobile Phones	61.9 million	50
Photovoltaic Batteries	4382 MW	46.9
Compact Fluorescent Light	3.65 billion	80

Sources: NBS; Ministry of Industry and Information Technology; the World Bank; IMF；BP Statistical Review of World Energy , June 2010； China Economic Information Network; People's Net; China Iron and Steel Industry Association; China Nonferrous Metals Industry Association; China Building Materials Industry Association; China Ceramics Industry Association; China Household Electrical Appliances Association and China Association of Lighting Industry

With low-cost labour and cheap resources, China's manufacturing industry boasts many products that secure a significant competitive edge. With increasing labour, resource and environmental costs, China's traditional low-end industry is losing its advantage. However, the average salary of China's manufacturing workers is still only a small proportion of that in developed nations. Though the neighbouring countries may have cheaper labourers, China's large market and well-established, competitive industrial chain and infrastructure still holds strong investment attractions.

China's domestic regional diversity is as great as the difference between China and other countries. Shanghai's income level is ten times greater than that of Guizhou. Parts of mid- and west- China still have a large amount of surplus labour and their costs are lower than those along the east coast. Securing this as an opportunity, the coastal areas have already started the process of industrial upgrading and heavy industries are moving to central and western regions of China. Mid and west China are becoming the new engines of sustainable growth behind China's economic development.

On the other hand, industrial upgrading doesn't mean elimination of labour intensive industries, but rather increasing product technology content. China needs to continue developing labour-intensive industries to absorb the surplus of rural labourers. To date, China's industrial development has taken in 200 million rural labourers. With restructuring and industrial upgrading, the manufacturing industry's ability to absorbing surplus labourers shall decrease.

2.1.4 Imbalance of China's Technologic Development

1. Remarkable progress by Chinese industry

In the last decade, many of China's large enterprises have reached the international advanced level: Shenhua Group, Huaneng Group, China National Building Material Group, Conch Group, Baosteel Group and the Aluminium Corporation of China, to name only a few examples. According to Steven Chu, the US Secretary of Energy (2010), China is now ahead of America in seven technologies, including ultra high voltage AC and DC transmission, high speed rail, supercritical and ultra supercritical thermal power generation, alternative energy cars, renewable energy and

supercomputers. China also takes the lead in clean coal utilization and renewable energy source development, as Table 2-8: and Table 2-9: show.

Table 2-8: China's Progress in Clean Coal Technology (2010)

Coal Preparation	Washing 1650Mt of raw coal, accounting for 50.9% of raw coal output, saving 160Mt of coal and reducing emission of 7.7Mt SO_2 and 320Mt of CO_2.
CWS	Annual production capacity reaches 80Mt, 30Mt of which is used as fuel for power plants, industrial boilers and furnaces and 50Mt of which is used as gasification material. Compared with direct burning, coal gasification can save energy and reduce emissions by at least 10%.
Ultra supercritical thermal power generating units	33 1000MW units in operation and 11 more under construction. Thermal efficiency at 45.5% and coal consumption of power supply at 283gce/kWh; 52gce/kWh less than the average level of 2010. The 33 units save 8.4Mtce coal and reduce emission of 22.8Mt CO_2 every year.
Circulating fluidized bed boilers	17 300MW boilers in operation, 50 more proposed or already under construction, and the construction of the world's first 600MW supercritical circulating fluidized bed unit. Compared with pulverized coal fired boilers, emissions of SO_2 and NO are reduced by 50%, CO_2 by 10% and coal usage by 10%.
Coal gasification combined cycle power generation	250MW demonstration plant under construction in Tianjin, to be finished by 2011. This project includes pollutant recycling and carbon capture to realize the goal of zero air pollutant emissions and CO_2.
Coal gasification	Independently-developed two-stage dry pulverized coal pressurized gasification technology and equipments are already used in Tianjin IGCC project and exported to the U.S.
Gas produced from coal	5 projects planned or under construction, with a total annual production capacity of 19 billion cubic meters. The project being constructed at Chifeng, Mongolia has an annual production capacity of 4 billion cubic meters and will be able to supply gas to Beijing in 2012. Compared with other coal utilization technologies, coal-derived gas consumes the least water and has lower CO_2 emissions.

Source: China Coal Processing & Utilization Association, Coal Industry Clean Coal Technology Engineering Research Center, CEC, CPCIF

Table 2-9: China's Renewable energy deployment and share of global deployment (2010)

	Deployment	Share of global/%	Top 3 in the world
Hydropower	721.02TWh	21	China, Canada, Brazil
Wind power generation installed capacity	41827MW	18	China, U.S, Germany
Photovoltaic cell output	8GW	50	China's Mainland, Taiwan, U.S
Solar heater inventory	170 million m3 (collector area）	60	China, Turkey, Japan
Direct geothermic utilization	8898MW	18	China, U.S, Sweden

Methane output	16.4 billion m3	40	China, U.S, Germany

Notes: see endnote #84

Sources: National Bureau of Statistics, National Energy Administration, Ministry of Science and Technology, Ministry of Land and Resources, China Renewable Energy Society, World Wind Energy Association, International Geothermal Association, Renewable Global Status Report; IEA, Global primary energy structure 2009; BP statistical Review of World Energy, June 2010.

The energy efficiency of some leading enterprises in industries such as thermal power, concrete and aluminium electrolysis has reached the international advanced level, as Table 2-10 shows.

Table 2-10 Energy Consumption Comparison of Selected High Energy-Consuming Products with International Level

	2005			2010		
	China	International advanced level	gap	China	International advanced level	gap
Coal consumption of thermal power supply gce/kWh	370	314	+17.8	335	310	+8.1
Comparable energy consumption of steel/kgce/t	732	616	+18.8	717	610	+17.5
AC power consumption of electrolytic aluminium /kWh/t	14575	12900	+13.0	13979	12900	+8.4
Comprehensive energy consumption of concrete/kgce/t	167	127	+31.5	126	118	+6.8
Comprehensive energy consumption of ethylene /kgce/t	1073	629	+70.6	950	629	+51.0

Notes: see endnote #85

Sources: National Bureau of Statistics, Ministry of Industry and Information, China Electricity Council, China Iron and Steel Industry Association, China Nonferrous Metals Industry Association, Chinese Building Materials Industry Association, China National Chemical Energy Saving Technology Association, Institute of Energy Economics Japan, Handbook of Energy and Economic Statistics in Japan (2010 Edition), Iron and steel Institute of Japan, Korea Iron and Steel Association, Japan Cement Association

2. Small enterprises account for a large proportion of high energy-consuming industries

Small enterprises account for a large proportion of the production of China’s high energy-consuming industries. With outdated production methods, technologies, facilities and management, many small enterprises consume 30-60% more energy per unit of products than larger ones. This is one reason why Chinese-made products have a higher energy intensity compared with the international average. In 2009, for instance, the average processing capacity of China’s oil refining companies was only 2.6 Mt, compared with the 22.5 Mt of counterparts in South Korea; the energy consumption of China’s oil refining industry was 22% above the advanced

international level; and brick and tile plants totalled 90,000, with comprehensive energy consumption twice the international advanced level. The number of large paper-making factories (annual revenues exceeding RMB 5 million from main businesses, prior to the change in 2011 to RMB 20 million) reached 5,700 and the average annual production of the 30,000 factories existing in 2006 was less than 1/10th of that in foreign countries. The comprehensive energy consumption of paper-making factories which supply pulp by themselves was nearly 80% higher than the advanced international level.

3. More efforts to eliminate outdated production capacities.

With strict policy measures, outdated production capacities in high energy-consuming industries have been rapidly phased out in recent years. Table 2-11 shows the outdated production capacities in high energy-consuming industries phased-out during the 11th FYP period.

This made a large contribution to energy conservation in heavy industry sectors: for example, coal-powered electricity plant of 100 MW capacity or less, consume 30%-50% more fuel than units with a capacity of over 300MW. The energy consumption of blast furnaces smaller than 300 m^3 was over 20% higher than those larger than 1000 m^3. The heat consumption of small shaft kilns is 40% higher than that of large NSP cement production lines.

Table 2-11: Production capacities eliminated in the industry sector from 2006 - 2010

	Production of 2010	Utilization rate in 2010/%	Production capacities eliminated from 2006 to 2010
Raw coal	3240Mt	90	450Mt，9000 mine wells
Coke	387.6Mt	83	10.38Mt
Coal power	3416.6TWh	5031 hours annually	72.1GW
Iron smelting	590.22Mt	88	111.7Mt
Steel smelting	626.96Mt	82	68.6Mt
Iron alloy	24.36Mt	72	6.63Mt
Cement	1876.6Mt	72	403Mt
Glass sheets	662.6 million weight case	76	152 million weight case
Electrolytic aluminium	15.65Mt	74	0.8Mt
Calcium carbide	14.30Mt	60	4.0
Paper-making	100.4Mt	90	10.3

Source: Ministry of Industry and Information Technology, National Bureau of Statistics, China National Coal Association, China Coking Industry Association, China Electricity Council, China Building Material Industry Association, China Paper Association

2.2 A strong foundation

2.2.1 Changing China's coal-based energy structure is a major challenge

China is among a small number of countries which rely on coal as a major energy source. In 2009, coal accounted for 70.3% of the total primary energy consumption in China, while the proportion in US was 22.8%, in Japan 23.4%, in EU 25.5% and the world average 23.7% as referred to in Table 2-12.

Table 2-12: Consumption and Structure of Primary Energy around the World (2009)

	Consumption of primary energy/Mtoe	Consumption structure/%				
		oil	natural gas	coal	nuclear power	hydro-power
US	2182.0	38.6	27.0	22.8	8.7	2.9
China	2177.0	18.6	3.7	70.6	0.7	6.4
Russia	635.3	19.7	55.2	13.0	5.8	6.3
India	468.9	31.7	10.0	52.4	0.8	5.1
Japan	463.9	42.6	17.0	23.4	13.4	3.6
Canada	319.2	30.4	26.7	8.3	6.3	28.3
Germany	289.8	39.3	24.2	24.5	10.5	1.4
France	241.9	36.1	15.9	4.2	38.4	5.4
South Korea	237.5	43.9	12.8	28.9	14.1	0.3
Brazil	225.7	46.2	8.1	5.2	1.3	39.2
Iran	204.8	40.8	57.9	0.7	—	0.6
UK	198.9	37.4	39.2	14.9	7.9	0.6
Saudi Arabia	191.5	63.6	36.4	—	—	—
Italy	163.4	45.9	39.5	8.2	—	6.4
Mexico	163.2	52.4	38.4	4.2	1.3	3.7
Spain	132.6	55.0	23.4	8.0	9.0	4.6
EU(27 countries)	1622.6	41.3	25.5	16.1	12.5	4.6
OECD	5217.1	39.7	25.0	19.9	9.7	5.7
The world	11164.3	34.8	23.7	29.4	5.5	6.6

Note: For nuclear power and hydro-power, we use 38%, the conversion efficiency of coal power plants, to convert thermal equivalent.

Source: BP Statistical Review of World Energy, June 2010

Compared with oil and natural gas, coal has lower utilization efficiency but higher CO_2 emissions. The utilization efficiency of coal was 23% and 30% lower than that of oil and natural gas, while its CO_2 emissions are 130% and 170% as that of the latter two respectively by calculating in unit heating value.

Due to a large proportion of coal in primary energy of China's energy mix, China's CO_2 emission level is much higher than the world average. In 2010, China emitted 7879MtCO_2.

In 2010, CO_2 emitted from coal combustion in China was 82.5% of its total emissions, or 48.2% of the world's total emission from coal combustion, which is shown in Table 2-13.

China is the largest coal producer and consumer. In 2010, its production was 3,240 Mt, 44.5% of the world's total. Its consumption was 32.92Mt, among which 53.4%, 13.9%, 15.3% and 6.0 % went to power and heat generation, steel, construction material and chemical industries respectively. China's current coal consumption far exceeds what had been expected. Just a few years ago, the coal demand of 2020 was anticipated to be 3000Mt, but consumption reached this level 10 years in advance. With the continuous growth of the demand from high coal-consuming products, it is inevitable for China's coal demand to increase on a huge scale. In 2008, coal accounted for 96.5% of the remaining recoverable reserves of fossil fuels in China. The price advantage on coal extraction, the development of clean coal technologies and supportive infrastructure conditions, are other factors that make it a major challenge to rapidly change China's coal-based energy mix.

According to many scenario studies of energy demand, in 2050, despite the decrease of coal's proportion, coal still will be the largest energy source for China.

2.2.2 Emissions from key industries

CO_2 emissions from China's industry sector take up an exceptionally high proportion of final energy consumption. Chinese manufacturing industry accounted for 33% of total CO_2 emissions in 2008, while the figure was only 11% in the US.

Table 2-13: Constitution of CO_2 emission in different categories and industries in different countries (2008) Unit: %

	China	US	Japan	World
Emissions by fuel %				
Coal	83	37	36	43
Petroleum	14	40	46	37
Natural gas	3	23	18	20
Total	100	100	100	100
Emissions by sector %				
Power generation and heat supply	48	43	41	41
Other energy industries	4	5	4	5
Manufacturing industry and construction industry	33	11	21	20
Transportation	7	30	20	23
Other industries	8	11	14	11
	100	100	100	100

Source IEA 2010.

The CO_2 emission in China differs from region to region, which is closely related to the layout of heavy chemical industries, as referred to in Table 2-14. In 2009, Inner Mongolia, Ningxia, Shanghai, Shanxi and Liaoning, all China's major heavy chemical bases, were the top 5 emitters calculated by per capita emission. In Inner Mongolia, the industrial output value was 60% of its GDP, and in Shanghai, the proportion was 51%. In Shanxi, the output value of heavy chemical industries accounted for 80% of its total industrial output value. That year, Shanghai's per capita emission reached 12.7t, the top one among cities with more than a 10 million population around the world, nearly doubling that of New York, Tokyo and London. In 2008, per capita emission in New York was 6.4t (Michael Bloomberg), in Tokyo 6.3t (keisuke Hanaki), and in London 6.2t (Daved Dodman).

Table 2-14: Energy consumption and Carbon Emission of Regions in China (2009)

	Energy consumption per unit of GDP/tce/RMB 10,000	Energy consumption per unit of industrial added value/tce/ RMB10,000	Per capita GDP/RMB	per capita energy consumption/kgce	per capita CO_2 emission/t-CO_2
Beijing	0.606	0.909	70452	3474	8164
Tianjin	0.836	0.911	62574	4132	9710
Hebei	1.640	2.999	24581	3614	8493
Shanxi	2.364	4.550	21522	4545	10681
Inner Mongolia	2.009	3.557	40282	6335	14887
Liaoning	1.439	2.257	35239	4425	10399
Jilin	1.209	1.621	26595	2809	6601
Heilongjiang	1.214	1.382	22447	3834	9010
Shanghai	0.727	0.957	78989	5397	12683
Jiangsu	0.761	1.107	44744	3069	7217
Zhejiang	0.741	1.123	44641	3005	7062
Anhui	1.017	2.100	16408	1451	3410
Fujian	0.811	1.150	33840	2458	5988
Jiangxi	0.880	1.674	17335	3112	7313
Shandong	1.072	1.543	35894	3423	8044
Henan	1.156	2.708	20597	2082	4893
Hubei	1.230	2.350	22677	2397	5633
Hunan	1.202	1.570	20428	2081	4890
Guangdong	0.684	0.809	41166	2558	6011
Guangxi	1.057	2.235	16045	1457	3424
Hainan	0.850	2.613	19254	1427	3353
Chongqing	1.181	1.854	22920	2459	5779
Sichuan	1.338	2.249	17339	1994	4686
Guizhou	2.348	4.320	10309	1992	4681
Yunnan	1.495	2.739	13539	1757	4129
Shaanxi	1.172	1.367	21688	2133	5013
Gansu	1.864	3.530	12872	2080	4888
Qinghai	2.689	2.936	19454	4215	9905
Ningxia	3.454	6.509	21777	5421	12739
Xinjiang	1.934	3.095	19942	3486	8192

Note: 1. The regional CO_2 emission was calculated according to national emission factor.

2. The national per capita GDP, energy consumption and CO_2emission were RMB 25,575, 2297kgce and 5365t.

Source: National Bureau of Statistics, National Development and Reform Commission, National Energy Bureau

2.2.3 Despite substantial achievements in energy consumption, the wasting of energy is still very serious.

1. The accelerated progress of energy-saving technologies

Recent progress in deploying energy-saving technologies is the result of a combination of market competition, government policies and enhanced technical capacity in China.

From 2005 to 2010, the proportion of power plants with a capacity greater than 300 MW has increased from 47% to 69%; the penetration rate of coke dry quenching (CDQ) technology in steel enterprises, from 35% to 83%; NSP cement production lines, from 40% to 80%; and ionic membrane caustic soda, from 34% to 76%, as referred to in Table 2-15:.

Table 2-15: Progress in Energy-Saving Technologies in China's High Energy-Consuming Industries

	2000	2005	2010	Energy-saving results
Electric power				
proportion of thermal power units larger than 300MW/%	43	47	69	The coal consumption of units at 100MW is 30%-50% higher than that of units at 300MW.
Steel				
proportion of production capacity of blast furnaces with a volume more than 1000 m3 /%		21	34	The energy consumption of blast furnaces with a 300m3 volumn is 20% more than that of blast furnaces with a 1000 m3 volumn.
penetration rate of CDQ technology/%	6	35	83	For every 1 mt of red coke Handled with CDQ technology, 100,000 tce of energy could be saved.
penetration rate of TRT facilities/%	50	81	100	With TRT facilities, power generation per tonne of iron could reach 30kWh
Electrolytic aluminum				
proportion of production by large pre-baked cells/%	52	80	90	Pre-baked cells larger than 160kA consume electricity 9% less than self-baked cells.
Chemical industry				
proportion of caustic soda production by ionic membrane method/%	25	34	76	For the production of every tonne of caustic soda, ionic membrane method consumes electricity 123 kWh less than diaphragm method.
Construction materials				
proportion of cement production by NSP production lines/%	12	40	80	The heat consumption of NSP production lines is 40% less than shaft kilns.

bulk rate of cement/%	28	39	48	For every 100 mt of cement, the bulk method could save 3.3 million m3 of wood and avoid 4.5% damages of paper bags, in this way saving 2.37 Mtce of energy
proportion of glass sheet production by float method/%	57	79	86	The comprehensive energy consumption of float method is 16% less than vertical drawing method
proportion of new wall material production/%	28	40	58	The energy consumption of producing new wall materials is 40% less than traditional ones.

Note: The penetration rate of CDQ technology means the proportion of the amount of coke handled with CDQ technology to the total; the penetration rate of TRT facilities means the proportion of blast furnaces larger than 1000 m3 with TRT facilities to the total number of blast furnaces larger than 1000 m^3.

Sources: China Electricity Council, China Iron and Steel Association, China Coking Industry Association, China Nonferrous Meals Industry Association, China Building Material Industry Association, China Chemical Energy Conservation Technology Association

2. Substantial achievements in technological energy-conservation

Thanks to the promotion of energy-saving technologies and phasing out of many outdated production capacities, the energy consumption of high energy-consuming products have been reduced obviously. Compared with that of 2005, in 2010, the comprehensive energy consumptions of coal power, cement, ammonia synthesis and chemical fibers was down by 9.5%, 24.5, 17.3% and 30.6% respectively.

During the “11th FYP” period, China’s industry sector has saved 339Mtce of energy by using new technologies, contributing 54% to the total energy conservation. Among this, 13 products in 7 industries have saved 172Mtce of energy by using new technologies. Since these 13 products consume 70% energy in the manufacturing industry, the total energy consumption reduced in this industry could be 246Mtce. The thermal power industry has saved 93Mtce of energy.

Table 2-16: Energy Conservation of China’s Manufacturing Industry during the “11th FYP” Period

	Product energy consumption			Production of 2010	Energy conservation during the “11th FYP” Period /Mtce
	unit	2005	2010		
Steel	kgce/t	760	701	626.96	37.00
Electrolytic aluminum	kWh/t	14575	13979	15.65	3.26
Copper	kgce/t	780	500	4.57	1.28
Cement	kgce/t	167	126	1876.61	76.94
Glass sheets	kgce/weight case	22.0	16.3	662.61	3.78
Oil refining	kgce/t	114	100	423.0	5.92

Coking	kgce/t	156	117	388.0	15.13
Ethylene	kgce/t	1073	950	14.17	1.74
Ammonia synthesis	kgce/t	1700	1464	51.50	12.15
Caustic soda	kgce/t	1297	1006	20.87	6.07
Soda ash	kgce/t	396	317	20.27	1.60
Calcium carbide	kWh/t	3450	3340	14.30	0.55
Chemical fibers	kgce/t	743	517	29.73	6.72
Total					172.14

Notes: see endnote # 86

Source: National Bureau of Statistics, Ministry of Industry and Information Technology, China Chemical Energy Conservation Technology Association, China Chemical Fibres Association; Wang Qingyi, "the Assessment of China's Energy Efficiency", Energy Conservation and Environment Protection, 2011, No.1, 38-42.

3. Huge amounts of energy could be saved

China has serious direct and indirect energy wastage, topping world figures. In some areas, wasted energy is far more than the amount conserved by implementing policies and measures.

i) Construction of Residential Buildings

China has the lowest utilization rate of residential buildings in the world. According to the estimate by Social Policy Research Center of the Chinese Academy of Social Science (2010), the housing vacancy rate in China's urban areas was about 25%, equivalent to more than 30 million housing units. The housing vacancy rate of developed nations is controlled to below 10%. According to this standard, 15% of the residential buildings or 2 billion m^2 are idle. Since it takes 50 kg of steel and 200 kg of cement to build each m^2 of residential buildings, 153 Mtce of energy is wasted. In contrast, in north China, 182 million m^2 of existing residential buildings were upgraded, saving only 2.0 Mtce of energy.

ii) Urban construction

In 2009, the GDP of 11 cities, which have a GDP greater than RMB 400 billion, totalled RMB 8,075 billion - 24% of China's gross GDP. Calculated by 10%, the GDP bubbles reach RMB 807.5 billion. For every RMB 10, 000 of GDP, 0.20t of steel and 0.48t of cement are consumed. In 2009, therefore, large demolition and construction projects wasted at least 55Mtce of energy.

iii) Government Organs

Chinese government agencies also waste a lot of energy, particularly in office buildings and government vehicles. China's per capita office building area is the highest in the world (Li Jinhua, 2009) and it is above the 'Standard of Per Capita

Office Building Area in Party and State Organs' provisions adopted by China's government in 1999. In 2009, the per capita electricity consumption of the 5 million administrative staff in China was 4,720 kWh, 2.1 times greater than electricity consumption in Japan. The total electricity consumption in administrative organs was 23.6TWh, equivalent to 8Mtce. In comparison to the electricity consumption standards of Japan, administrative organs in China waste at least half of the power generated – equal to 4Mtce of energy every year.

iv) Food

An estimated 50 Mt of food is wasted in China each year (Zheng Chuguang, 2010) - 9.4% of food production in 2009. Based on the diesel, electricity and fertilizer consumption required for agricultural production and irrigation, equals 12.5Mtce of energy waste.

2.2.4 Low-carbon technologies show the potential of carbon reduction.

Low-carbon technologies in the industry sector include energy production and utilization technologies, new material technologies, and carbon capture and storage. With active efforts, China has made many achievements in developing and applying low-carbon technologies and demonstrating their carbon-reduction potential. Table 2-17 shows China's low-carbon technology cases.

Table 2-17: China's Low-Carbon Technology Case Studies

Low-carbon technology	Carbon-reduction effects
1. Coal preparation	With this technology, 70% of ash and 60% of pyritic sulphur could be removed from coal, with a 10% reduction in coal usage. In 2010, by processing 1,650 Mt of coal, China reduced its coal consumption by 160 Mt and its CO_2 emissions by 320 Mt (China Coal Processing and Utilization Association).
2. Green coal power	China's Huaneng Green Coal Power Project, which involves Integrated Gasification Combined Cycle (IGCC), pollutant recycling and carbon separation, utilization and storage, is among the global leaders in clean coal technology. In July 2009, the project was launched in the Coastal Industrial Zone of Tianjin; in the same year, the Two-Stage Dry-Feed Pressurized Gasification Technology, developed independently by this project, was introduced into the Future Fuels Company in Pennsylvania, USA. This project, a RMB 2.1 billion investment, has power units with a capacity of 205 MW. With expected completion in 2011, it could achieve a 99% sulphur removal rate with near-zero pollution and CO_2 emissions (Green Coal Power Company).
3. Smart grid	With advanced communication, information and control technologies, the smart grid could improve power grids to achieve the objectives of IT application, digitalization, automation and interaction. Using the smart grid, China could optimize the allocation of power grid resources, improve the reliability of power supply, enhance power quality and integrate power from renewables. Through demand management, it could also raise the terminal power utilization rate. China's smart grids, currently existing as pilot projects, are expected to be finished by 2020, leading to energy savings of up to 400Mtce and a 1100Mt recutions in CO_2 emissions (Jiang Liping, 2010).
4. Recycling process of iron and steel	The new generation of recycling incorporates advanced technologies in iron and steel production, energy conversion and waste utilization. By establishing a strategic alliance on this new technology, 6 large iron and steel enterprises in China aim to produce 100 Mt of high quality steel and generate 210 TWh of

production	electricity per year, while cutting energy consumption per tonne of steel to below 640kgce and reducing CO_2 emission by 100Mt. At the end of 2010, the Shougang Caofeidian Iron and Steel Company was set up, with an annual steel output of 9.7 Mt. Using the new technologies, the Shandong Iron and Steel Group plans to build itself into a world-class iron and steel company with an annual output of 50Mt (Science and Technology Daily, 2010; Shougang Caofeidian Iron and Steel Plant, 2010).
5. New wall materials	New wall materials refer to replacements for traditional bricks and include over 20 types in 3 categories, for example hollow bricks, aerated concrete blocks and other fired hollow products. Also included are fired products made from industrial waste residue (coal gangue, coal ash and other waste residue) and silt sediment from rivers or lakes; polystyrene foam boards, rock wool boards, glass wool boards and gypsum boards. Compared with traditional bricks, the new, lighter wall materials consume less energy but have better quality, could speed up the construction process and avoid the excessive use of earth. The new wall materials consume 40% less energy during production than traditional bricks and lead to energy savings of 30% through improved building insulation. In 2010, new wall materials accounted for 60% of the total amount.
6. Building houses by assembling technologies	Materials, energy and land to assemble buildings could be saved with pre-made structures. Such buildings are also resistant to earthquakes, environment-friendly and produce very little waste during the construction process. Currently, China has mature technologies to assemble steel structures, high-strength pre-stressed concrete prefabricated units and light building materials. Compared with traditional building methods, there are savings in time (20%), materials (30%), energy (70%) and land (20%). The industrialization rate of residential housing construction in Europe and the US exceeds 60%, 70% in Japan and about 20% in China. China's industrialization rate is expected to double by 2015 (Zhu Hengjie, 2011; Hu Baosen, 2011).
7. Chemical industry zone	By building chemical industry zones, China could integrate materials, medium products, side-products and waste, maximizing its resource utilisation. China has set up more than 60 chemical industry zones, for example the Shanghai Chemical Industry Zone with an energy consumption of 1.2 tce and water consumption of 33t per RMB 10,000 output value; 50% and 20% of the industrial average respectively. In this way, the investment could nearly be halved (China Petro and Chemical Industry Association).
8. Recycling of nonferrous metals	Recycled waste copper to produce secondary copper. Pure waste copper could be recycled in induction furnaces and mixed waste copper in reverberatory smelting furnaces with electrolysis refining process. The energy consumption per unit of secondary copper is only 55% of that for primary copper. This figure which covers energy consumed in exploitation, ore dressing and smelting. The mixed waste aluminium could be recycled by smelting in single-chamber reverberatory furnaces. The energy consumption per unit of secondary aluminium is only 3.7% of that for primary aluminium. The outputs of secondary copper, lead and aluminium were 2.4 Mt, 4 Mt and 1.35 Mt respectively in China in 2010, with energy savings of 17.2Mtce compared to primary metals.
9. Integration of forest development and paper-making	It could accelerate the development of planted timber forests and is conducive to water conservation, energy conservation and collective waste treatment to integrate forest planting, operation, logging, pulp-making and paper-making. The COD emission of China's paper-making industry is 1/3 of that of the industry sector. Taking advantage of the integration system, Jindong Paper-making Company in Jiangsu province produces over 1 mt of art paper, with water consumption of 10.7 m^3 per tonne of paper (only 18% of the national standard) and COD emissions of only 1/6 of the national standard. At the end of

	2008, 30 pulp and paper making enterprises planted forests which were anticipated to cover 5 million hectors by 2010 (Gu Mingda, 2011). Each hector of forests could absorb and fix 150 tonnes of CO_2.
10. Carbon capture and storage	In capture trial in 2008, China's Huaneng Gaobeidian Power Plant successfully captured 3000 tonnes of CO_2, 0.75% of the amount generated. Experiments show that for a 300 MW power plant to capture every 1 Mt of CO_2, the construction price will increase from RMB 4000 /kW to RMB 8000 /kW. At the same time, the energy consumption will increase by 30% and the power generation cost by 20%-30%. In 2010, the CO_2 capture project finished in Shanghai Huaneng Shidongkou Plant could potentially capture 100,000 tonnes of CO_2 with 99.9% purity. For every tonne of CO_2, it consumes 3.5J heat and 90kWh electricity. The Shengli Oil Field in China is also launching projects of CO_2 capture, purification, oil displacement and storage. Currently, it injects 100 tonnes of CO_2 into 4 wells, 50%-60% of which is stored underground, 40%-50% above ground. The upward CO_2 is captured again to experience the whole process. After completion, this project will be the largest CCS project around the globe, capturing, utilizing and storing 1 Mt of CO_2 every year at an estimated cost of RMB 230/ t-CO_2. (Southern Weekly, 2009; GDCCSR Project Team, 08/2010; Research Institute of Sinopec Nanjing Chemical Plant, 2011).

The new technologies in the manufacturing industry have great potentials for carbon reduction. For instance, the ironless PM motors developed by Chinese firms could reduce electricity consumption by 30% compared with traditional ones.

Shougang Caofeidian Iron and Steel Plant, completed in 2010, is a good example. It makes use of over 140 technologies for recycling processes in iron and steel production. Some of the innovation was undertaken by the company itself. The plant has production capacities of 9.89 Mt of pig iron, 9.70Mt of steel and 9.05 Mt of steel materials and, with a volume of 5,500 m3, the No1 and No2 blast furnaces are the largest and most advanced blast furnaces in China, with a coal injection ratio and blast furnace utilization coefficient of international standards. Other facilities, such as efficient large coke furnaces and 2250 cold-rolled plate production lines, also contain cutting-edge technologies. By recycling remaining heat, pressure, gas, waste water, solid waste and waste containing iron, this plant achieves much reduced emissions. Besides the usage in iron smelting, steel smelting and steel rolling, the recycled coal gas from blast furnaces, revolving furnaces and coke furnaces can also be used to generate 5,500 GWh annually, 94% of the power consumed by the plant itself. Steel slag could be used as raw materials of construction materials and blast furnace slag could be used in concrete mixed materials and cement production.

The rare-earth ironless PM motor developed by the Shenzhen Antuoshan Special Electric Machinery Company is another example of world-leading Chinese technology. The motor consumes 30% less energy, 80% of steel materials and 50% of copper materials compared to traditional ones. Avoiding siliceous steel sheets and iron core makes it more reliable, it is better insulated and is water, moisture and dust resistant. In 2010, China built three production lines for bulk production. If one third of newly-added motors follow this model, China could save 50 TWh, 500,000 tonnes of siliceous steel sheets and 20,000 tonnes of copper every year. In 2011, the government will introduce financial subsidies to encourage widespread usage of 1770 MW of these rare-earth ironless PM motors.

Lafarge, the French concrete producer, has established a joint venture in China to produce its ultra high-performance concrete. In construction this concrete can be

strengthened with reinforced steel fabrics rather than steel bars. Its pressure resistance intensity is 6-8 times greater, its anti-fold intensity 10 times greater and fire resistance 100 times greater than ordinary concrete. It is also more heat resistant. It may also lead to new types of cement products – it can be made into very thin products in different colours and shapes, as with plastics. By replacing traditional reinforced concrete, the ultra high-performance concrete could save 30-70% of cement, 15%-25% of steel materials and 46% of energy, as well as reducing CO_2 emissions by 53% (Economic Daily News, 2010; France Lafarge Company, 2010).

Japan has developed superior steel with an intensity and service-life double that of ordinary steel materials. This project was carried out in 3 stages. For the 1^{st} stage, from 1997 to 2001, the Japanese government earmarked 12 billion yen, whilst for the second, from 2002 to 2007, the 8 billion yen investment came from enterprises. Over the next 30 years, it is predicted that Japan will have the capability to produce iron and steel by using steel craps, rather than imported iron ore (Economic Information Daily, 2010).

2.3 Overcoming the challenges

2.3.1 Transforming high carbon industries

1. China's High-Carbon Industrialization

China's current industrialisation is fast-growing, carbon-intensive and expected to last for 10 years. According to IEA data, China's CO_2 emissions in manufacturing and construction industries accounted for 37% of the world's total in 2008, a figure equivalent to the OECD's total emissions in industry and building industry.

2. High Reliance of China's Industry on Coal

Avoiding and overcoming lock-in to a high carbon pathway, stemming from an overdependence on fossil fuels, is perhaps the greatest challenge for low-carbon development.

China's industry is highly dependent on coal. According to IEA data, coal for industry totalled 387 Mtoe in 2008 - 59% of the total energy consumption in the industrial sector, 60% of total global coal consumption and 2.5 times more than consumption in the OECD. Only 110 Mtoe coal was consumed by OECD, accounting for 13% of the global total energy consumption in industry sector (IEA, 2010).

In China, future demand for coal in the manufacturing industry, especially for steel, building materials and chemicals, will significantly increase. Coke (or coal injection) is still needed in iron-smelting, for example. Approximately 100Mt coal is consumed per year for brick production, while in the US coal is used in only 10% of brick factories. In 2006, 64% of China's synthetic ammonia was coal and this figure rose to 77% in 2009 as coal replaced oil due to rising oil prices.

3. Reliance of China's Manufacturing Industry on the International Market

China's manufacturing industry is highly dependent on the international market. According to several studies (IEA, 2008; Weter et al; Qi Ye et al. , 2008; Yao Yufang et al. , 2009), CO_2 emissions in net exports are approximately 30% of China's total emission; a figure that is not expected to significantly reduce in the next 20 years.

2.3.2 The Weak Foundation of Technology Innovation

Since China put forward the development strategy to build an innovative country in 2005, innovation abilities in the industrial sector have been dramatically enhanced. R&D professionals in large and medium-sized enterprises have increased from 0.4 million to 1.3 million by 2009; R&D expenditure has increased from RMB 95.4 billion to RMB 321.2 billion, as Table 2-18 shows.

Table 2-18: R&D expenditure in national large and medium-sized enterprises in energy and energy-intensive industries (2009)

	RMB 100m
Total amount of national large and medium-sized enterprises	3211.6
Coal mining and washing	93.0
Petroleum and natural gas exploitation	62.4
Petroleum Refining, Coking and Nuclear Fuel Processing	33.8
Production and Distribution of Electric Power and Heat Power	29.4
Steel	305.4
Non-ferrous metal ores	97.4
Building materials	59.0
Chemical industry	197.3
Chemical fibres	32.4
Food, beverage and tobacco	83.6
Textile wearing	82.1
Paper and paper products	32.0
Manufacture of transport equipment	460.0
Manufacture of communication equipment, computers and other electronic equipment	549.6
Manufacture of general purpose and special purpose machinery	407.8

Source: National Bureau of Statistics

However, compared with developed countries, China still has a long way to go. In 2008, R&D expenditure only contributed to 0.84% of sales revenue in large and medium-sized enterprises while the proportion in developed countries was over 5%. Take electric power enterprises as an example: China's R&D expenditure in 2008 was 0.38 billion dollars, compared to the IEA's 24 billion (IEA, 2008). As for perineum and natural gas enterprises, the R&D expenditures of the 10 largest enterprises in IEA were 2.6 and 10 billion dollars respectively. In industrial equipment manufacturing enterprises, the figures were 4.7 and 15 billion dollars for the 8 largest enterprises in IEA: Siemens, GE, Mitsubishi Heavy Industries, ABB, Alston, United Technologies, Caterpillar and IHI.

China's innovation ability is still weak. Less than a quarter of its large and medium-sized enterprises have R&D centres, very few own key technologies with independent intellectual property rights and up to 98.6% have not applied for a patent (Ministry of Science and Technology, 2008). In comparison, R&D expenditures in IEA energy and related industries amounted to USD 40-60 billion, 4 to 6 times as much as government expenditures.

Absorption and re-innovation abilities still need to be improved. In 2008, whilst RMB 44.04 billion was spent on technology imports, only RMB 10.64 billion was on digestion and absorption. In Japan and Korea, the expenditures on absorption are usually 3-10 times greater than introduction funds.

Technology is of prime importance to low-carbon industry. According to UNDP, at least 60 key technologies are needed to achieve low-carbon development, yet 42 are currently unavailable from Chinese companies. At present, RMB 1,000 billion is spent on equipment per year and 60% needs to be imported, including 90% of optical fibre manufacturing equipment, 85% of chip making equipment, 80% of petrochemical plants and 70% of car manufacturing equipment, numerical control machines and textile machinery (Ministry of Industry and Information Technology, 2011). 120 billion dollars were spent on semiconductor chip imports, accounting for 80% of the total. This is 106.2 billion dollars more than expenditure on crude oil and refined oil imports (Zou Shichang, 2010).

2.3.3 Inadequate Market Mechanism.

The general principles of the market mechanism are market pricing, competition, free access for enterprises and privatization.

Accelerate the market-oriented reforms in energy industry

Market pricing for energy products has huge potential to deliver energy conservation. According to an IEA study, China's average subsidy rate of energy consumption in 2005 was 11%, calculated as the difference between end-user price and international market price and reflecting all supply costs. The rate of gas, diesel, kerosene oil, LPG, natural gas and coal respectively went to 5%, 13%, 3%, 18%, 45% and 17%. Subsidies here include both direct and indirect financial intervention, for example allowances, tax credits, tax deduction and soft loans (direct interventions) and ceiling price, energy infrastructure and tax-free service (indirect interventions). 14% of energy could be saved through the removal of subsidies (IEA, World Energy Outlook 2006).

State-owned enterprises continue to play a major role in China's energy industry. In 2009, the gross industrial output, total assets and total profits of state-owned and state-holding enterprises accounted for 79.9%, 94.6% and 75.4% respectively of enterprises above a designated size.

The petroleum and natural gas industry is a typical oligopoly in China – it exhibits low efficiency, slow technology advancement, provides a poor deal for consumers and even aggravates inequality in distribution. Compared with foreign petroleum enterprises, the performance of the China National Petroleum Corporation in 2008 was relatively poor, with per capita crude oil production, per capita total income and per capita net profit of CNPC at only 5.5%, 2.0% and 1.1% of that of Exxon Mobil (US Petroleum Intelligence Weekly, 2009).

Open access for enterprises is another important principle. However, in China's energy industry, due to excessive government intervention, obstacles for SMEs both entering and exiting the market still remain.

Research shows that if China adheres to its current energy strategy, CO_2 emissions in 2020 and 2050 would reach 23.6 billion and 62.3 Gt respectively. However, with the advance of market reforms, emissions would be 11.8 billion and 31.1 billion – 50% lower (Mao Yushi, Sheng Hong et al., "The Impact of China's Marketization on Demand-Supply of Energy and CO_2 Emissions", 2009).

2.3.4 Imperfect Policies and Regulations.

In recent years, the Chinese government has introduced or reformed a series of relevant laws, regulations and policy measures. These include amendments to the "Energy Conservation Law" and promulgation of the "Circular Economy Promotion Law", "Regulations on Energy Conservation of Civil Buildings", and "Regulations on Energy Conservation of Public Institutions".

Other measures include, a system of responsibility for achieving the goals set for energy conservation; the elimination of outdated production capacity in energy intensive industries; accelerated development of energy-saving technologies and industrial information systems; enhanced services for and monitoring of energy-saving technologies; energy pricing reforms; new fiscal policies and economic incentives to motivate energy conservation; the promotion of energy-saving products; and the mobilization of popular participation. Furthermore, seventeen state organs have jointly launched a nationwide campaign on energy conservation and emissions reduction.

However, in April 2007 Premier Wen Jiabao noted that in key areas - energy conservation, awareness, responsibility, implementation, policies, funds and coordination – improvements are still required. The problems and obstacles are set out below:

1. Slow reform in energy prices

Today, most of China's energy prices are influenced by government intervention. Without a sound pricing mechanism, the oil price is only nominally within the international market. Moreover, vast subsidies for losses are offered to oil monopolies which have already earned huge super-profits. For example, the net profits of three state-owned petroleum enterprises in 2010 reached to RMB 265.1 billion, while the subsidies to SINOPEC in 2008 was RMB 50.3 billion.

Despite the fact that coal pricing is already market-oriented, most external costs such as excessively high circulation costs are not included, unfavourable for the "Mechanism of Coal-Electricity Price Linkage". The circulation cost of Shanxi Datong coal, for example, equalled 55-60% (2010) of ex-factory prices if the coal was carried to Shanghai and Guangzhou. China's average industrial electricity price in 2009 was RMB 0.586 /kWh, 25% higher than that of US, while residential electricity price was 35% lower (Li Ying, 2010). Subsidies from local governments are given to electricity intensive sectors, amounting to RMB 15 billion in 2009. In spite of the certain effect of differential prices (enterprises in eliminated categories have to pay RMB 0.3 more per kWh), some enterprises build self-owned power plants or utilize small hydropower facilities to generate electricity, whilst others transfer the higher costs to consumers.

2. Imperfect fiscal and taxation policies

China has implemented a series of fiscal and taxation policies to save energy, reduce emissions, adjust industrial structure, improve technologies and develop new energies. In view of climate change, policies in mineral, water, agriculture and forestry should also be adopted. Currently, the performance of these policies is poor due to the lack of financial investment and sound input mechanisms. Both tax relief and preferential policies are inadequate, and the government's energy saving production purchases need to be improved (Su Ming, 2011). A fiscal policy system, including carbon taxes, conducive to low-carbon development is currently under study.

3. Excessive Use of Administrative Measures

Administrative means are overused in pursuit of the goal of energy conservation. Rapid returns are expected via simple quota-setting for energy consumption; the imposition of energy audits in industrial fixed asset investment projects, creating barriers to entry; the issue of instructions to eliminate outdated production capacity; and mandatory indicators of energy consumption decline per unit of GDP.

In practice, regardless of cost effectiveness and market variations, these instructions and standards are often rudimentary and arbitrary, and can have dramatic adverse effects. The reckless expansion of energy-intensive industries has not been effectively curbed. In some areas, electricity and even heating have been cut off to achieve the goal of energy conservation, causing enterprises to utilize diesel oil to generate power – leading to higher cost and higher emissions.

Box 2-1: Unemployment and the closure of small power plants

Huge social challenges must be addressed in the transition to a low-carbon economy. For example, unemployment generated from the elimination of outdated production capacity. According to research conducted by the National Development and Reform Commission and the China Power Investment Corporation, 62 workers on average need to be resettled when shutting down every 10MW small thermal power unit. By the end of 2010, 27.1 GW have been closed, leading to redundancy for 0.45 million workers. New larger generation units and desulfurization units can indeed create some jobs, but the effect is quite limited. For example, a power company in Shanxi Province who shut down 15 small units - 800 MW in total - led to redundancy for 3,600 workers; in comparison, for every 2 units built - 600 MW each - only 380 workers are resettled.

4. Energy conservation by SMEs

Currently, 99% of the enterprises in China are small and medium-sized enterprises. In the industrial sector, their output value accounts for 60% of the total. Their energy consumption per unit product is 30% higher than that of large enterprises. In terms of energy conservation, SMEs are faced with many difficulties including financing, information, technology and skills. In addition, policies aimed at promoting energy conservation in the industry have often been designed for large state-owned enterprises. This means that financial rewards for energy conservation are sometimes awarded to enterprises that either do not merit them, or do not require financial assistance.

In comparison, in the US and Japan governments provide free energy audits for SMEs in energy conservation. For examples, USDOE provides assistance to SMEs in the development of energy-saving and environmentally-friendly technologies, transferring the scientific achievements of government research institutes without charge. In Japan, a fund has been established to offer preferential loans for small and medium-sized enterprises' efforts towards energy conservation; in addition, tax exemptions are provided for technological development by SMEs.

5. Barriers to private investment

State-owned industrial monopolies are a key barrier to the development of private enterprises. In 2009, the output values of petroleum and natural gas exploration industry, and the electric power industry in state-owned enterprises accounted for 96% and 91% of the gross value of industrial output respectively. Several legislative decisions designed to open up these markets ("36 Items on Private Economy" in 2005 and "36 New Items" in 2010 - opinions of the State Council on 'Encouraging and Guiding the Healthy Development of Private Investment') have not seen substantive progress to date.

Depending on regulatory structures, monopolies can lead to inefficient operation and poor industrial competitiveness; in addition, they can lead to higher prices which are against the interest of consumers. In Brazil, state-owned enterprises have been engaged in petroleum industry since 1998 and have opened their businesses to private and overseas enterprises. Ten years on, the output and reserves of petroleum have nearly doubled and Brazil transitioned from being a net importer to a net exporter. (Yang Lei, 2010/1/15)

6. A statistical system of carbon emissions monitoring needs to be established

A comprehensive statistical system of carbon emission monitoring is still in the research phase in China. Three key challenges must be overcome so that progress on low carbon industrialisation can be effectively managed and encouraged:

- Categories of energy products are few and poorly-defined
- The "factory method" used to classify production activities does not reflect energy consumption or emissions of certain industries. For example, statistical data on energy consumption in the building materials industry solely includes data from enterprises (accounting for around 60% of the total energy consumption), and statistical data on the fuel consumption of highway transportation only includes data on transportation departments (accounting for around half of the total fuel consumption).
- The statistical data of energy consumption and the emissions monitoring of facilities is incomplete.

3 LOW CARBON INDUSTRIALIZATION PATHWAYS

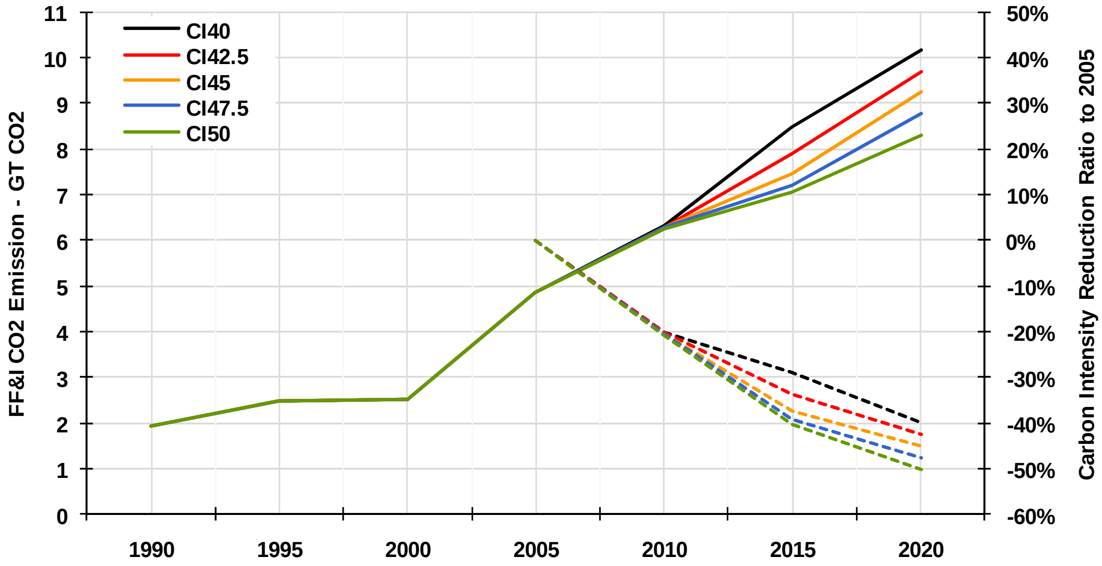
This chapter evaluates the role of low carbon industrialization in the wider process of low carbon economic development; considers pathways for low carbon industrialization and their potential in emissions reductions; and identifies the major industrial sectors required to realize the low carbon industrialization. The final sub-section sets out the critical role of innovation.

3.1 A key component of the low carbon economy

A scenarios approach was used by the Task Force to analyze the impacts of achieving 40-45% reductions in carbon intensity by 2020 on economic and social development, and the supply and demand of energy. The specific paths for low carbon industrialization were also analyzed. Three post-2005 scenarios are outlined: Situation CI-40 - a 40% reduction in carbon intensity; Situation CI-45 – a 45% reduction; and Situation CI-50 – a 50% reduction. Detailed descriptions of each scenario and the methodology can be found in the appendix.

The impact of realising different carbon intensity policy targets is shown in Figure 3-1. Under the 40-45% reduction target of carbon intensity, fossil energy use and industrial process emission can be controlled at 7.5 - 8.5 Gt/year in 2015, and 9 -10 Gt/year in 2020.

Figure 3-1: Impact of different carbon intensity policy targets on CO_2 emissions

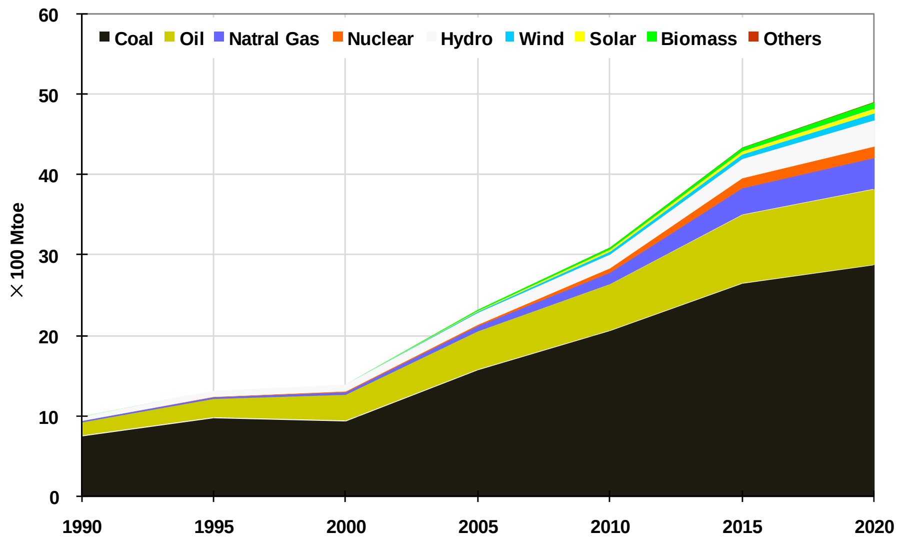


Source: LCIS Task Force analysis

As shown in Figure 3-2, Figure 3-3 and Figure 3-4, projected primary energy consumption under the CI40, CI45 and CI50 policy scenarios in 2015 is 4.33, 4.01 and 3.79 billion tce, respectively, and 4.90, 4.67 and 4.43 billion tce, respectively, in 2020.

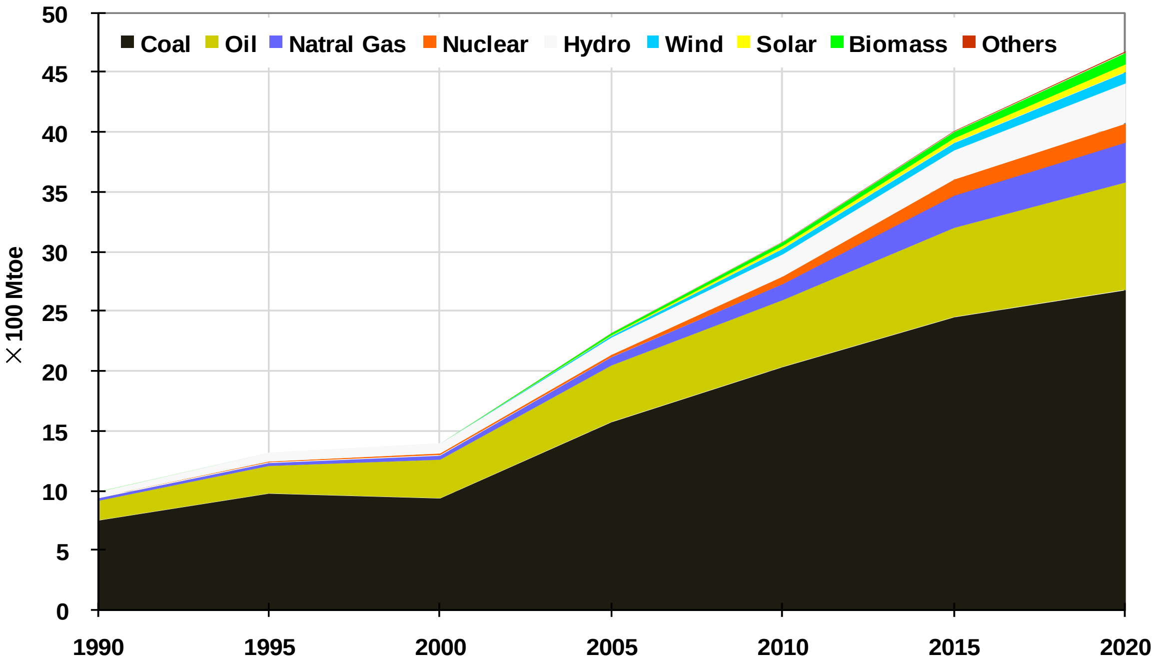
The terminal energy demand is predicted to be 2.81, 2.55 and 2.38 billion tce, respectively, in 2015, and 3.29, 3.05 and 2.82 billion tce, respectively, in 2020.

Figure 3-2: Primary energy consumption under CI40 scenario



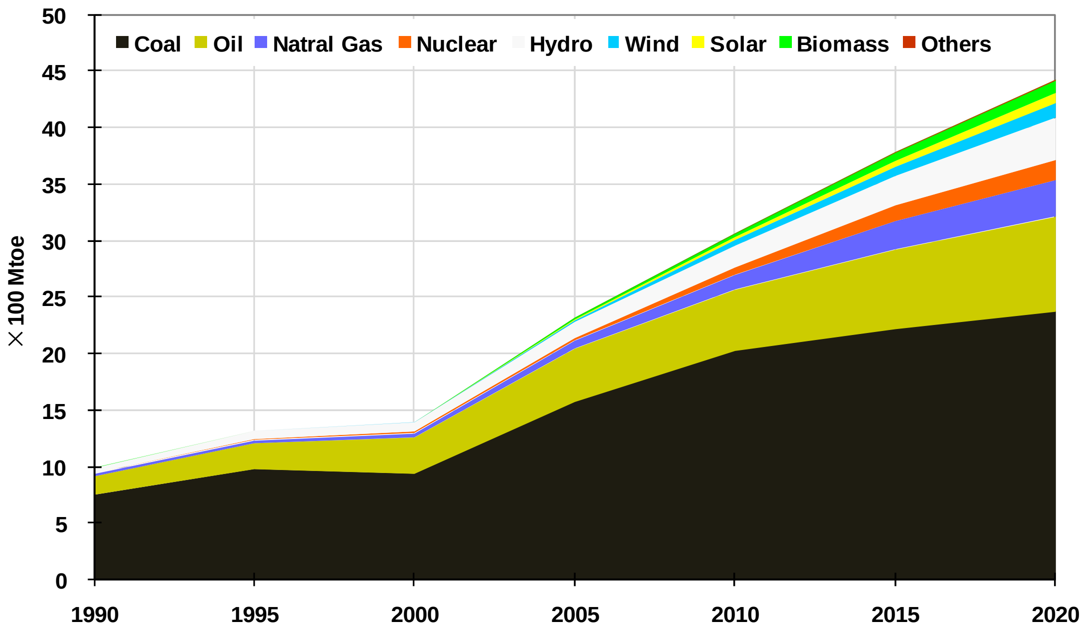
Source: LCIS Task Force analysis

Figure 3-3: Primary energy consumption under CI45 scenario



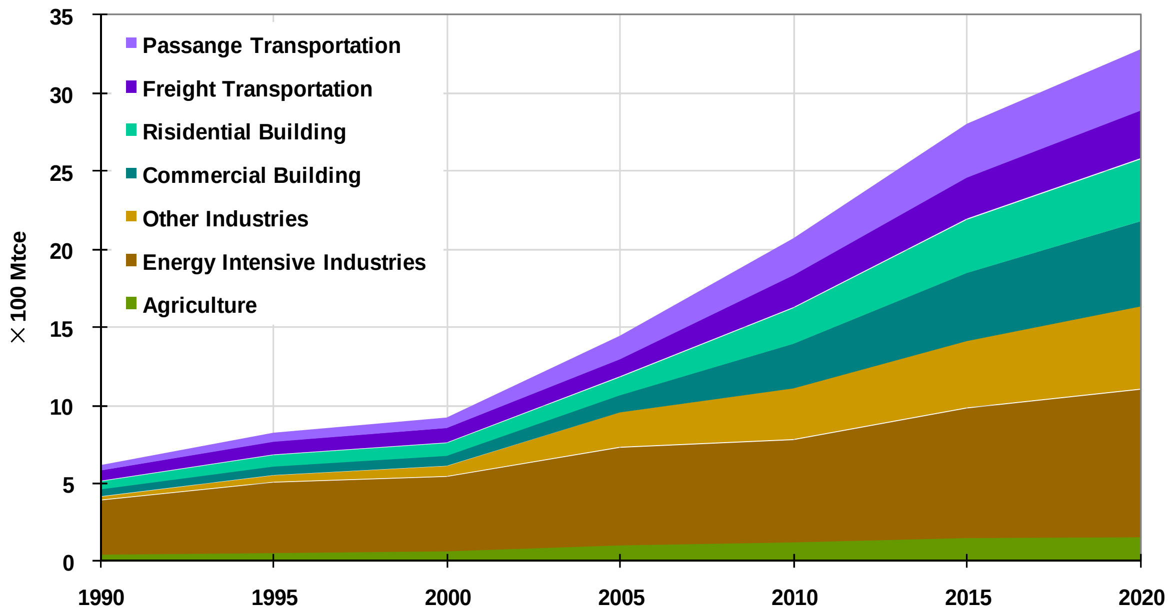
Source: LCIS Task Force analysis

Figure 3-4: Primary energy consumption under CI50 scenario



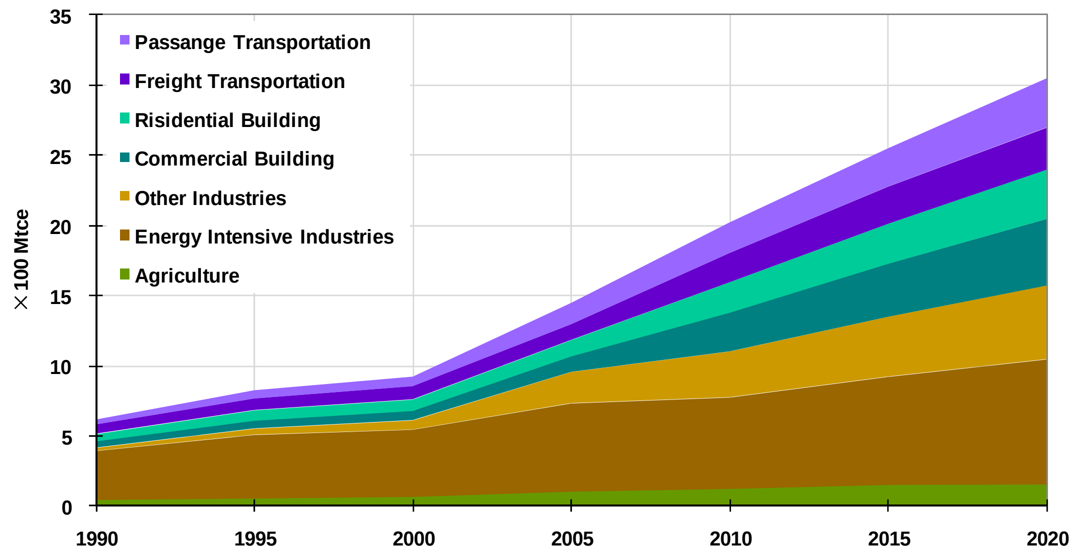
Source: LCIS Task Force analysis

Figure 3-5: Terminal energy demand under CI40 scenario



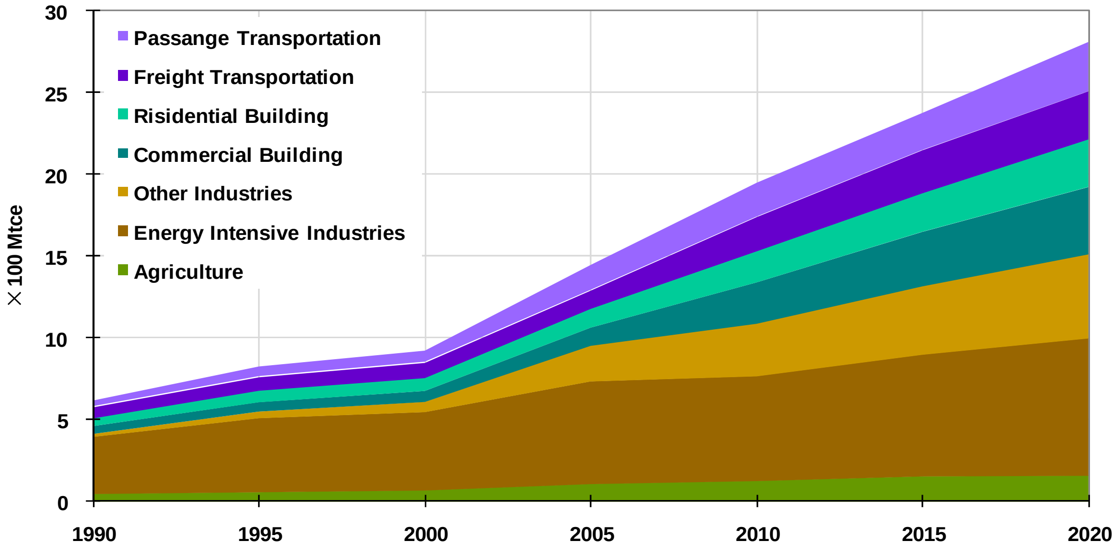
Source: LCIS Task Force analysis

Figure 3-6: Terminal energy demand under CI45 scenario



Source: LCIS Task Force analysis

Figure 3-7: Terminal energy demand under CI50 scenario



Source: LCIS Task Force analysis

The proportion of final energy consumption taken by the manufacturing sector – currently 63% - is expected to fall. The proportion of terminal energy consumption of the transportation industry (including aviation, water transport, railway, highway and pipeline transport) – currently 17%; the residential sector – currently 13%; and the service industry – currently 5%, are all expected to rise.

The energy consumption demand of the manufacturing industry will continue to remain high, closely related to the high proportion of energy intensive industries, such as steel and cement. In addition, China's industrial structure is difficult to adjust in the short-term. Although the energy-saving effects brought about by technical advances can partly offset the energy demand increase brought about by the increasing output of heavy industries, its effect is limited.

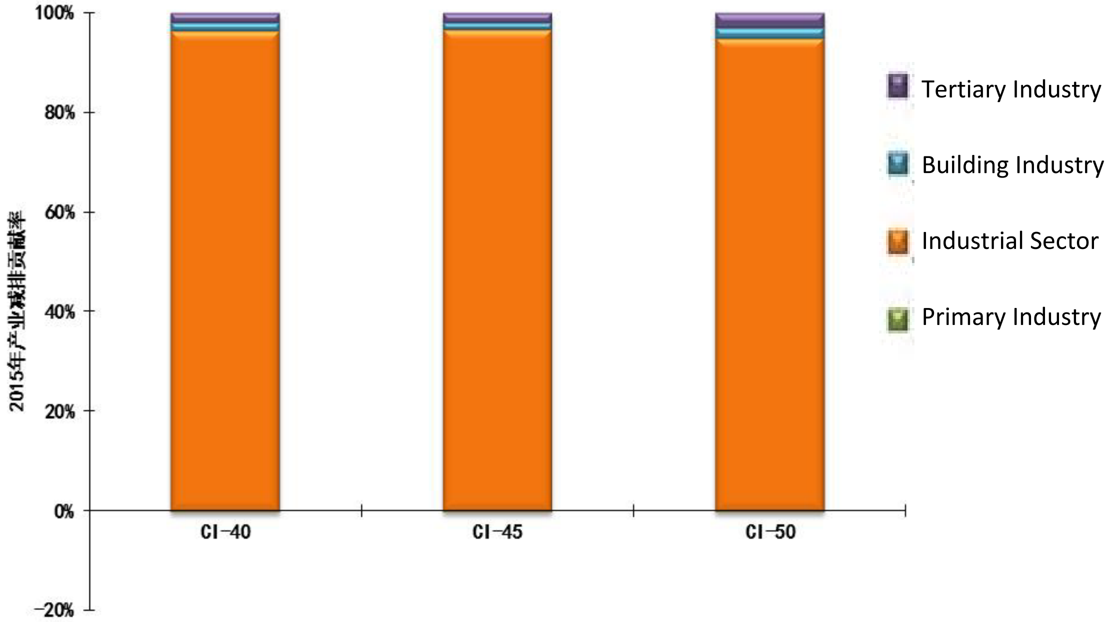
The transportation sector will be the main force behind China's future energy consumption increases. With the improvement of residential income levels, demands for travel quality and quantity will also continue to increase. As result, this sector's energy consumption is predicted to increase to levels second only to the industrial sector. With improvements in living standards, the energy consumption demand of Chinese residents will also grow rapidly, particularly in urban areas.

As China develops, urban populations are growing and increasing their energy consumption; in addition, energy demand in rural populations due to improvements in living standards is also growing, reducing the urban and rural energy demand gap. With the optimization of China's economic structure and an adjustment of its industrial structure, the service industry will play an increasingly key role in the national economy and, as a result, terminal energy consumption will rise significantly.

With economic development and income increase in the next ten years, energy consumption and emissions will continue to grow. The main contribution to emissions reductions, therefore, will be from industrial production systems. According to the scenario analysis (see appendix), the industrial sector's contribution to overall emissions reduction will be about 94.5% under CI40 96.7% under CI45 and 95.1% under CI50 in 2015 and 95.3%, 94.8% and 95.2%, respectively, in 2020.

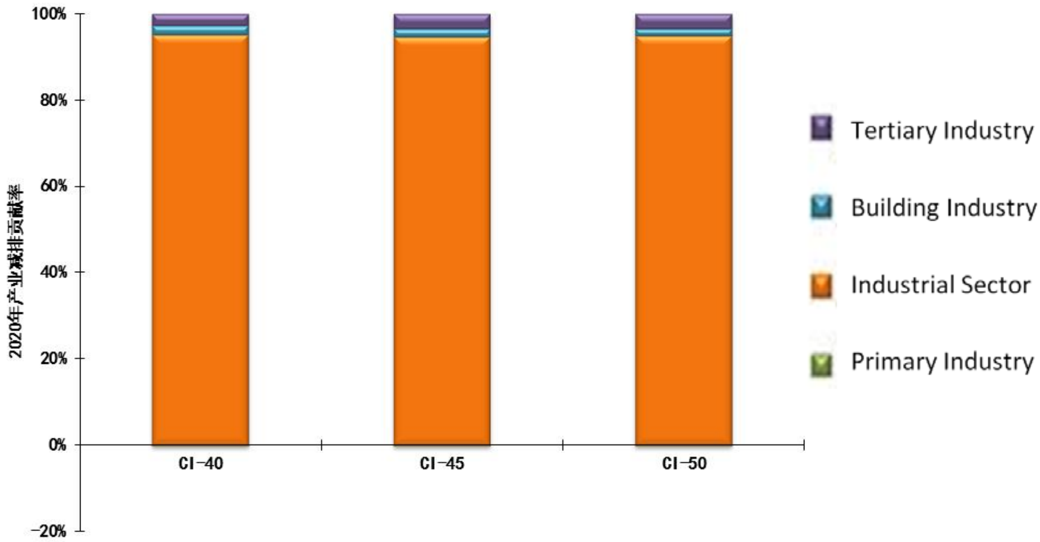
Figure 3-8 and Figure 3-9 show the contribution of reductions in industrial emissions under different carbon intensity policy targets.

Figure 3-8: Contribution by industries to emissions reductions in 2015



Source: LCIS Task Force analysis

Figure 3-9: Contribution by industries to emissions reductions in 2020



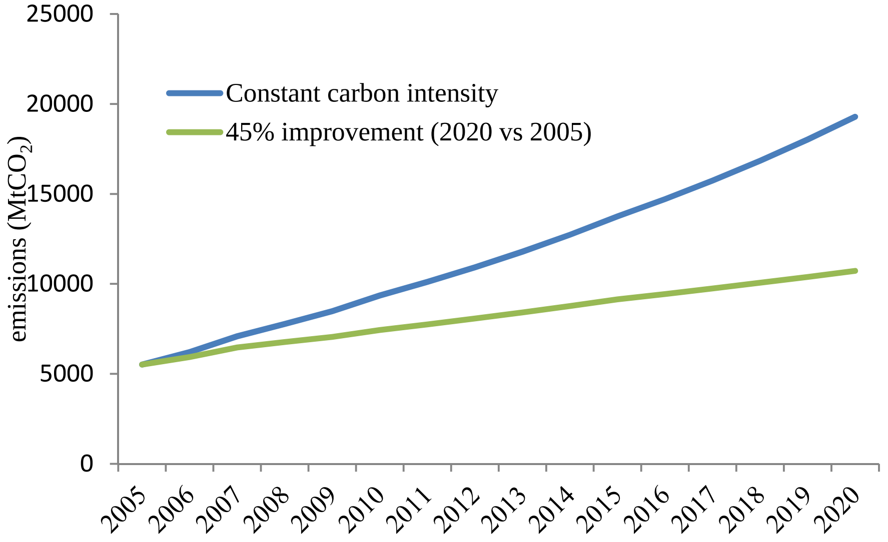
Source: LCIS Task Force analysis

3.2 Key dimensions: efficiency, restructuring and the circular economy

In 2005, China's CO_2 emissions were 5,513 Mt and its gross national product was 18.49374 trillion RMB: carbon emissions were, therefore, 2.98 tonnes/10 thousand RMB per unit of GDP. By 2020, if CO_2 emissions per unit of GDP remains constant, it is estimated that, with a predicted GDP of 64.7 trillion RMB, its CO_2 emissions will be 19,285 Mt. If the goal of reducing CO_2 emissions per unit of GDP by 45% is

achieved, total CO_2 emissions could be reduced to 10,728Mt by 2020. The contribution of industries to reductions in carbon intensity was 94.8% - 8,112 Mt, according to the analysis mentioned above. See Figure 3-10 for details.

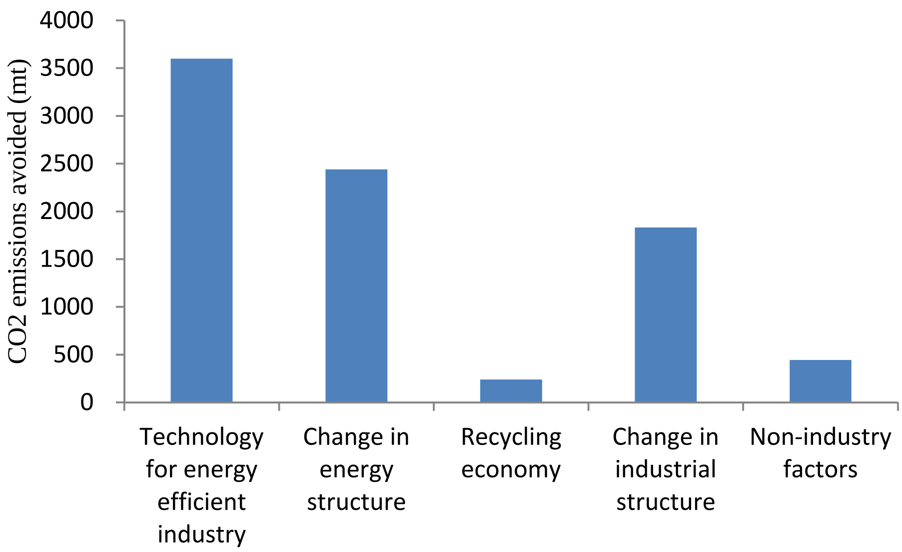
Figure 3-10: Emissions avoided due to 45% carbon intensity improvement in 2020



Source: LCIS Task Force analysis

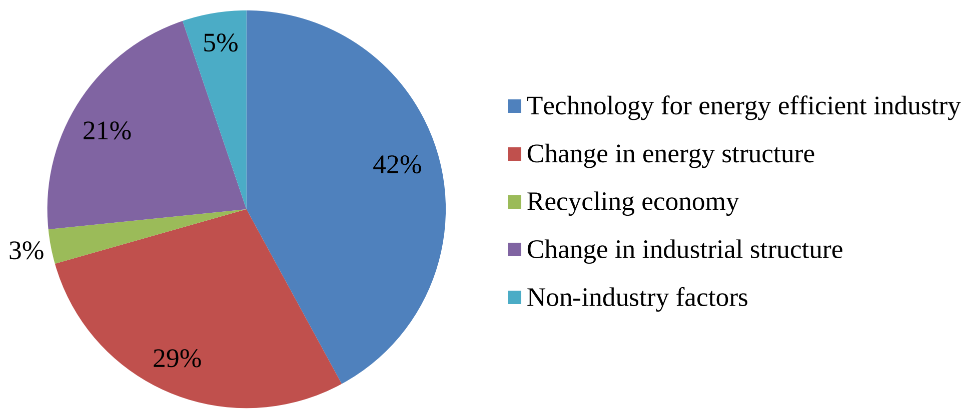
High energy-consuming industrial technologies have contributed 3,600 Mt to energy saving (see Figure 3-11 and Figure 3-12). The contribution of the optimization of energy structure was 2,440 Mt and the contribution of developing the circular economy was 240 Mt. The contributions of adjustments in industry structure, therefore, could be 1,832 Mt and in non-industry factors, 445 Mt: see Figure 3-11 for details.

Figure 3-11: Key areas of emissions reduction potential



Source: LCIS Task Force analysis

Figure 3-12: Key areas of emissions reduction potential (by %)



Source: LCIS Task Force analysis

3.2.1 Increase in energy efficiency of high energy-consuming industries

In the past 10 years, driven by market demand, China's energy intensive industries have gone through a rapid expansion, with energy intensive products seeing an average annual growth of 10%. However, the energy consumption of and emissions from these industries has also greatly increased, correspondently. In 2010, the energy consumption of China's energy-intensive industrial sectors accounted for about 56% of the total primary energy consumption.

Over the next decade, as the Chinese economy and society develops and continues to industrialization and urbanize, it is estimated that the energy-intensive industrial sectors will continue to expand to varying degrees. This will result in an increase of energy consumption and greenhouse gas emissions from these sectors. Accelerating the transition in these sectors, therefore, will play a crucial part in helping China achieve a low-carbon economy.

The industrial sector can reduce energy intensity in several ways: by reducing the proportion of energy intensive sectors as a share of China's industrial output; increasing the proportion of sectors with high added value; accelerating the improvement of energy conservation technologies in industrial sectors; and enhancing companies' energy management. In order to accelerate the take up of energy conservation technologies, actions include stricter regulations for new entrants into the energy intensive sectors and an energy conservation assessment system for new fixed assets investment projects. Existing energy intensive industries will need to retrofit with updated technology and outdated production capacity should be eliminated.

It is estimated that by 2020, the added value of energy-intensive industrial sectors will account for less than 25% of GDP, with their energy consumption per added value dropping by 40% compared to 2005. This accounts for a potential 1.5-1.6 billion tce of energy conservation and 3.6-3.8 billion t-CO_2 in emissions reductions.

3.2.2 Adjustment of the energy supply structure

China's primary energy supply structure is carbon-intensive compared with other countries. Coal accounts for 70% of the total energy consumption, while non-fossil energy sources only make up a small proportion. This is a key factor in China's high CO_2 emissions – and adjusting the structure will therefore play a key role in low carbon transition.

China's government has made the establishment of a safe, stable, economic, clean and low carbon energy system a long-term strategic objective. Non-fossil energy sources will account for 15% of China's total energy supply by 2020 according to the official target. To progress in this direction, in the 12th FYP, a binding target was made for the first time, requiring the proportion of non-fossil energy sources in the primary energy supply to increase from 8.3% to 11.4% by 2015.

The 12th FYP also makes strategic plans on accelerating the adjustment of the energy structure supply. These include:

- co-production and co-R&D between industries of synthetic natural gas, coal-produced liquid fuel and coal;
- steady progress in industrialization;
- enhancements in the exploration and development of oil and natural gas to stabilize domestic oil output, increase natural gas production and promote the exploration and utilization of unconventional oil and gas resources, such as coal-bed gas and shale gas;
- the use of clean coal-fired generators with high capacity and efficiency; thermoelectric cogeneration generators; and the construction of large coal-fuelled power plants that are able to comprehensively utilize coal refuse in large and medium-sized cities and industrial parks.

To enhance environmental protection and reduce rural-urban migration, the construction of hydropower plants should be actively promoted, particularly in southwest China. In addition, the utilization of water resources in medium and small rivers, according to the local conditions and scientific planning, could be enhanced by the construction of pumped storage plants. There are further plans for: the development of nuclear power; promotion of smart grids; development of wind power stations, solar energy, biomass, geothermal energy and other new energies; wider use of distributed energy systems; implementation of energy conservation strategies and consumption control; a two-way regulation of supply and demand; and, finally, differentiated management of coal resources.

Box 3-1: Key Energy Projects in the 12th FYP

1) The exploration and transformation of coal

Accelerating the construction of coal bases in Northern Shaanxi, Huanglong, Shendong, Mengdong and Ningdong; steady development of coal bases in northern, middle and eastern part of Shanxi, Yunnan and Guizhou; and the establishment of coal bases and large-sized coal-fuel power plants in Xinjiang.

2) Stabilize oil output and increase gas output

Promoting the formation of five large-scale oil and gas production zones in the Tarim and Junggar Basin, Songliao Basin, Ordos Basin, Bohai bay Basin and Sichuan Basin; speeding up the exploration of oil and gas resources in offshore and deep-sea areas; developing the extraction and utilization of coal bed methane in coal mining areas; and a significant increase in oil refining capacities.

3) Nuclear power

Accelerating the development of nuclear power in coastal provinces, maintaining a steady development of nuclear power in mid-China, and the establishment of a 40 GW nuclear power station.

4) Renewable energy

The construction of large hydropower stations in the Jinsha, Yalong, Dadu and other main rivers with total capacities of 1.2 TW; six large wind power stations in mainland China and two in coastal areas, with a capacity of more than 70 GW; and solar power stations, with capacities of 5 GW, in key areas such as Tibet, Inner Mongolia, Gansu, Ningxia, Qinghai, Xinjiang and Yunnan.

5) Network of oil and gas pipelines

Construction in the second phase of the Sino-Kazakhstan oil pipeline projects; in Chinese regions involved in the Sino-Myanmar Oil and Gas Pipeline; in the second phase of Central Asian natural gas pipeline; and in the third and fourth project of the West - East Gas Pipeline Project. The total length of pipelines under construction is 150 000 km. The construction of gas storage facilities is also being accelerated.

6) Power grid

Accelerating the construction of large coal-fuelled power stations, hydropower stations and wind power stations, which can provide electricity to other regions; the development of several cross-regional power transmission channels with advanced UHV technology (the length of the constructed electrical power transmission channels has a capacity of over 330 kV and amounts to more than 200 000 km); pilot projects in the construction of an intelligent electric grid and sub-station; and a widened application of intelligent electric meters and charging facilities for electric cars.

Source: The 12th FYP on National Economic and Social Development

In order to achieve the 11.4% non-fossil energy target by 2015, the Chinese central government and local governments have implemented a package of incentives and restrictive policies relating to industry, investment, financing, land pricing, taxation and environmental protection. By 2015, the proportion of coal energy in primary energy consumption is expected to decrease by 7% from 2010 and the proportions of natural gas, hydropower, nuclear power and new energies (wind power, solar power and biomass) will increase by 4%, 1.3% and 1.8% respectively.

The power sector is expected to be a ‘national pioneer’ in the adjustment of China’s energy supply structure and in the reduction of CO_2 emissions. In 2010, generator capacity reached 962 GW, 73% of which were fossil-fuel powered (99% of which are coal-fuelled) and China’s total power capacity reached 4.2 trillion kWh, (80% of which was sourced from fossil-fuels).

China’s economic and social development continues to drive demand growth in electricity. Over the course of the next decade, power sector adjustment will need to accelerate – the scale of change provides a valuable opportunity for the sector to transition towards a low carbon path. Five large Chinese power companies have already developed strategic plans with such changes as their core focus. In addition, China’s two grid companies have developed green strategies, focussing on accelerated construction of advanced cross-region electricity transmission lines.

Priorities for the future of China’s power development are as follows: to give priority to hydropower development; to optimize coal power; to actively develop nuclear power; to promote the use of low carbon energy; to appropriately develop concentrated supplies of natural gas; and to build distributed power stations adapted to local conditions.

The installed-capacity of hydropower is expected to reach 284 GW by 2015 and 330 GW by 2020, and the installed-capacity of pumped storage power station is predicted to reach 41 GW by 2015 and 60 GW by 2020. The proportion of coal-fuelled power is

expected to decrease by 4-5% every 5 years. As the 12th FYP laid out, the areas around Bohai, the Yangtze River Delta, the Pearl River Delta and north-east China will limit their number of coal power stations and new coal stations will be built in mid-west China, whilst the large coal stations in Shanxi, Northern Shaanxi, Ningdong, Zhungeer and Ordos will be the main suppliers of coal-fuelled power.

The development of natural gas aims to lessen the pressure on power supplies caused by seasonal energy-sources, such as nuclear, wind and hydropower. Its installed-capacity is expected to reach 60 GW by 2020.

By 2015 and 2020, the installed capacity of nuclear-powered generators is predicted to increase to 42 GW and 90 GW, respectively; the installed capacity of wind-powered generators to reach 100 GW and 180 GW, respectively; and the installed capacity of solar power generators to reach 20 GW and 200 GW, respectively. The areas not covered by grid extension must take advantages of local resources by building small hydropower stations in water-abundant areas and developing small-sized wind, solar and geothermal power stations, to suit local characteristics.

The potential contribution of the power sectors' supply structural adjustment to China's transition to a low carbon economy will involve three aspects: the development of non-fossil energy resources as substitutes for coal energy.; the development of clean, efficient, high-capacity generators units in substitution for the small, inefficient generators with high emissions and fuel consumption; and the third is the development of natural gas as a substitute for coal-fuelled power. The research results are as follows:

- The non-fossil energy target (15% of the primary energy supply by 2020) will lead to a net increase in non-fossil generating capacity of 500 GW compared with 2005. Their proportion of China's generators installed-capacity will increase to 36.5% from 24.4% in 2005, reducing coal consumption by 600 Mtce and emissions by 16 $MtCO_2$.
- By 2020, the proportion of the installed-capacity of coal fuel generators will decrease to 60% from 73.6% in 2005. Most will be relatively clean, efficient generators with large capacities by global standards, saving 260 Mtce of energy and reducing CO_2 emissions by 7 $MtCO_2$.
- The development of natural gas-fuel generators will achieve energy conservation and emissions reductions in two key ways: increased efficiency and substitution of coal. By 2020, it is estimated that the installed-capacity of natural gas powered generators will hit 60 GW, the potential contribution to energy conservation will increase to 32 Mtce from 2005 figures and emissions will be reduced by 140 $MtCO_2$.

3.2.3 Development of circular economy

China's government views circular economy development as a main strategy for the national economic and social development, and has enacted the Circular Economy Promotion Law. During the 11th FYP, China's energy intensive industrial sectors actively explored the development of a circular economy development and achieved preliminary results. In the 12th FYP, circular economy development in industrial sectors is expected to accelerated, playing an increasingly important role in the transition to low-carbon industry.

There are substantial foundations for and advantages to the development of a circular economy. Firstly, the pilot projects implemented in the 11th FYP period provide

practical methods and patterns as reference points for energy intensive industrial sectors to develop a large-scale circular economy. Industries of steel, non-ferrous metal, electoral power, chemicals, building materials and paper have conducted pilot projects and these provide an effective pattern for circular economy development and cooperation between related industries in resource recycling. Systematic assessment mechanisms for a circular economy and some sample enterprises have been established.

Secondly, a sufficient material basis exists for China's energy-intensive industrial sectors to develop a large-scale circular economy. Since the creation of the 11th FYP, the Chinese economy developed very quickly and people's living standards greatly improved. This led to an increased demand for and expansion of energy-intensive products. China is now a major producer of iron and steel, cement, plate glass, various nonferrous metals, caustic soda, soda ash, paper and cardboard.

With the accumulation of waste steel, metals and paper in society, waste resource output is becoming very productive. By the end of 2010, for example, China's crude steel accumulation was more than 5.6 Gt, social waste steel accumulation was nearly 18 Gt, and annual waste steel output was 54 mt. China has also established a waste resource recycling system. All of these conditions provide the material basis required for the development of a circular economy in energy intensive industries like steel, non-ferrous metals and papermaking.

Box 3-2: Key circular Economy Projects in 12th FYP

1) Comprehensive utilization of resources

Supporting the utilization of large bulk solid wastes such as associated and symbiosis mineral resources, fly ash, coal refuse, industrial by-product gypsum, smelting wastes, chemical waste residue, tailings, construction wastes and straws and waste wood. The development of several resource utilization bases.

2) Recycling system for waste products

Setting up 80 demonstration cities with waste product recycling systems which are rationally distributed and operated under regulated management, with multiple recycling methods and high recycling efficiency for key products.

3) Demonstration bases of "the mineral industry in the city"

Establishing 50 demonstration bases of "the mineral industry in the city" with advanced technology and regulated management, environmental standards compliance and radial impact and scale effect, in order to recycle the waste metals, electronic products, paper and plastics at large scale and with high value.

4) Industrialization of re-manufacturing

Building several national re-manufacturing zones and nurturing several re-manufacturer businesses in the fields of automotive parts, construction machines, mining machines, machine tools and office supplies in order to achieve the sound development of the re-manufacturing industry in scale and industrialization . Improvements to the standard system of re-manufactured products.

5) Reclamation of kitchenware waste

Building several kitchenware waste reclamation facilities in 100 cities with advanced technology and good economic returns, bettering order to improve the utilization and harmless disposal of kitchenware waste.

6) Recycling transformation in industrial parks

Developing recycling transformation in main industrial parks or industry cluster areas.

7) Promotion of resource recycling technologies

Creating certain demonstration projects and service platforms which are consistent with a circular economy, used exclusively for several important technologies and to assist the production and application of a whole set of machines.

Source: The 12th FYP on National Economic and Social Development

China's central and local governments have already put forward a series of measures aimed at promoting the circular economy, including plans and guidance, construction projects, economic incentives and regulatory restrictions.

Under the 12th FYP, the utilization of industrial solid waste rate will reach 72% by 2015 and the resource yield rate will increase by 15%; more supportive fiscal and financial policies will be introduced; and laws, regulations and standards will be adjusted. China will introduce an extended responsibility system, as well as a database of technologies and products involved in circular economy, set up a labelling system for remanufactured products and introduce a statistical and evaluation system for the circular economy. Technologies for energy conservation and zero emissions in initial stages, recycling and remanufacturing will be developed and used and best practice will be widely promoted. In addition, activities promoting the national demonstration bases of the circular economy will be carried out and the circular economy "Demonstration campaign" will be undertaken. The plan also mentions carrying out six major circular economy projects.

In 2010, the National Development and Reform Commission together with People's Bank of China and other administrative departments, produced 'Opinions on Investment and Financing Policies to Support Circular Economy Development'. This paper advised the establishment of an investment and financing policy system to support the circular economy development, including measures of:

- increasing financial support for investment in circular economy projects;
- research on and improvement to industrial policies;
- research on and policy formulation around prices and charges;
- improvements to and upgrading of the financial services supporting circular economy development, including the exploration of more direct financing channels. For example, encouragement of equity investment funds and venture capital investment to provide financial support through various debt financing products
- Supporting for enterprises using recycling resources to get listed on the stock market
- encouragements of foreign loans to support projects related with circular economy.

Currently, the National Development and Reform Commission is developing its "Circular Economy Development Plan for the 12th FYP Period". At the local level, many province and city governments are also developing plans for circular economy development, with a specific focus on specific industrial sectors. Examples of local governments undertaking this work include: Gansu, Henan, Hebei, Zhejiang, Shenzhen and Dalian. In addition, some local governments have set up special funds

for circular economy development, such as in Fujian. The implementation of these policies aims to provide effective incentives and the necessary restrictions for China's energy intensive industrial sectors to develop circular economies.

Box 3.3: The Overall Plan of the Circular Economy in Gansu

Following active development of its circular economy, Gansu province is estimated to see a drop in its resource consumption indicator in 2015 in comparison to 2005 figures. Energy consumption per industrial added value unit is expected to decrease by 35% and energy consumption per tonne of nickel is expected to decrease to 3.59tce/t. Meanwhile, the comprehensive utilization indicator in Gansu will grow substantially, with a rise in the comprehensive utilization ratio of industrial solid waste from 29.43% to 74% and a rise in the recycling ratio of waste iron steel, non-ferrous metals, paper, plastic and rubber to 77.7%, 84.4%, 74.5%, 75.0% and 86.5%, respectively. 10 Mtce of energy will be saved and CO_2 emissions will be reduced by over 20 mt.

Source: The overall plan of circular economy in Gansu

Based on the prioritisation of reducing energy consumption, China's energy-intensive industrial sectors focus primarily on improving resource output efficiency. However, as the accumulation of waste resources increases and the technologies of utilization and recycling keep expanding, circular economy development in energy-intensive industrial sectors will gradually shift its priority from reducing energy consumption to balancing their emphasis across energy consumption reduction, reutilization and reclamation. In these ways, China's energy-intensive industrial sectors can increase their resource output and waste recycling efficiency; in reducing their energy, water and raw materials consumption; and in reducing their waste and CO_2 emissions. The use of waste steel in steelmaking can save 60%[87] more energy than using iron from iron ore. It is estimated that, in comparison to primary metal production, one tonne outputs of recycled copper, aluminium and lead can lead to energy savings of 1054kgce, 3443kgce and 659kgce, respectively and reduce CO_2 emissions.[88]

Over the next decade, the development of the industrial circular economy will significantly support and promote the low carbon transition of energy-intensive industrial sectors. For example, in 2010, secondary non-ferrous metal production exceeded seven Mt, accounting for about 23% of overall production. If this had amount of secondary metal been produced from virgin material, energy consumption would increase by 10 mt of standard coal.

3.2.4 Adjustment of industrial structure

The adjustment of industrial structure will play a critical role in realizing China's CO_2 intensity targets, as shown in Figure 3-13 and Figure 3-14. Under the CI45 scenario the share of industry in China's total GDP would decrease from 41.8% in 2005 to 38.2% in 1015 and 36.5% in 2020. CI40 would mean a slightly slower pace of restructuring – the share of industry in GDP would be 36.7% in 2020 – while under CI50 structural change would occur more rapidly – falling to 35.2% in 2020. To produce a unit of added value, China's industry currently emits 2 to 3 times more CO_2 than its service industry.

Figure 3-13: Change in industrial structure by 2015

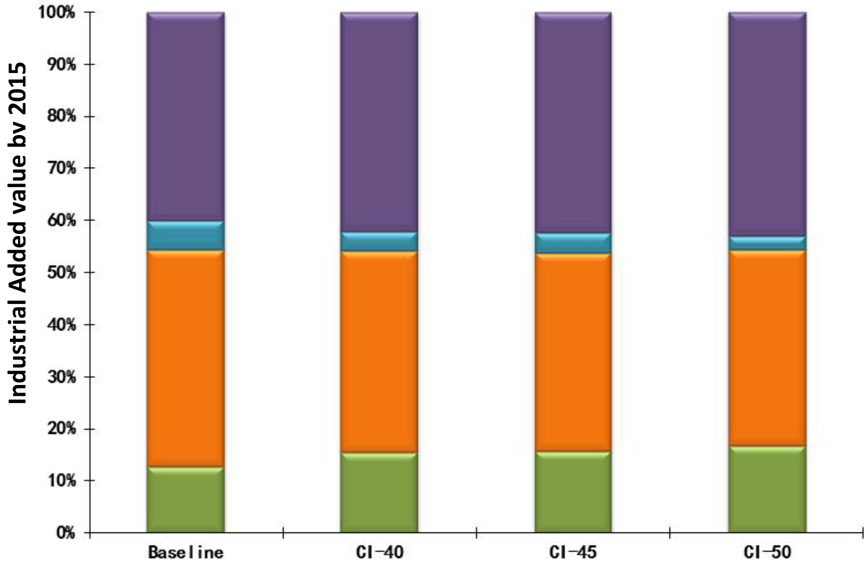
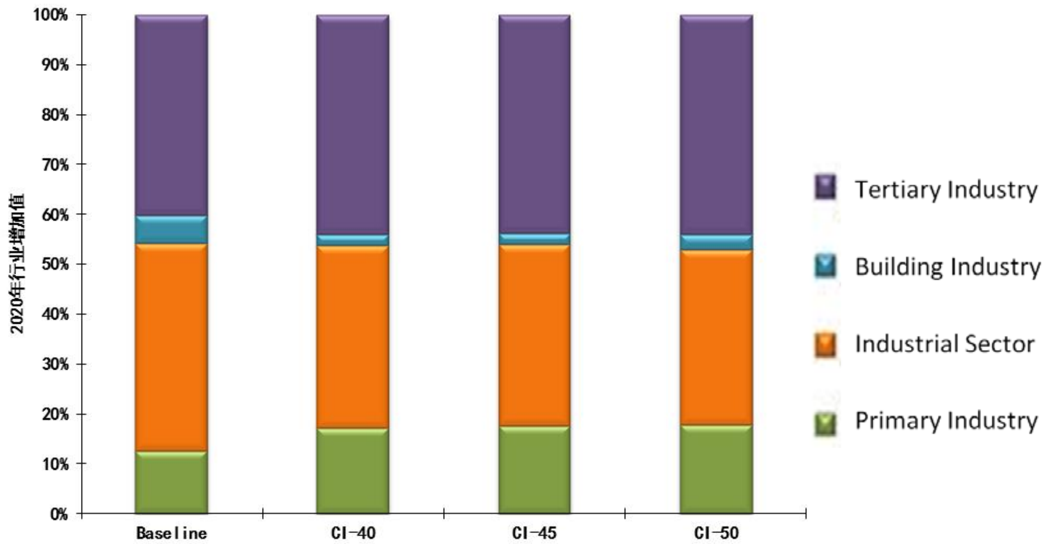


Figure 3-14: Change in industrial structure by 2020



Source: LCIS Task Force analysis

Within industry, internal structural adjustment will also play a significant role, as shown in Figure 5-11 and Figure 5-12 under different CI scenarios. The proportion of the top 10 high energy-consuming and high emissions industries will reduce from 50% today to 36.6% in 2015 and 31.8% in 2020 under the CI45 scenario. About 80 to 85 Mtce of energy consumption can be avoided in 2020 for every 1% decline in the proportion of high energy-consuming industrial added value, compared with 2005.

Figure 3-15: Change in industrial structure in 2015

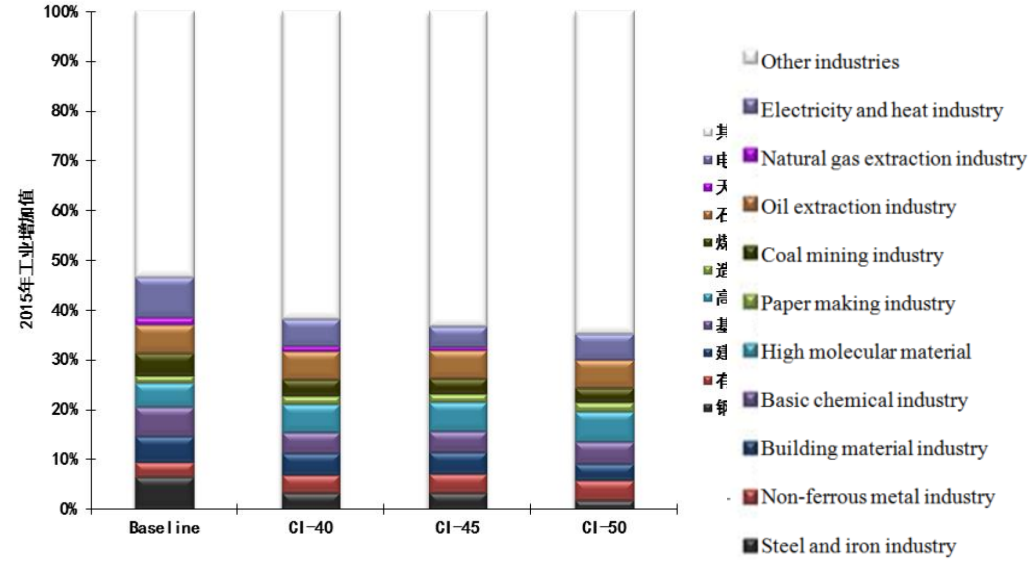
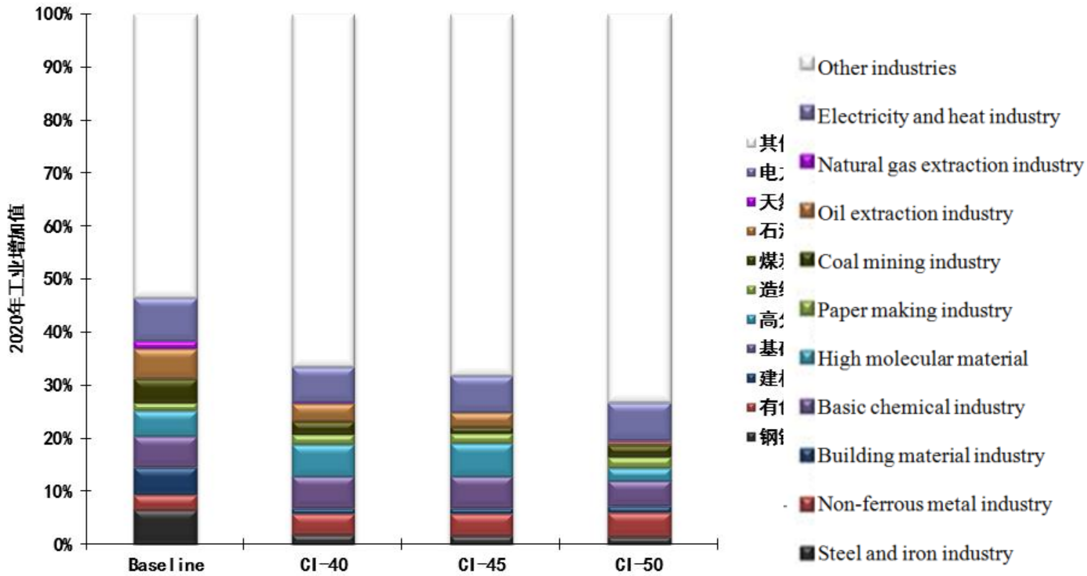


Figure 3-16: Change in industrial structure in 2020



Source: LCIS Task Force analysis

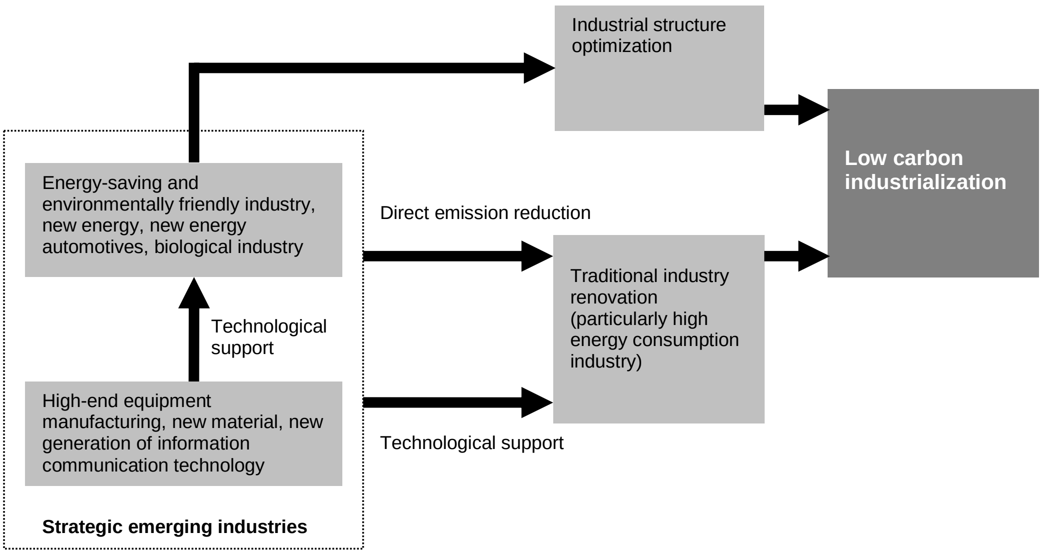
Although China has become a sizable industrial nation, it is far from being an industrial powerhouse. Overall, products tend to have relatively low added value. In 2007, China's manufacturing sector achieved 26.5% value added, far below the average level of 35% in developed countries and even further behind the US, which is at 45.9%. The Chinese government plans to adopt various measures to encourage enterprises to increase R&D investment, enhance the capability of new product R&D, move to the high end of industrial chains and keep raising product technology content. This will help to promote the international competitiveness of the products, raising product added value and further increasing the output efficiency of energy input.

A reduction of 1,832 Mt of CO_2 can be achieved through adjustment of industrial structure – a combination of changing the internal structure of secondary industry and increasing industrial added value.

3.3 Energy-intensive and emerging strategic industries are the two pillars

As mentioned above, the reform and upgrading of energy-intensive industry will play a critical role in the development of low carbon industrialization in China. 3.6 to 3.8 $GtCO_2$ can be avoided through energy efficiency measures. Strategic new industries, such as energy efficient, environmentally-sensitive automobiles, biological industries, the new generation of information technology, new materials and high-end equipment manufacturing industries can also play a supporting role in the development of low carbon industrialization.

Figure 3-17 - Processes of low carbon industrialization



Source: Development Research Center of the State Council, 2011

The emerging strategic sectors can contribute to China's low carbon industrialization in three distinct ways.

First, energy-saving technology and low carbon energy sectors will reduce the energy consumption and emissions of heavy industries. Switching to renewable energy, for example, will reduce emissions from the power-hungry aluminium sector, while 'waste' heat from industrial processes can be utilized through combined heat and power systems, driving up overall efficiency. Deeper improvements often require change at the system level. Electric vehicles, for example, can act as storage for the grid, reducing peak capacity.

Second, advanced materials, high-end manufacturing, biotechnology and information and communications are sectors that will provide key technologies to the energy-intensive industries as they upgrade. These range from lighter, stronger materials to data-driven analysis of the whole supply chain. These sectors are also in the front line in the search for low carbon alternatives to energy-intensive products such as cement, steel and fossil fuels – potential breakthroughs with potentially transformative impacts.

Finally, these seven emerging industries will contribute an increasing share of China's GDP, reaching 15% by 2020 according to China's current ambition. Meanwhile, the share of heavy industries in overall GDP will decline. This shift in economic structure will play a key role in reducing the country's energy and carbon intensity beyond

2020, since the emerging pillars tend to require much less energy and resources per unit of economic output than traditional sectors.

3.3.1 The development of strategic emerging industries can renovate and upgrade traditional industry and directly reduce industrial carbon emission

By reducing energy consumption in industrial processes, contributing to the circular economy and through developing high-efficient, energy and material-saving products, the energy-saving and environmental protection industry can save 356 Mt of coal and reduce CO_2 emissions by 818 Mt by 2015, and save 834 Mt of coal and reduce CO_2 emissions by 191.2 Mt by 2020.

Low carbon energy technologies will displace fossil fuel-based energy. By 2015, 467 Mtce can be replaced – a reduction of 1.15 $GtCO_2$ and, by 2020, a reduction of 720 Mtce and 1.771 $GtCO_2$. Low carbon vehicles will reduce greenhouse gas emissions both in production stage and more importantly in use. Biotechnology industries, particularly biological manufacturing, could replace the traditional materials needed in the process of industrialization, reduce energy and resource consumption, and decrease greenhouse gas emissions, as Table 3-1 shows.

Table 3-1: Impact on Emission Reduction of Development of Strategic Emerging Industries

	Emission Reduction Effect (CO_2)		Note
	2015	2020	
Energy Saving and Environmental Protection	818 Mt	1.912 Gt	Direct Effect
Low carbon energy	1.15 Gt	1.771 Gt	Direct Effect
Low carbon energy Automotive		300 Mt	to reduce industrial emission by reducing emission from material flow and personnel flow
Biological Industry	can replace oil and serve as an industrial material		Direct Effect
Information Communication Industry	615 $MtCO_2$ will be reduced by 2020 and the ratio of direct emission reduction to indirection emission reduction is 1:5		the ratio of direct emission reduction to indirection emission reduction is 1:5
New Material	Will have an important impact on resources saving, environmental treatment and material recycling and reutilization		Indirect Effect
High-end Manufacturing Industry			

Note: Due to the crossover and differentiation in comparison benchmark in the above emission reduction effect, the results cannot be directly overlapped or used to compare with the results of the model analysis.

3.3.2 The development of strategic emerging industries can provide support for renovation and upgrading of traditional industries

Information communication technology, new and advanced materials and high-end manufacturing industries will all contribute to the upgrading of heavy industries and the development of low carbon, environmentally-friendly alternatives. For example, low carbon energy such as wind power and solar power is characterized by

intermittence and large-scale application may have an impact on the safe operation of the power grid. But the reliability of the power grid can be improved by smart grid technology and a more interactive relationship between suppliers and providers (demand side management). Another example is that light and strong structural materials, such as high performance composite and high performance light metallic materials (e.g. aluminium, magnesium, titanium and relevant alloys), can reduce energy and resource consumption in many sectors, including aerospace, automotive, transportation, marine and construction.

3.3.3 The development of strategic emerging industries will optimize industrial structure, enhance the industrial added value and thus enhance the carbon production rate of industrial departments

Strategic emerging industries will also change China's industrial structure, reducing the proportion of energy consumption and high pollution industries and rising up the value chain. These industries are expected to account for 8% and 15% of the GDP by 2015 and 2020, respectively. This will have a significant impact on carbon intensity.

3.4 The pivotal role of innovation

China's energy-intensive industrial sectors have invested heavily in the development and promotion of low carbon technologies in recent years, especially technologies for improving industrial energy efficiency. Rapid development has occurred in, for example: ultra and supercritical fossil-fuel technology; CDQ technology; the utilization of differential pressure of BF gas to produce electric power; the utilization of cement kiln waste heat to produce electric power; the use of ammonia for energy conservation; and regenerative combustion technologies.

In the 11th FYP period, one thousand large energy intensive companies achieved an average energy intensity improvement of 22%. For every tonne of alumina, ethylene and caustic soda production, the amount of energy required dropped by more than 30%; Crude oil processing, electrolytic aluminium production and cement production decreased each fell by more than 10%; and coal-fired power consumption decreased by nearly 10%. This led to 1.5 billion tce of energy conservation - avoiding CO_2 emissions of 3.5 billion t. This was primarily due to the development and promotion of key energy conservation technologies.[89]

Many available and mature energy efficiency technologies are already available but barriers have prevented their widespread deployment – for example, technical and financial risk and a lack of investment and information. In many cases they have only reached between 1% and 10% of their potential market. Future innovations will increase the size and scope of energy efficiency opportunities.

The 12th FYP highlights priorities such as: developing energy conservation and environmentally-friendly strategic new industries and pilot projects and conducting major projects on the energy conservation transition, the industrialization of energy conservation technology and contracted energy management (see Box 3-3). In addition, the government will ensure that new energy-intensive businesses reach strict performance standards and will eliminate energy intensive businesses with low efficiency and high emissions. This will create market space and more favourable conditions for energy-intensive industrial sectors to develop and use advanced energy technologies.

Box 3-3: Key Projects on Energy Conservation in the 12th FYP

1) Projects on energy conservation and transition

Continuing the cogeneration, optimization of energy system in motor equipment, utilization of surplus heat and pressure, reformation of boiler (kiln), projects of saving and replacing oil, energy saving in building and traffic, and green lighting.

2) Projects on popularization of energy conservation production for the convenience of the people

More financial subsidies for energy saving and high efficiency products of electrical appliances, automobiles, motor equipment and lighting.

3) Demonstration project of Industrialization of energy conservation technology

Supporting the demonstration of crucial energy conservation technologies, products utilizing surplus heat and pressure and highly efficient generators; promoting the large-scale production and application of products with crucial energy conservation technologies.

04 Project of contracted energy management

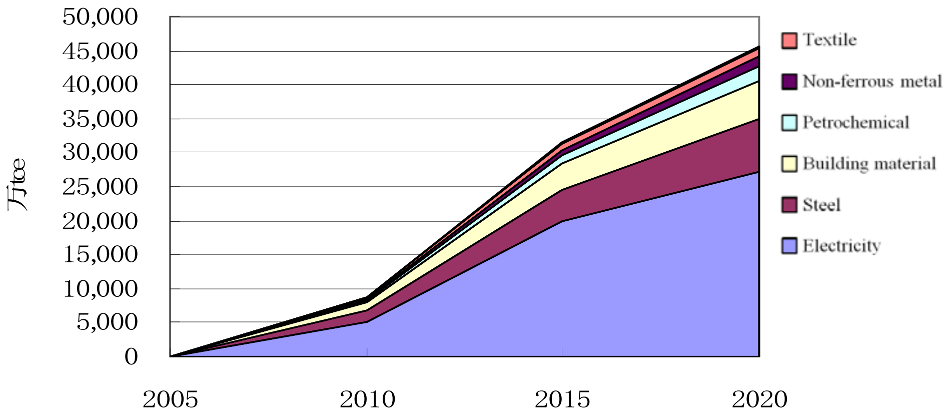
Promoting the energy conservation service companies to use contracted energy management to reach the energy conservation target, and supporting the development and growth of energy conservation service industry.

Source: The 12th FYP on national economic and social development

Scenario analysis has identified 79 key industrial energy efficiency technologies which, if widely deployed, have the potential to avoid 456 Mtce of energy conservation and 1.22 billion t-CO_2 by 2020 (see Figure 3-18 and Figure 3-19). If all energy efficiency technologies (including existing ones and newly-emerging ones) were widely and immediately adopted by energy intensive sectors, by 2020, there would be a cumulative saving of 0.65-0.75 billion tce of energy, and 1.7-1.9 billion t-CO_2 compared to business as usual.

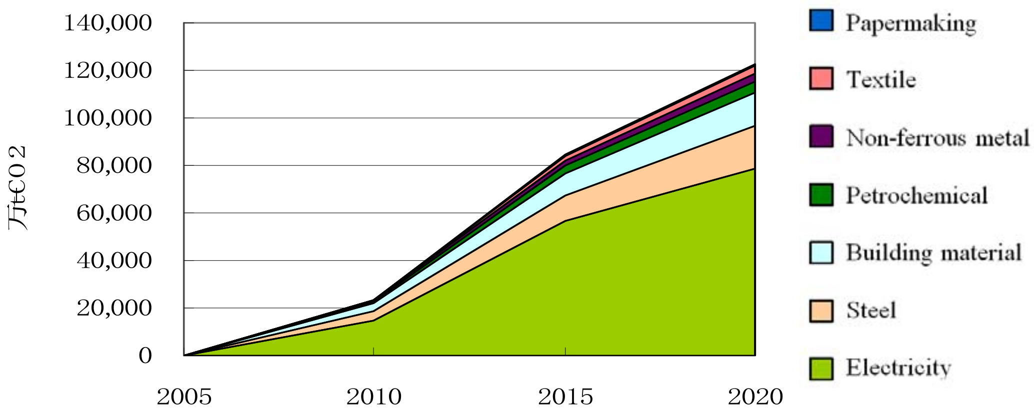
There are, however, many challenges to overcome before widespread adoption is achieved. One of the most important factors is whether there will be enough investment in the development and promotion of these technologies. Research shows that RMB one trillion will be required between 2011 and 2020 to deploy the 79 key technologies.[90] If all the energy technologies developed for the energy intensive industrial sectors get timely promotion and application, then 1.6-2.0 trillion RMB of investment will be required in the next decade.[91]

Figure 3-18: 79 kinds of crucial industrial energy conservation technologies – the potential for avoiding energy consumption (2006-2020)



Source: LCIS Task Force analysis

Figure 3-19: 79 kinds of crucial industrial energy conservation technologies – potential to avoid CO_2 emissions. (2006-2020)



4 THE ROLE OF ENERGY INTENSIVE INDUSTRY

This chapter will discuss the issue of low carbon development in high energy-consuming industries. The current situation, potentials emission reductions, paths of emissions reductions and the policies and measures required in industries such as the power sector, steel, building materials, petrochemical, non-ferrous metal, textile and paper-making industry, will be presented.

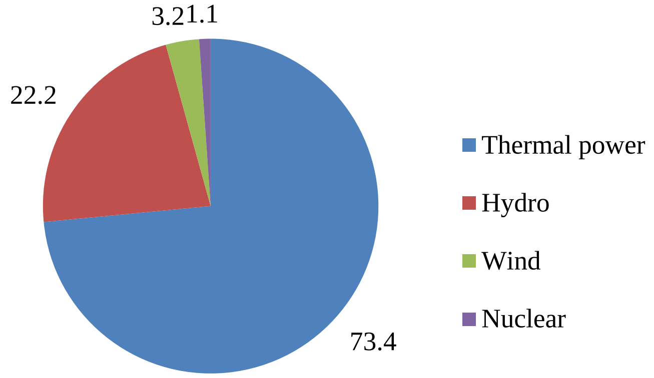
4.1 Electric Utility Industry

4.1.1 Current situation and development trends

The 2008 global financial crisis had a widespread impact on China, particularly on its energy-intensive industries. Nonetheless, China's economy has maintained a growth rate of 11.2% per annum. This rapid growth has led to an unprecedented expansion of electricity generation. China has now become the world's second largest power producer.

Between 2005 and 2010, installed capacity increased to 962 GW: a net increase of 450 GW. The capacity is made up of 706.6 GW on fossil-fuel power, 213.4 GW on hydropower, 31.07 on wind power and 10.82 GW on nuclear power, as shown in Figure 4-1.

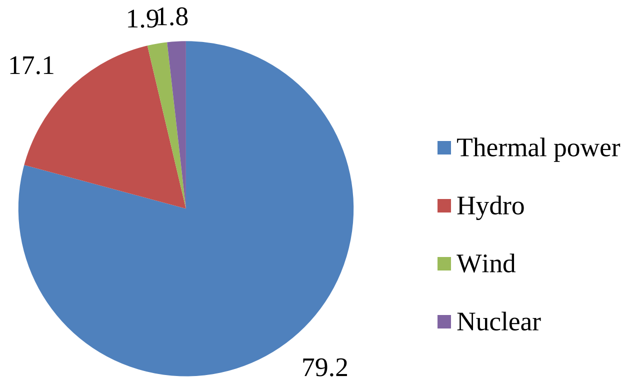
Figure 4-1: China's power supply structure in 2010



Source: LCIS Task Force analysis

In terms of power generation, the 2010 total of 4207 TWh is made up of 3330 TWh from fossil-fuels, 721 TWh from hydropower, 82 TWh from wind power and 74 TWh from nuclear power (Figure 4-2).

Figure 4-2: China's power generation structure in 2010

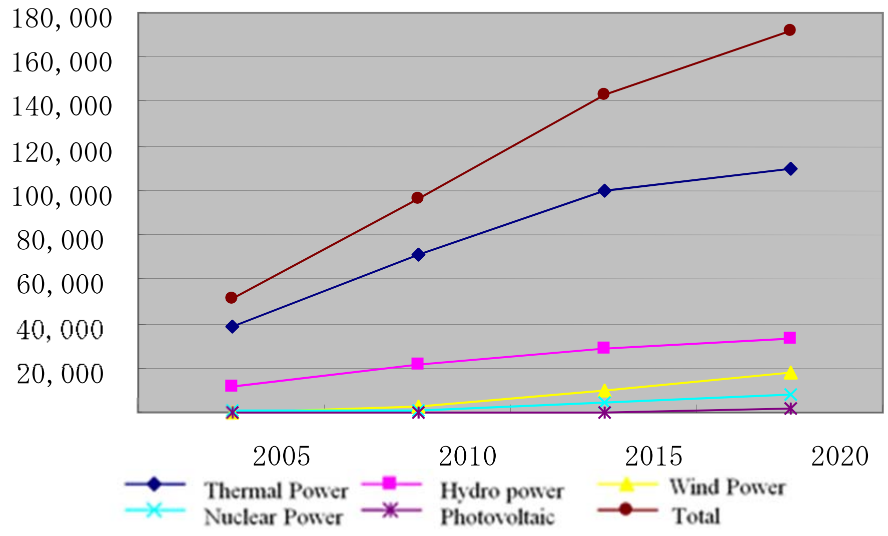


Source: LCIS Task Force analysis

China will continue to undergo an industrialization and urbanization phase over the next ten years. In addition to significantly raising living standards, it is expected that China's economy will maintain a high growth rate; together these will increase power demand. Furthermore, the gradual popularization of future plug-in hybrid vehicles and pure electric vehicles will also bring about new power demands. The driving forces for China's future electricity demand therefore continue to be relatively strong.

The national generating installed capacity will increase to 1.7 TW by 2020, with a national power generation of over 8,000 TWh. As China heads towards the 15% target for low carbon primary energy consumption by 2020 (see section 3.2.2), there will be a big adjustment in the power supply, with huge increases in the installed capacity of nuclear, wind, solar and hydro power. Newly-added coal generation will be much more efficient than the current average. Consequently, there will be a significant decrease in the proportion of fossil-fuelled power installed. The proportion of highly efficient and low effluent natural gas power generation capacity will also increase.

Figure 4-3: China's Power Trend from 2005 to 2020 (10,000kw)



Source: LCIS Task Force analysis

4.1.2 Low carbon evolutionary path and potential contribution of the low carbon fossil-fuel power

(1) Low carbon fossil-fuel power development of the "11th FYP"

For a long time, China's power supply has been reliant on fossil fuels. The restructuring of fossil fuel power industry, therefore, will play a key role in China's low-carbon transition. During the "11th FYP", the significant progress was made, for example:

- The proportions of fossil-fuel installed capacity and fossil-fuel generating capacity reduced by 2.2% and 2.3%, respectively, compared to 2005 figures.
- 72 million small, inefficient and highly effluent coal units were eliminated.
- Clean and efficient high-capacity coal units were constructed, a total of 33 GW-class ultra-supercritical coal power units were put in operation and the proportion of coal power units of over 300 thousand kW in fossil-fuel installed capacity increased from 47% in 2005 to over 70%.
- The fossil fuel power consumption rate declined to 335gce/kWh in 2010; a 35gce/kWh decrease since 2005.

Overall this avoided around 100 Mtce energy and a corresponding reduction of 300 $MtCO_2$.

(2) Low carbon development path of fossil-fuel power in 2020

Taking into account future predictions on China's power industry and previous experience from the "11th FYP" in the development of low-carbon electricity, plans for the next 10 years for the low carbon development path of fossil-fuel power include:

- Continued shutting down of inefficient coal units.
- Increasingly rapid construction of clean and effective high-capacity coal units.

- The development of heat powered plants.
- The implementation of energy-efficient generation and distribution, and enhanced electricity trade.
- The adoption of energy-efficient technologies by heat powered plants and improved management measures.

i) Continued shutting down of inefficient coal units

The proportion of China's present fossil-fuel installed units with less than 300 GW units is close to 30%; made up by a considerable part of old, inefficient and highly effluent coal units. The closure of such units will be an important contribution towards energy conservation and reductions in CO_2 emissions.

ii) Increasingly rapid construction of clean and effective high-capacity coal units

In the next ten years, in order to satisfy the rapid growth in electricity demand and replace the old, ineffective coal units, the Chinese government will continue to construct fossil-fuel power units of no less than 300 GW, apart from developing nuclear, wind, solar and hydro- power. Moreover, the fossil-fuel power units will be clean, efficient and high-capacity ultra-supercritical units and natural gas generating units. This should enable significant energy conservation effects.

iii) Actively developing cogeneration units

Heat power units constitute an important part of the low-carbon transition. For example, for 200MW sub-critical units, when the heating ratio is 30%, coal consumption is equal to the ultra-supercritical fossil-fuel units.

iv) Energy-efficient generation and distribution

Grid dispatch should be prioritised for efficient and low emission units by according to unit energy consumption and pollutant/emission levels, recognising the need for a reliable and affordable power supply. In recent years, the Chinese government undertook pilot projects in five provinces - Guangdong, Guizhou, Sichuan, Jiangsu and Henan. These have successfully demonstrated the benefits of adjusting grid dispatch processes on the basis of energy and environmental performance.

v) Electricity trade

To move towards an electricity market that promotes low carbon, energy conserving generation, the State Grid Corporation has explored various approaches to electricity trading and contracts, including bilateral trade, centralized matching and listing. The principle of "large replaces small" electricity trade means that, through an open and transparent trading platform, the replacement of low capacity power units by hydropower units or high capacity fossil-fuel power units should be encouraged.

vi) The adoption of energy-efficient technologies by thermal generation plant and improved management measures.

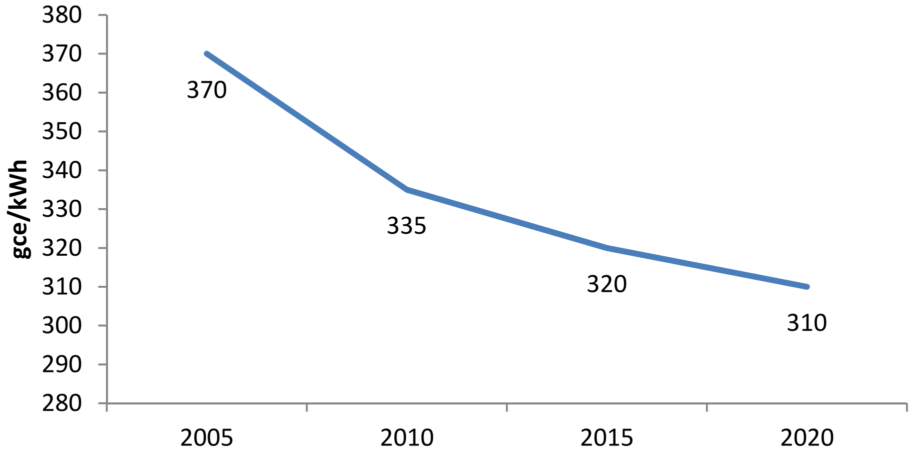
Power plants are, themselves, an energy-consuming industry. Energy conservation management and energy-saving technologies should be promoted in existing and future power stations.

(3) The potential contribution of low carbon development in 2020

Overall, it is projected that the fossil-fuel power supply will decrease to 310gce/kWh by 2020; that the proportion of coal generation installed capacity in state generation

installed capacity will drop from 73.6% in 2005 to 60% by 2020; and that the proportion of natural gas generation units will increase to 3% by 2020. The fossil-fuel power industry may achieve up to 292 Mtce in energy savings in 2020, compared with 2005 figures. In total, this will avoid emissions of 840 $MtCO_2$.

Figure 4-4: Energy intensity of China's fossil fuel power generation from 2005 to 2020



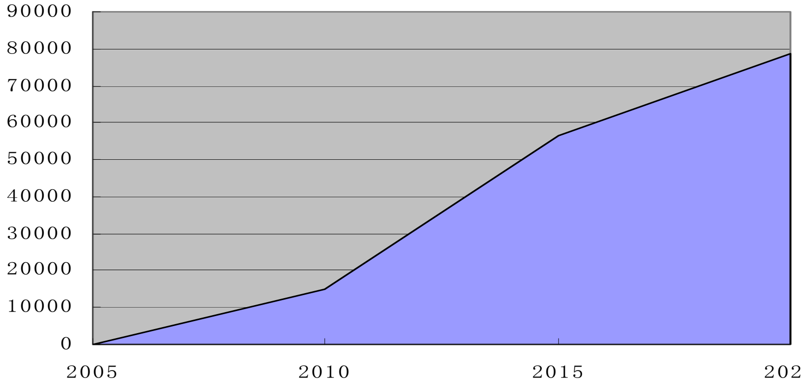
Source: LCIS Task Force analysis

(4) Analysis of low-carbon technology potential in thermal power generation by 2020

17 major low-carbon technologies for the power generation industry have been identified through the scenario analysis. Research on these 17 low-carbon technologies shows that if they can be applied broadly by 2020, 272 Mtce could be saved annually, equivalent to an annual reduction of 7.8 $GtCO_2$ emissions. The 17 technologies are as follows:

Ignition of gasified oil in coal-fired boilers; the ignition of pulverized coal plasma particles in coal-fired boilers; dust-removing technologies; electric-bag composite dust-collectors; flexible contact seals for air pre-heating in coal-fired boilers; intelligent soot-blowing and coking warning systems in boilers; waste steam-heating and boiler starting systems; waste heat recovery from flue gas desulfurization island and fan operation optimization; thermal power plant supervisory information systems (SIS); integrated flue gas heat recovery and optimization systems; upgrading of steam turbine circulation; seal modification for steam turbines; cleaning devices for condensers with spiral ties; energy-saving vacuum systems; Ultra supercritical thermal power generation; integrated gasification of coal-fired power generation; and fuel-gas-steam combined cycle.

Figure 4-5: Potential CO_2 reduction from application of 17 major low-carbon technologies in the coal-fired power industry (2006-2020 – 10,000t CO_2)



Source: LCIS Task Force analysis

4.1.3 Policies and measures

1) Energy and power generation plans should be strengthened to guide and promote structural reform in the power generation industry.

2) Coal-fired power plants with small capacities should be closed and co-generation should be rapidly expanded. Shut-down efforts should be prioritised ahead of building larger power plants, especially for those small plants in local SOEs, collectively-owned enterprises and foreign-owned enterprises. Problems arising from the shut-down process and provide relevant policy support to affected enterprises will need to be tackled.

3) Incentives for the power-generation industry to save energy and reduce emissions should be introduced. Price incentives should be implemented and tariff compensation for power plants with energy-saving efforts should be adjusted and improved in order to encourage the development of low carbon energy and the instalment of large fire-power generators. China should explore a CO_2 emissions trading system for the power generation industry.

4) The development and application of low-carbon energy technologies in the fields of cleaner coal, natural gas, renewables and low carbon energy should be promoted, with a particular focus on wind and solar power. In addition, carbon capture and sequestration technologies should be explored. A roadmap and application strategy should be developed that combines independent R&D and the introduction of foreign technology.

6) Power-generation licencing and trading reform should be pushed forward. Regulators and companies should summarize useful experience, identify existing problems, explore possible solutions and carry on with effective implementation of power-generation license trading.

7) Regulations for coal-fired power plants should be strengthened to encourage coal-fired power plants to aggressively enhance their energy efficiency.

4.2 Steel Industry

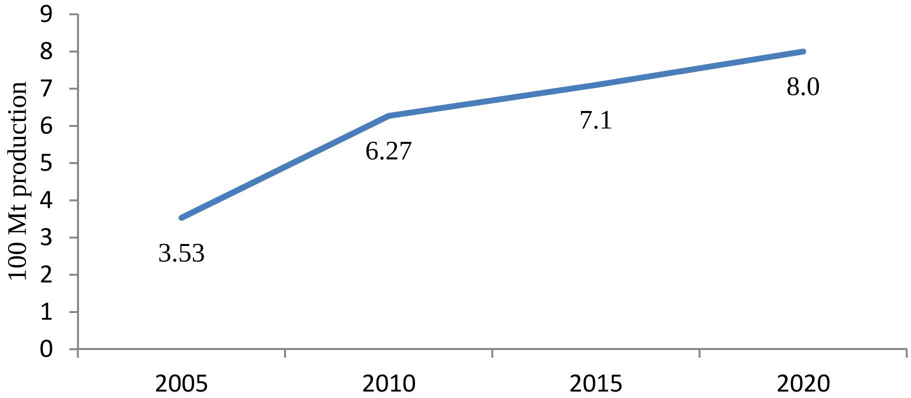
4.2.1 The current situation and development perspective of the steel industry

The steel industry is an important pillar of China's economy. During the "11th FYP" period, despite the temporary impact of the global financial crisis, China's steel industry maintained a strong growth record thanks to vigorous domestic demand. The production of crude steel increased from 353 Mt in 2005 to 627 Mt in 2010, accounting for over 40% of the global crude steel production; an annual growth of 12.2%. China has become the world's largest steel producer.

Currently, China's per capita steel production, storage volume and consumption are still lagging behind industrialized countries compared to relative levels during their peak era of industrialization. In the next decade, China's continued economic growth, population growth, industrialization and urbanization will lead both directly and indirectly to growing steel demand.

There is still space for further development of steel industry: production capacity will continue to grow, though at a slower pace. China's crude steel production is estimated to be over 700 Mt by 2015, and reach 800 Mt by 2020. The annual growth during 2011-2020 is predicted to be around 2.5%.

Figure 4-6: Production growth in China's steel industry 2005-2020



Source: LCIS Task Force analysis

4.2.2 Low carbon development path and potential contribution of steel industry

(1) Progress made in low-carbon development by steel industry during the "11th FYP" period.

China's steel industry, with coal as its staple fuel, is energy-intensive and a major emitter of CO_2 – it is ranked third after the power generation industry and the building materials industry. In 2010, the energy consumed by the steel industry accounted for 13.3% of overall national energy consumption.

During the "11th FYP" period, multiple energy conservation measures were introduced by steel companies, including the elimination of outdated iron and steel making capacity, products mix adjustment and R&D on major energy-saving technologies. Outdated iron-making capacity of 121.72 Mt and outdated steel-making capacity of 69.69 Mt were closed. In addition, key breakthrough technologies were introduced, such as continuous casting, pulverized coal injection in blast furnaces, long-term maintenance of blast furnaces, slag splashing of converters, localized production of rod and wire rollings, optimization of steel production processes and improved energy management.

In 2010, the comprehensive energy consumption per tonne of steel production by medium to large steel enterprises had reduced from 741kgce/t in 2005 to 687kgce/t;[92] a reduction of 7.3%. Energy consumption in major production processes has been decreasing steadily, leading to energy savings of about 32 Mtce and a reduction of 80 $MtCO_2$ emissions. Through the development of a circular economy, the compressive capacity of utilizing waste gas, water and residue has been strengthened. The comprehensive utilization rate of smelting residue, for example, is near 100%. This progress has laid down solid foundations for the low-carbon development of the steel industry.

(2) Low-carbon development for the steel industry up to 2020

In the next decade, China's steel sector should continue to make rapid progress through: the elimination of outdated steel-making capacity, the application of large-sized equipment, R&D in major energy conservation techniques, adjustments in the products mix, acceleration of the circular economy and rigorous energy management. These are described below.

i) Elimination of outdated steel-making capacity

Small-sized coking furnaces, blast furnaces, converters, electric furnaces and rolling machines still account for a considerable proportion of the industrial capacity. Continued elimination of outdated steel-making capacity is, therefore, still very important. During the "12th FYP" period, the industry is expected to eliminate outdated iron-making capacity by an additional 100 Mt and backwards steel-making capacity by an additional 22 Mt.

ii) Application of large-sized equipment

In China, the development level of steel enterprises is uneven and their equipment sizes vary significantly. Compared with large steel-making equipment, small-sized equipment tends to lack environmental protection equipment and, therefore, releases much dust and CO_2. Furthermore, such equipment consumes a large amount of primary energy and has a low rate of waste heat recovery.

During the "11th FYP" period, equipment in the steel industry has seen significant improvements. According to research by the China Iron and Steel Association in 2009, the were 456 sintering machines, among which 135 are larger than 180m^2 - 85 more than in 1995; 560 blast furnace, among which 189 are larger than 1000m^3 - 110% more than in 1995; and 689 converters, among which 197 are larger than 100t.

The proportion of medium to large-sized sintering machines, blast furnaces and converters is still under 50% across the industry – there remains a large gap between China and advanced countries in the application of large-sized steel-making equipment.

iii) R&D and the application of major energy conservation techniques

By the end of 2009, there were 340 mechanical coking furnaces in major medium and large steel enterprises, equipped with 89 sets of CDQ devices, achieving a CDQ rate of 70%; 45% higher than in 2005. For blast furnaces above 2000m^3, a TRT device rate of 100% has been achieved; for blast furnaces under 1000m^3, the TRT device rate is 96.3%. The converter gas recovery rate increased from 50m3/t steel in 2005 to 88m3/t steel in 2009. However, the overall application rate of major energy conservation techniques is low and a tremendous amount of energy conservation and emissions reduction techniques remain to be tapped.

iv) Adjustment of the products mix

The demand for steel products with high added-value is on the rise, especially for cold rolled sheets, H beam, high strength twisted steel, high magnetic oriented electrical steel, high-end car panels and supercritical high temperature and high pressure boiler steel. As the steel industry is expected to undergo faster structural upgrading in the future, it is important for the industry to produce more products with high added-value, reduce CO_2 emissions of per unit added-value.

v) Acceleration of a circular economy

Crude steel and waste steel storage facilities in China are extensive, providing a solid material foundation for the development of a circular economy in the steel industry. As the *Development Policy for the Steel Industry* specifies, the steel industry should practice sustainable development and develop a circular economy through enhancing its capacity for environmental protection and comprehensive energy utilization, reducing its consumption and maximizing the comprehensive utilization of waste gas, water and materials to achieve zero emissions.

During the "11th FYP" period, Anben Steel Group, Panzhihua Steel Group Ltd., Baotou Steel Group Ltd., Jinan Steel Group Ltd., Laiwu Steel Group Ltd., Baoshan Steel Group Ltd., Taiyuan Steel Group Ltd., Ma'anshan Steel Group Ltd., Fujian Sangang Steel Group Ltd. and Chongqing Steel Group Ltd. carried out pilot projects to explore effective models of circular operations and industrial chains with other sectors to achieve circular energy utilization. A circular economy in the steel industry will develop from these pilot projects and be practiced more widely.

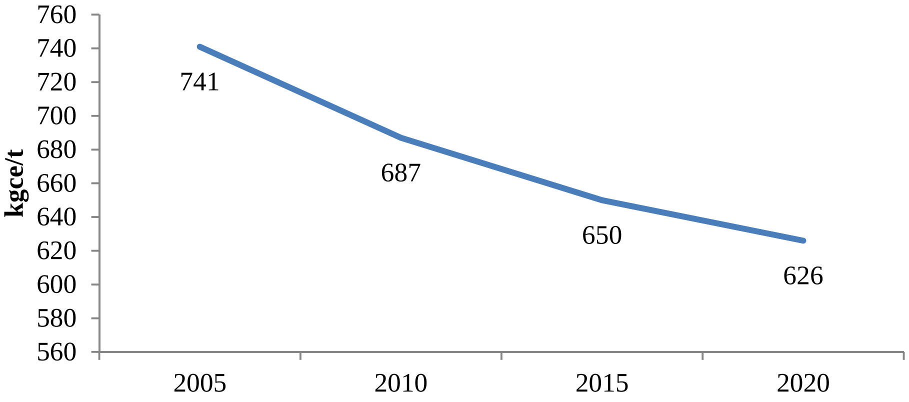
vi) Rigorous energy management

It is important for steel plants to establish rigorous energy management to achieve low-carbon transition. Bao Steel, for example, has established a comprehensive energy management centre, while An Steel, Wu Steel, Ben Steel, Tai Steel, Shang Steel First Plant, Mei Shan and Jiu Steel have developed functional energy management centres. The Ministry of Industry and Information Technology has made a specific request that all steel enterprises with an annual production capacity of over 3 Mt should establish energy management centres. In the next ten years, many steel companies are expected to establish energy management centres with comprehensive functions, constituting an important pillar to the industry's low-carbon development.

(3) Potential contribution of the steel industry's low-carbon development to 2020

Over the next decade, with effective implementation of the above measures, the steel industry could achieve remarkable energy conservation and CO_2 emissions reductions. By 2020, the comprehensive energy consumption of per tonne of steel by medium and large-sized steel enterprises is expected to fall to 626 kgce/t, a decrease of 115 kgce/t from 2005. With evident reductions in energy consumption per tonne of steel, the steel industry could achieve an annual conservation capacity of 92 Mtce by 2020, equivalent to a reduction of 220 $MtCO_2$ emissions.

Figure 4-7: Potential energy intensity improvements in steel 2005 - 2020

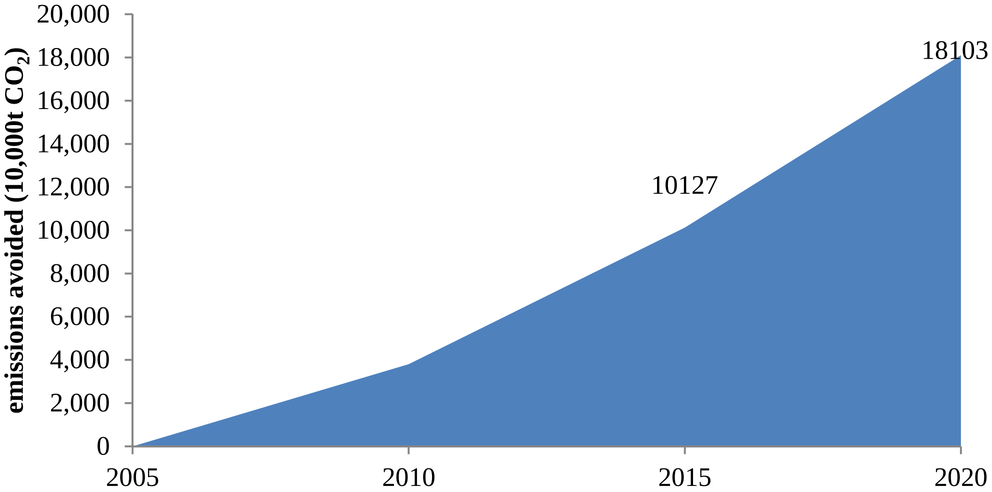


Source: LCIS Task Force analysis

(4) Research on low-carbon technology in the steel industry to 2020

Energy conservation and low-carbon technology application is very important for the low-carbon development of China's steel industry. Currently, there are 11 major energy conservation and low-carbon technologies for the steel industry. These include coke dry quenching (CDQ), coal moisture control (CMC), power generation by sintering waste heat, top gas recovery turbines (Dry TRT), combined cycle power plants (CCPP), blast dehumidification of blast furnaces, blast furnace gas-fired boilers, the recovery and utilization of converter gas, regenerative combustion, energy management centres and submerged arc energy-saving furnaces. As research on these technologies shows, if they can be applied broadly to the expected proportion by 2020, 78.04 Mtce per annum, could be saved compared to 2005 figures, equivalent to an annual reduction in emissions by 182 GtCO_2 .

Figure 4-8: Avoided emissions potential from the application of 11 major energy conservation and low-carbon technologies in the steel industry (2006-2020)



Source: LCIS Task Force analysis

4.2.3 Policies and measures

The major issues to be resolved in low-carbon development of the steel industry are: low industrial concentration; the slow pace of structural adjustment; under-developed independent innovation capacity; and inadequate exit mechanisms for outdated production capacity. Governmental agencies have developed policy measures to promote the low-carbon transition of the steel industry, with the aim of fostering sustainable growth through low energy consumption, low pollution and low emissions.

1) Long-term mechanisms for energy conservation and emissions reductions in the steel industry

The effective and sustained low-carbon growth of the steel industry depends on a comprehensive mechanism framework covering legal, administrative, technical and economic aspects. The environmental protection requirement should be vigorously enforced as the primary consideration in steel project approval. All new steel projects (including upgrading and expanding of existing ones) should go to qualified professional agencies for energy conservation and emissions reductions evaluation. Granting of access for new steel projects should be strictly controlled and no green-light should be given to heavily-polluting or high energy-consuming projects which have not meet the threshold requirements.

2) Establishment of effective monitoring systems for energy conservation and emissions reductions

A one-on-one monitoring system should be established between regulatory agencies and enterprises, and the regulation process should be face-to-face. China should accelerate the development of an on-line monitoring system and make sure all major production sites of medium and large steel plants are equipped with on-line monitoring devices.

3) Improvement of price adjustment mechanisms

Regulators should enforce differentiated tariff and progressive water pricing to eliminate outdated steel capacity. Punitive measures should be imposed on steel enterprises with excess energy consumption, such as highly progressive rates for, and limited supplies of, power and water. China should explore policy incentives for land transfer and outdated equipment disposal by steel enterprises to encourage disposal of outdated capacity and to provide transfer payment and subsidies for regions with heavy outdated capacity to take transformation measures.

4) Faster elimination of outdated steel capacity to foster industrial consolidation

China should strictly enforce national and provincial requirements in energy conservation and emissions reductions and design regional and yearly implementation plans to eliminate outdated steel capacity. The plans should be formulated on the variety, quality, and M&A plans of relevant steel enterprises. China should concentrate resources to support high-end steel bases and upgrading projects, and foster M&A among small and medium sized steel plants. China should support the growth of large steel groups with cutting-edge techniques, high-end products, advanced large equipment, circular economic process and a clean production environment.

5) Acceleration of technique innovation in steel production

Steel enterprises should be encouraged to develop low carbon energy-saving and environmental protection equipment, new production techniques and new products through incentives such as government procurement and patent protection. Based on national and provincial technology centres, steel enterprises can be encouraged to establish R&D hubs for energy conservation and emissions reductions. Major technologies and equipment demonstration projects are needed to accelerate R&D and achieve wider application of relevant technologies in the steel industry.

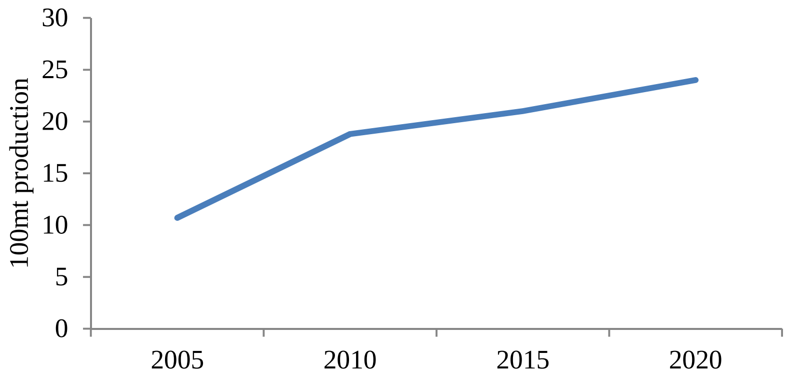
4.3 Building Materials Industry

4.3.1 The current situation and development perspective of the building materials industry

The building materials industry is an important sector for raw materials and manufactured products. During the 11th FYP period, with China's rapid economic growth, domestic demand for, and the export of, building materials increased rapidly, fuelling robust expansion of the industry. The average annual growth of cement production was 11.9%. In particular, plate glass, building and sanitary ceramics, glass fibre, glass steel and other building materials have seen remarkable output growth. In fact, the output of cement, plane glass, building and sanitary ceramics have ranked number one in the world for many years. Nearly half of all cement, plate glass and household sanitary ceramics in the world are now produced in China.

As China's industrialization and urbanization process continues, the growth rate of various building materials will eventually slow. The cement production of 2015 and 2020 is expected to be around 2 Gt and 2.1 Gt, respectively.

Figure 4-9: Expected growth in China's cement industry 2005 - 2020



Source: LCIS Task Force analysis

4.3.2 Low-carbon development path and potential contribution of building materials industry

(1) Progress made by building materials industry in low-carbon development during the 11th FYP period.

China's building materials industry energy intensive and a major emitter of CO_2. Its energy consumption accounted for 10% of the total national energy consumption in 2010 – primarily coal and electricity. This makes it the second largest emitter of CO_2 – only the power generation industry consumes more. Cement manufacturing

accounts for 70% of overall energy consumption within the building materials industry.

During the "11th FYP" period, the building materials industry has made significant progress in low carbon development and energy conservation. The annual use of solid waste is now over 600 Mt and the comprehensive utilization of fly ash and gangue facilitation accounts for 30% and 50% of the country total, respectively. Energy consumption per unit of added value and per unit of major building materials and their CO_2 emissions intensity have decreased significantly.

This is particularly evident in the cement industry, where 330 Mt of outdated cement production capacity has been eliminated; more efficient dry production processes now account for more than 70% of total output; and power generation installed capacity from waste heat from cement production has reached 5 GW. The energy intensity of cement production fell from 149.2 kgce/t in 2005 to 118.9kgce/t[93] in 2010, a reduction of 30.3kgce/t. This has avoided energy consumption of 57 Mtce annually, equivalent to CO_2 emissions of 135 Mt.

(2) Low-carbon development path for building materials industry by 2020

As one of China's major energy-intensive and high-emission sectors, the building materials industry has long been the focus of energy-saving and emissions reductions efforts. Low industrial concentration is a key challenge, since smaller producers of these materials tend to be more inefficient in China. The industrial concentration of cement-making and plate glass-making are both under 40%.

Over the next decade, low-carbon development of the building materials industry will be achieved through the following major efforts: speeding up scientific and technological progress, vigorously promoting the application of advanced energy-saving technology, techniques and equipment; adjusting and optimizing the industrial structure; implementing clean production processes; enhancing energy utilization; fostering development of a circular economy; and applying scientific management.

i) Adjustment and Optimization of Industrial Structure

300 Mt of outdated cement production capacity and all glass-making capacity that uses the horizontal sheet process is expected to be eliminated during the 12th FYP period. Strict controls should also be applied to energy efficiency and emissions of new building materials' production capacity. Thirdly, emphasis should be placed on the development of sub-sectors with low energy intensity, low emissions and high added-value, including: deep processing for cement and glass; modern windows and doors, household kitchen units, bathroom units and roof materials. To cater to the needs of the emerging energy sector and other strategic industries, China should promote the development of new inorganic non-metallic materials and products, as well as sophisticated processed materials and products of non-metallic minerals.

ii) Broader application of low carbon energy-saving techniques, technology and equipment

The cement industry should improve existing dry cement-making processes, apply high-efficiency clinker burning systems and powder equipment and integrate online control technology and equipment in order to reduce energy consumption in clinker and cement production and cut CO_2 emissions. By the end of the "12th FYP" period, the waste heat power generation rate in cement-making and glass-making production lines will reach 80% and 30%, respectively.

iii) Accelerating the transition to a Circular Economy

The building materials industry is an important node in the chain of China's circular economy and its utilization of solid waste, in particular industrial solid waste, plays a significant role. So far, the research and practice of using cement kilns to dispose of municipal solid waste has made significant progress, and R&D has been launched on the production of building materials from construction waste.

The building materials industry should develop the capacity to turn waste into wealth and, at the same time, achieve energy conservation and CO_2 emissions reductions. It has a very important role to play in the comprehensive utilization of waste in the future and much to contribute in the coordinated disposal of industrial waste, municipal waste, sewage sludge and construction waste.

iv) Vigorous energy management

During the 11th FYP period, cement enterprises made positive progress in energy efficiency benchmarking management. During the 12th FYP period, the cement industry should speed up R&D on smart production and information management systems, and establish an energy and resource consumption management platform. Many cement companies are expected to build energy management centres, playing an important role in improving energy management and expanding energy-saving and emissions reductions capacity.

(3) Potential contributions by the low-carbon development of the building materials industry to 2020

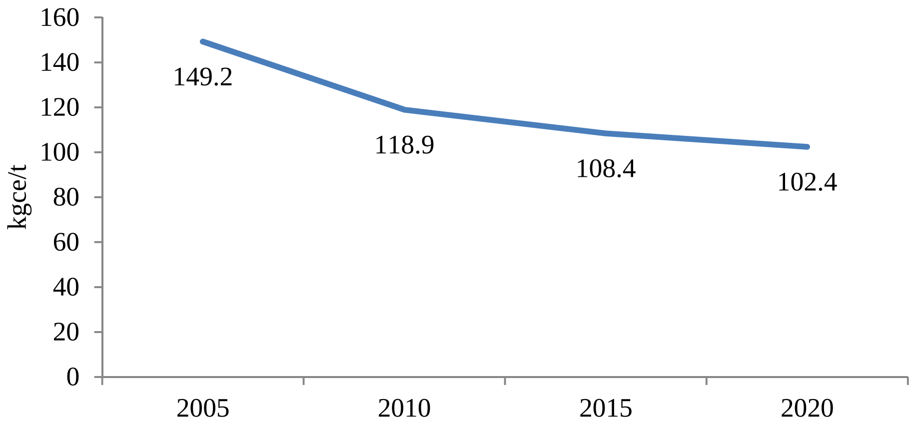
If the above measures are implemented in the building materials industry over the next decade, significant contributions can be made in energy conservation and CO_2 emissions reductions. By 2020, the main building materials, including cement, plate glass, construction ceramics and sanitary ceramics will experience an absolute decline in energy consumption compared to 2005; the CO_2 emissions per unit added-value will also be significantly reduced. By 2020, the comprehensive energy consumption per unit of cement will be reduced to 102.4kgce/t, 46.8 kgce/t less than in 2005. This will avoid energy consumption of 98.28 Mtce per year, equivalent to a reduction of 234 $MtCO_2$.

(4) Research on the low-carbon technology application potential in the building materials industry to 2020

Currently, there are 15 major available energy-saving and low-carbon technologies for building materials industry. These are: *power generation by low-temperature waste heat; high-efficiency powder screening; roller grinding; vertical roller grinding; multi-channel combustion; cement clinker cooling by steady-flow system; power generation by waste heat from glass-making furnaces; oxygen-fuel combustion; oxygen-enriched combustion; HFKH rapid drying; vertical cement kilns; low-E glass-making; fired perforated and EPS fired hollow bricks; energy-efficient synthetic resin curtain wall systems; and premixed secondary combustion.*

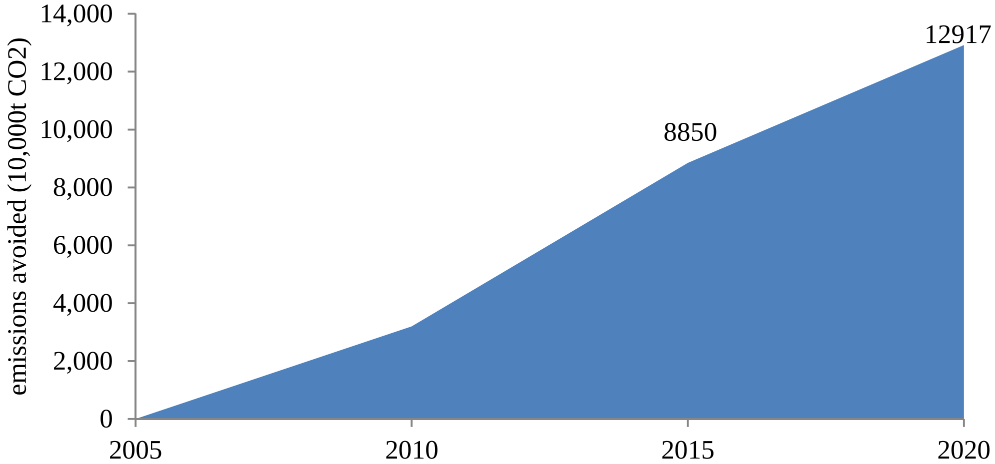
If these 15 technologies can be widely applied by 2020, 55.69 Mtce can be avoided per year, equivalent to 136 $MtCO_2$.

Figure 4-10: Potential energy intensity improvements in cement industry 2005 - 2020



Source: LCIS Task Force analysis

Figure 4-11: Potential CO_2 avoided with application of 15 major low-carbon technologies in cement industry (2006-2020 – 10,000t CO_2)



Source: LCIS Task Force analysis

4.3.3 Policies and measures

The building materials industry faces a range of problems: low industrial concentration, slow structure adjustment, inadequate innovation, slow spread of new technologies, a weak exit mechanism for outdated production capacity, insufficient resource efficiency and poor energy management. The relevant government departments should formulate polices on energy saving and emissions reductions, and promote clean and low-carbon technologies in order to achieve sustainable development.

1) Enhance supervision on energy saving and emissions reductions

The government agencies in charge of energy efficiency and emissions reductions should strengthen their supervision of large energy consumers and emitters, and enhance their management of energy utilization, measuring instruments allocation and target responsibility assessment. They should set up and improve the systems for statistics compiling, monitoring and assessing. Stricter access conditions for the

cement industry must be laid down: the faster that measures for project assessment are introduced, the fewer projects will be approved without such examination. In addition, the government should improve its subsidy mechanism for the exit of outdated production capacity.

2) Set up a new mechanism of energy saving and emissions reductions, and issue favourable policies

Energy management companies (EMCs) should be encouraged to provide technology application services including energy audits, engineering services, energy performance contracting (EPC) and project finance. In addition, they should guide enterprises to participate in power demand side management to control pollution and achieve systematic energy efficiency; issue favourable policies to promote waste recycling, upgrade waste management systems and to straighten out channels of pollution sources; specialize refuse collecting and disposal; and facilitate the development of the waste pre-treatment industry.

3) Improve the standard system for energy efficiency and emissions reductions

Research institutes and standardization committees should be given the power to enforce technology standards for cement, glass and other industries, and establish comprehensive systems for the standard of limited quantity and for monitoring, examination and certification. More specifically, a CO_2 calculation system and an evaluation system for energy intensive units, such as cement kilns, should be established; the standard system for resource comprehensive utilization should be updated; supervision on efficiency benchmarking should be intensified; and industry associations should be encouraged to carry on with their benchmarking achievements to strengthen technical guidance for enterprises.

4) Support technological innovation in the building materials industry

Measures to be adopted include: promoting the establishment of state-level research institutes and a cross-industry innovation system integrating production, teaching and research; inputs for technology retrofitting, especially generic technologies and engineering applications that address key problems in environmental protection; encouraging building materials manufacturers to raise energy efficiency by localizing and scaling up cement production equipment, which is highly efficient, energy saving and environment friendly; and the provision of tax rebate policies for building materials equipment.

5) Build up the energy saving capacity of enterprises

Corporate responsibilities on energy saving and emissions reductions should be clarified as part of efforts to reinforce management systems. Building materials enterprises should designate positions responsible for energy management and clarify target assessment requirements; corporations should conduct trials to actively promote energy management capacity. In addition, corporations should, according to the requirements of statistics, monitoring and assessment, improve the system of online monitoring and analysis in order to enhance efficiency management.

6) Grant responsibility to industry associations and other intermediary organizations

To bring industry associations and other intermediary organizations into full play, government agencies should support associations in research on energy efficiency, data collection, statistics and analysis. In addition, intermediary organizations should

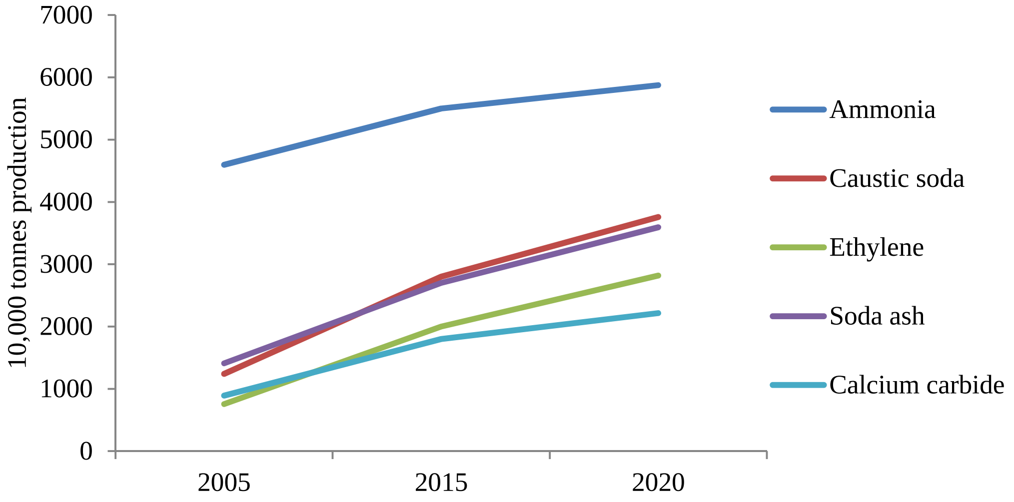
accelerate communications on technologies and products in the building materials industry.

4.4 Petrochemical industry

4.4.1 The status quo and development trend of the petrochemical industry

During the 11th FYP, China's petrochemical industry grew at more than 20% per year. Currently, China is the second largest producer of oil and chemical products in the world. Its output of more than twenty petrochemical varieties also ranks among the highest in the world: the production of nitrogen fertilizer, phosphate fertilizer, calcined soda, caustic soda, sulphuric acid and calcium carbide ranks first, globally; the production of ethylene, synthetic resin and synthetic rubber, second; and crude oil, fifth.

Figure 4-12: Expected growth in China's petrochemical production 2005 - 2020



Source: LCIS Task Force

The petrochemical industry in developed countries may have passed its peak. In China, however, it is booming. Strong demand for oil products, fertilizer and pesticides will be sustained for up to a decade, and the demand for petrochemical products in high-end markets is enormous. By 2020, the outputs of synthetic ammonia, calcined soda, caustic soda, calcium carbide and ethylene are expected to reach 58.74 Mt, 35.93 Mt, 37.57 Mt, 22.16 Mt and 28.19 Mt, respectively.

4.4.2 The development path and potential of low carbon in the petrochemical industry

(1) The development of low carbon in the petrochemical industry during the 11th FYP

Energy consumption in the petrochemical industry accounts for 13% of China's total. Eight of its sub-industries, for example crude oil processing, nitrogen manufacturing and organic chemical material manufacturing, are big energy consumers, accounting for 85% of the total. In the petrochemical industry, the energy consumption mix is dominated by raw coal and coke – about 50% of the total; electricity and natural gas make up most of the rest.

By 2010, the energy intensity of this sector had dropped by more than 10% compared with 2005 figures, and several sub-sectors (crude oil, ethylene, synthetic ammonia, calcined soda, caustic soda, calcium carbide and yellow phosphorus) each avoided more than 10 Mtce, the equivalent of 25 $MtCO_2$.

(2) Petrochemicals development path to 2020

China's petrochemical industry faces the following major challenges to low carbon development: low industry concentration, irrational industry structure, inadequate technological innovation and a coal-dominated energy consumption mix.

In the coming decade, ways to shift petrochemicals onto a low carbon path include:

i) Improving the energy efficiency of newly-added production capacity and eliminate outdated production capacity

Improvements to average energy efficiency will occur through newly-added production capacity and the elimination of outdated production capacity - this contributed to more than 80% of the 10 Mtce of energy saved from 2000 to 2005.

ii) Rapid restructuring

The industry should develop high-end chemical and petrochemical products, which are now limited in supply, and lower the proportion of low-end and primary products with high energy consumption, high emissions and low added value.

iii) Develop and promote energy saving and low carbon technologies

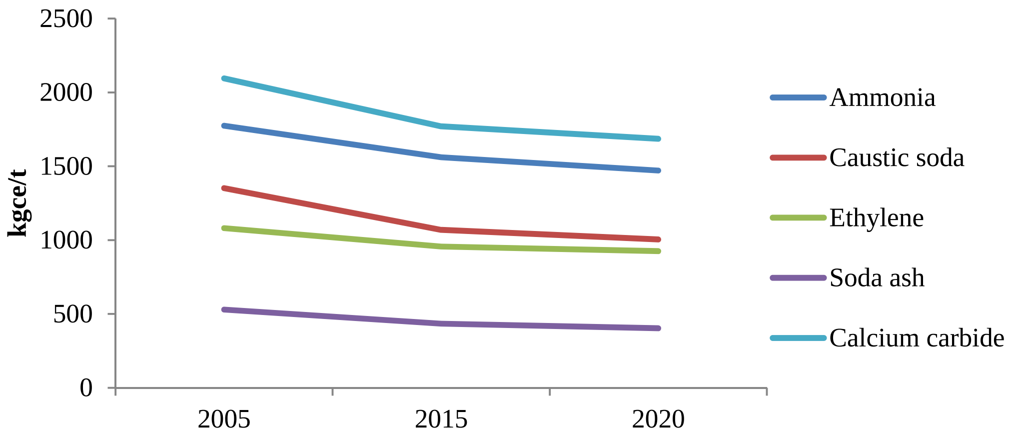
Energy and emissions can be avoided through generic technologies for clean production, resource conservation and product deep processing. In addition, through technology retrofit in traditional areas such as oil refining, fertilizer, pesticide, chlor-alkali and calcined soda.

iv) Develop a circular economy

Towards a circular economy, the petrochemical industry should strengthen its resource conservation, transform its waste into resources, develop energy cascade use and recycle energy.

(3) Potential contribution of low carbon by 2020

Figure 4-13: Potential improvements in the energy intensity of petrochemical products in China 2005-2020

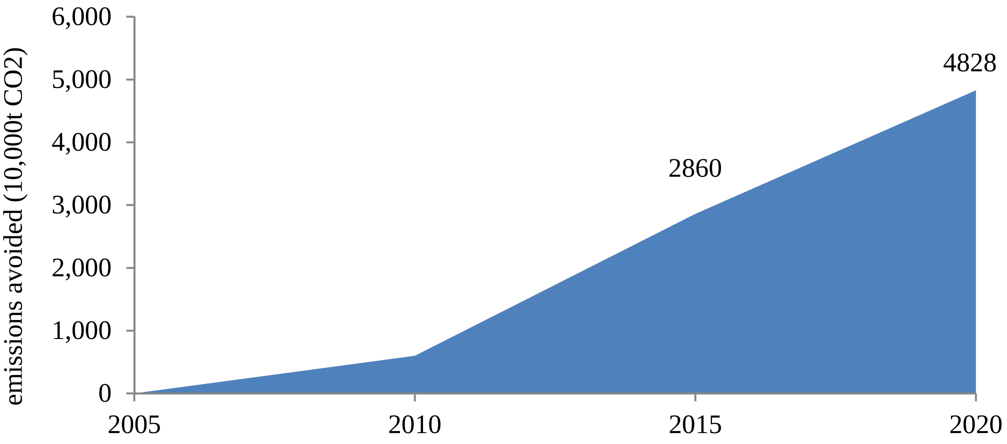


Source: LCIS Task Force analysis

If all the above methods are put into practice over the next decade, China will avoid significant amounts of energy, in addition to reducing its CO_2 emissions. By 2020, the energy consumed by ethylene, synthetic ammonia, calcined soda, caustic soda and calcium carbide is predicted to decrease by 48.89 Mtce per year, equivalent to an annual reduction of 116 $MtCO_2$.

(4) Research on the potential of low carbon technology for 2020

Figure 4-14: Potential CO_2 avoided with the application of 17 major low-carbon technologies in the petrochemicals industry (2006-2020 – 10,000tCO_2)



Source: LCIS Task Force analysis

The 18 technologies that will play a key role in the petrochemicals sector are: *environmentally-friendly production of calcium carbide; surplus heat utilization in the production of black carbon and power generated by end gas; recycling of low-temperature potential energy by large- and medium- sized sulphuric acid plants; energy conservation in ammonia production; recycling of ethylene from catalytic dry gas through pressure swing adsorption; an ion-exchange membrane of caustic soda; polar distance ionic membrane electrolysis; new full fluid phase hydrogen-added technology; thermal integration of gas fractionation plants; technology for the utilization of low temperature; Pervaporation Membrane Separation Technology; incrustation removal of ultrasonic techniques in heat exchangers; water solution total-cycling urea energy-saving process; utilization of the waste heat from hydrogen chloride synthesis; a molecular sieve in the ammonia synthesis loop; utilization of heat energy evolved from thermal-process phosphoric acid production; air pre-heaters in cracking furnaces; triple-effect counter-current falling-film evaporation technology.*

Research on these 18 technologies indicates that by 2020, they could avoid 0.8 Mtce of energy consumption per year, equivalent to an annual reduction of 48.28 $MtCO_2$.

4.4.3 Policies and measures

1) Promote technological innovation, localize and scale-up equipment manufacturing

The central government could introduce a special fund for studying and promoting key and generic technologies for energy saving, emissions reductions, clean production, resource conservation, comprehensive utilization and products deep processing.

2) Support the development of high-end fossil fuel based products and optimize product structure

To advance the technology and techniques in certain key areas, the government should set up a special fund for technological retrofit and delegate industry associations to evaluate the projects before hand.

3) Intensify macro-level controls to promote energy saving and emission reduction within industry

The government should introduce laws and regulations, adopt economic, fiscal and executive methods, taxation policies, and technological and environmental standards - especially compulsory and reach energy efficiency standards - to curb waste in the petrochemical industry.

4) Complete the exit mechanism and the elimination of outdated production capacity

The government should map out and regularly update the catalogue for outdated production capacity. Central and local governments should set up special funds to compensate redundant enterprises and their staff, in order to encourage voluntary exits. Companies that develop projects in line with national policies can receive support in administrative examination, land and finance. The government should lead and delegate associations to control ‘hot’ investment, and limit access conditions to curb capital flow towards excessive production capacity.

5) Encourage some energy intensive fossil products to transfer their production overseas

Energy-intensive products such as urea, ammonium phosphate, calcined soda, tires and chlor-alkali exceed domestic demand in China, yet competition in these areas remains fierce. If the government could set up a special fund, encourage enterprises to internationalize and transfer to resource-abundant places, China could, simultaneously, increase its international market shares and reduce national energy consumption and CO_2 emissions.

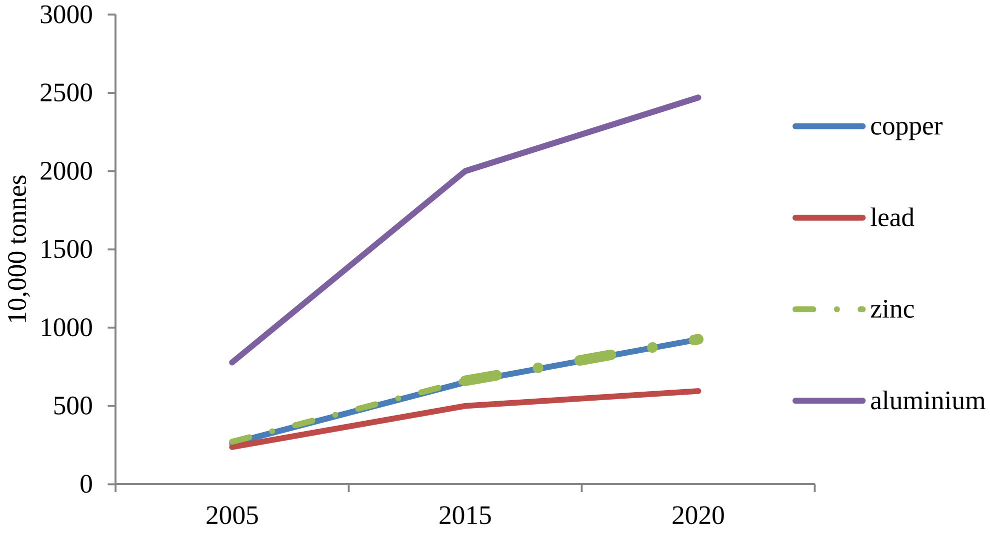
4.5 Non-ferrous Metal industry

4.5.1 The status quo and the development trend of non-ferrous metals industry

During the "11th FYP" period, robust domestic demand for non-ferrous metals from many industries such as construction, electronics, electrical and mechanical manufacturing drove a rapid growth in the industry. In 2010, China’s ten non-ferrous metals production totalled 31.35 Mt: 4.574 Mt of refined copper; 16.195 Mt of primary aluminium; 419.9 tonnes of lead; 5,164,000 tonnes of zinc; 171,000 tonnes of nickel; 149,000 tonnes of tin; and 187,000 tonnes of antimony.

Over the next decade, the government will continue to discourage industries with high energy consumption, heavy pollution and strong resource demands. Export tax rebates and tariffs will be adjusted; resource taxes introduced; and energy-conservation and emissions reductions will be promoted. These measures will end the period of rapid growth in the non-ferrous metal industry and induce a period of steady growth. By 2020, the total production volume of the 10 non-ferrous metals in China is estimated to reach 42 Mt, of which copper accounts for 9.25 Mt, lead 595 Mt and zinc 926 Mt.

Figure 4-15: Projected production of non-ferrous metals 2005-2020



(1) Progress in low carbon development of non-ferrous metals industry during the "11th FYP" period

Energy consumption in the non-ferrous metals industry accounts for 4% of the national total. Within this sector, coal and electricity make up 87% and coke, gasoline and diesel make up 13%.

During the "11th FYP" period, the non-ferrous industry has adopted measures to save energy and cut carbon emissions.

In addition to upgrading a range of technologies, the government has also implemented benchmarking of energy efficiency in industrial organizations of copper, aluminium, lead, zinc and magnesium. During this period, the non-ferrous metal industry cut energy intensity by about 19%. Between 2005 and 2010, energy avoided by the non-ferrous metals sector exceeded 10 Mt, a reduction of 25 $MtCO_2$.

(2) Low carbon development solutions for non-ferrous metals in 2020

Learning from the experiences of the 11th FYP period, solutions for China's non-ferrous metals industry's low carbon development are as follows:

i) Phase-out outdated production capacity

During the 12th FYP period, the non-ferrous metal industry will phase out the following technologies: *100 kA pre-baked aluminium tanks; smelting, electric and reverberatory furnaces, other cooper smelting technologies and equipments; sintering pots; sintered plate; simple lead smelting furnaces; outdated lead refining technologies and equipments; sintering lead smelting process without proper acid and gas absorption systems; outdated technologies such as muffle and manger furnaces, horizontal tanks and vertical small tanks; using simple condensation and cooling facilities for powder-collecting; and other outdated production techniques and equipment for producing zinc or zinc oxide products.*

ii) Develop and promote new technology, new techniques and new equipment

In the coming decade, the industry will focus on the development and promotion of energy efficient mining technology and equipment; self-heating enhanced smelting and electrolytic processes; equipment and automatic control technology; energy-

saving hydrometallurgy technology; aluminium alloy casting solution prepared by direct continuous billet; casting slab; and efficient combustion technology.

Aluminium smelting will focus on the development and promotion of new electrolytic aluminium reduction cell cathode flow channels; energy efficient aluminium structure technology; large aluminium reduction cells with high anode current density technology; efficient low-temperature electrolytic technology; high-quality energy saving anode and new cathode; the optimization of bauxite flotation, de-silicon technologies and equipments; efficient pharmaceutical bauxite refining; efficiency and energy saving technology for alumina production from low-grade bauxite; Bayer efficient separation of high concentration slurry leaching technology and high decomposition production technology; semi-dry and dry-firing technology; separation of high concentration of fast liquid-solid by sintering technology; and heat recovery during alumina production process technology.

iii) Rapid restructuring

Structural adjustment of the non-ferrous metal industry should be accelerated, minimum standards for new entrants to the market should be introduced and low efficiency and high carbon emissions production capacity should be identified and blocked. Non-ferrous metals enterprises will undergo various reforms, such as trans-regional and inter-regional restructuring of both the upstream and downstream, and cross-industrial restructuring, in order to achieve scale and group management, improve industry competitiveness and cut CO_2 emissions.

iv) Improve the recycling of secondary metal

Over the next ten years, the non-ferrous metal industry will vigorously develop secondary metals processing parks and secondary metal utilization industries, experiment with and pilot new approaches, create a new system of recycling within the non-ferrous metal industry and improve the utilization rate of recycled metal. By 2015, the volume of secondary metals production will expand to 380 Mt of recycled copper, 580 Mt of recycled aluminium and 150 Mt of secondary lead. Secondary refined copper, secondary aluminium and secondary lead will account for over 58%, 29% and 30% of the production of refined copper, electrolytic aluminium and refined lead. By 2020, secondary metal recycling capacity will reach 12.4 Mt. CO_2 emissions could be reduced by 240 Mt through the development of a circular economy if the production volume of steel scrap was 80 - 100 Mt by 2020.

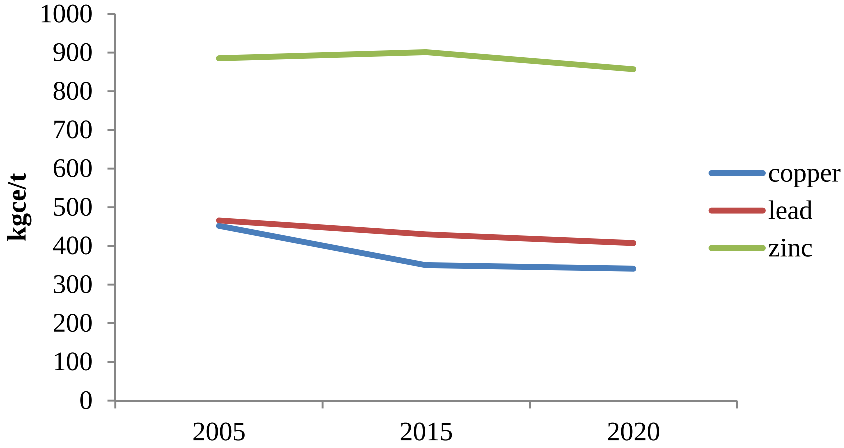
v) Strengthen energy management in enterprises

The non-ferrous metal industry will further promote energy efficiency benchmarking management, and strengthen energy saving and emissions reductions management in the key enterprises and non-ferrous metals varieties.

(3) The potential contributions of low-carbon development in non-ferrous metal industry to 2020.

By 2020, the energy consumption of the ten non-ferrous metals will continue to decrease, avoiding energy consumption of about 25 Mtce per year and emissions of about 60 $MtCO_2$. Of this improvement, decrease in the overall energy consumption of aluminium will account for about 80%. The recycling of secondary metals will amount to 20 Mt of primary metal production, and lead to a reduction of 50 $MtCO_2$.

Figure 4-16: Energy intensity of China's major non-ferrous metals 2005 to 2020



Note: energy intensity of aluminium production (not shown) is projected to decrease from 14575 kwh/t in 2005 to 13,670 in 2015 and 12357 in 2020

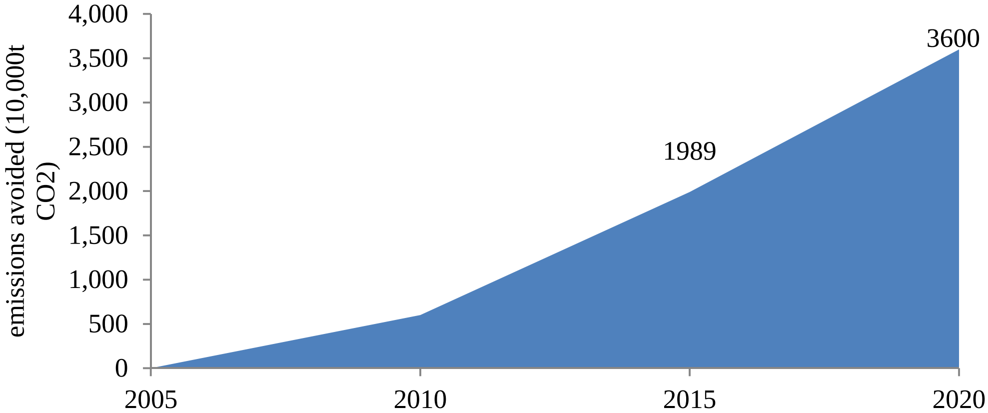
Source: LCIS Task Force analysis

(4) Analysis of the potential of low-carbon technologies' popularization and application in non-ferrous metal industry towards 2020.

There are 9 major energy-saving and low-carbon technologies adopted in China's non-ferrous metal industry. These include: *oxygen enriched bottom-blowing copper smelting technology; intensifying electric current in pre-baked aluminium smelting cells; new cathode structuring in aluminium cells; the operation and control technology of baking; lead flash smelting technology; the direct reduction of liquid lead slag; pressure and oxygen-rich direct leaching of zinc and zinc oxidizing ore; efficient and clean metallurgical technology of recycled resources; system restoration by combusting magnesium in high temperatures; and large pneumo-mechanical flotation machines.*

Around 14.34 Mtce of energy could be saved by 2020 if these technologies were widely adopted. This would avoid 36 MtCO_2.

Figure 4-17: Potential avoided emissions with application of nine major technologies for energy-saving and carbon-cutting in non-ferrous metal industry (2006-2020)



Source: LCIS Task Force analysis

4.5.2 Policies and measures

1) Create more favourable fiscal and tax policies to support R&D and application of key and common technologies for energy-saving and low-carbon in the non-ferrous metals industry

Government departments should establish more favourable fiscal and tax policies to support R&D and the application of key technologies. This could involve:

- including key technologies in the industry, such as aluminium smelting, continuous copper and lead smelting, and flash smelting of lead, copper, and nickel as major national science and technology programs;
- supporting R&D of high value-added materials processing and high-end products;
- listing the technologies involved in the processing and manufacturing of high-performance copper alloy materials, intensive processing of tungsten and carbide alloys;
- supporting research and development of high-end products as national major science and technology programs;
- supporting the research and manufacturing of key facilities for production in non-ferrous metal industry to increase their independent research and manufacturing capabilities;
- highlighting the strategic importance of metals like tungsten, tin, antimony, molybdenum, indium and rare earths;
- supporting the exploration of high-performance material, research and manufacturing of high value-added products to translate resource abundance into industrial and economic competitiveness;
- offering incentives, such as financial support and tax relief, for energy-saving programs

2) Establish and improve the incentives mechanisms for energy-saving in non-ferrous metal industry

The government should establish and improve incentive mechanisms for energy-saving in non-ferrous metal industry. In accordance with relevant national policies, funds from the central government could be used to reward or subsidize enterprises that have excelled in energy-saving. The government should also offer an income tax relief to those enterprises that have met the targets according to the principle of “more tax relief for more energy conservation”.

3) Allocate responsibility to industry associations in promoting energy-savings

After the reform of managerial systems in the industrial sectors, relevant government organs have mainly relied on industry associations to organize and coordinate scientific and technological programs. In some cases local and regional governments and other investment entities are included, leading to inconsistency over program management. Industry associations should lead in organizing, coordinating and mobilizing plans in order to help the researchers of key technologies yield more breakthroughs. The government should also enable industry associations to perform

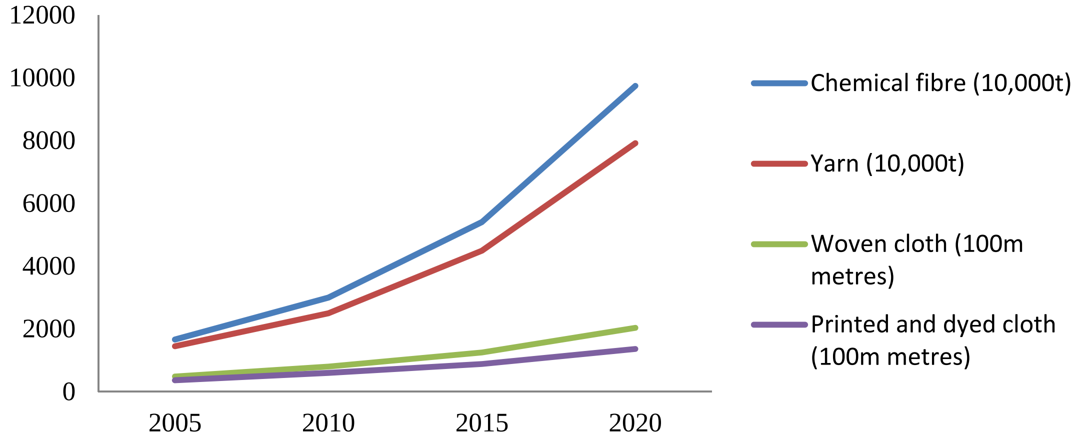
tasks such as surveying, auditing, supervising and assessing the industry's performance.

4.6 Textile Industry

4.6.1 Current Status and Development Trend of Textile Industry

The textile industry not only serves as a traditional pillar industry of China's national economy, but also enjoys a remarkable competitive advantage in the global economy. During the 11th FYP period, despite the impacts of the global financial crisis, this industry has maintained double-digit growth. In 2010, China's outputs of major textile products, such as chemical fibre, yarn, woven cloth and printed and dyed cloth, reached 30.90 Mt, 27.17 Mt, 80 billion meters and 57 billion meters, respectively. China is the world's primary producer and exporter of textile products.

Figure 4-18: Growth Trend of China's Outputs of Major Textile Products between 2005 and 2020



During the 12th FYP period, this industry will accelerate its industrial innovation and restructuring. By 2020, China's outputs of chemical fibre, yarn, woven cloth and printed and dyed cloth are expected to reach 97.42 Mt, 79.20 Mt, 203.4 billion meters and 136.2 billion meters, respectively.

4.6.2 Development Paths and Potential Contributions to Low-Carbon Development of Textile Industry

(1) Progress in Low-Carbon Development of Textile Industry during the Eleventh FYP Period

The energy consumption of the textile industry accounts for about 3.6% of China's national total. During the Eleventh FYP period, the textile industry has adopted various measures in energy conservation and low-carbon development and has made remarkable progress and achievements. This industry has substantially enhanced its independent innovative capability; developed and applied a series of technologies with proprietary intellectual property rights; further optimized its industrial structure; and substantially upgraded the overall level of its technical equipment; In 2010, the energy intensity of yarn, woven cloth, printed and dyed cloth, viscose fibre and polyester had decreased between 7.5% and 42% compared with their levels in 2005.

(2) Development Paths to Low-Carbon Development of Textile Industry by 2020

The textile industry requires measures to accelerate the elimination of outdated industrial capacity, promote its progress in energy conservation technologies, further adjust its industrial structure, actively develop cycling economy and improve its corporate energy management.

i) Elimination of Outdated Industrial Capacity

During the 12th FYP period, this industry is expected to achieve the full elimination of its outdated industrial capacity. Despite rapid progress, the outdated industrial capacity of the chemical fibre sector, cotton textile sector and the printed and dyed textile sector still account for about 10%, 10% and 20%, respectively, of their total industrial capacity.

ii) Promotion of Progress in Energy Conservation Technologies

To promote progress in energy conservation technologies, the textile industry will adopt measures to optimize its ecological design process sequence and streamline its production links and processes. It is expected to achieve systematic energy conservation across the industry; develop common energy conservation technologies and establish an innovation technology system with enterprises as its major players; organize the development, promotion and application of energy conservation and alternative technologies for raw materials and water; introduce advanced foreign energy conservation technologies; and promote and apply advanced and mature new technologies, processes and equipment for energy conservation.

iii) Further Adjustment of Industrial Structure

The textile industry will utilize information technology to improve and upgrade its industrial structure; adopt strict industrial access standards to restrict the expansion of its outdated industrial capability; adjust the industrial structure of its various sectors and their product mix to phase out its low grade products and increase the proportion of its high value added products; and accelerate its response to market demand to shorten its product design cycle and accelerate its product updating and upgrading.

iv) Acceleration of the Development of Circular Economy

The textile industry will follow the principle of "giving priority to reduction" to strive for the systematic reduction of its resource depletion, waste generation and CO_2 emissions from the starting point of its production process and for the comprehensive utilization of various resources. It can develop technologies to use renewable fibre and partially replace chemical fibre with renewable fibre as raw materials; develop and apply technologies to recycle used clothes, to separate the chemical and natural fibres in blended products and to use the separated natural fibre in pulp production; and develop technologies to remanufacture and reuse textile equipment and devices.

v) Improvement of Corporate Energy Management

Textile enterprises will accelerate the development of their energy management centres and utilize information technology to improve and upgrade the level of their energy management. These enterprises will incorporate Computer-Aided Design (CAD), Computer-Aided Manufacturing (CAM), Computer-Aided Process Planning (CAPP) and Energy Resource Planning (ERP) into the manufacturing of textile machinery to shorten their design cycle and enhance their material utilization; apply computer control technology and advanced Radio Frequency Identification (RFID) technology to the processing, inspection and transportation of cotton; apply centralized management and Distributed Control System (DCS) to the production of

chemical fibre; apply automatic air-conditioning monitoring system and ERP automatic cotton blending system to the production of textile products; apply comprehensive inspection and control information system, automatic energy supply monitoring system and video monitoring system to the production of printed and dyed products; and apply Enersys Intelligent Power Management System to power supply. All these measures will play an important role to facilitate the efforts of textile enterprises to upgrade the level of their corporate energy management and reduce their CO_2 emissions.

(3) Potential Contributions to Low-Carbon Development of the Textile Industry by 2020

By 2020, the textile industry will achieve remarkable reductions in the overall energy consumption per unit product of major textile products as chemical fibre, yarn, woven cloth and printed and dyed cloth. It is expected to avoid 35 Mtce energy consumption and more than 80 $MtCO_2$ emissions per year.

Table 4-1 - Energy intensity of China's Major Textile Products between 2005 and 2020

		2005	2015	2020
Chemical fibre production	kgce/t	1421	1160	1090
Yarn	kWh/t	2256	2060	1965
Woven cloth	kWh/100 metres	55	42	38
Printed and dyed cloth	Kgce/100 metres	30	24	21

Source: LCIS Task Force analysis

(4). Analysis of the Potential Application of Low-Carbon Technology of Textile Industry by 2020

The five major energy conservation and low-carbon technologies available to this industry include: *energy conservation technology for the intelligent air-conditioning systems of cotton textile enterprises, energy conservation technology based on the heat gathering of dying and finishing enterprises, dying technology based on high-temperature and high-pressure air stream, refrigerating technology based on the residual heat from the etherification process of polyester chemical fibre and heat transfer technology based on the heat recovery of waste water*.

These five technologies if widely applied can avoid 13.34 Mtce of energy conservation per year, equivalent to 31 $MtCO_2$ by 2020.

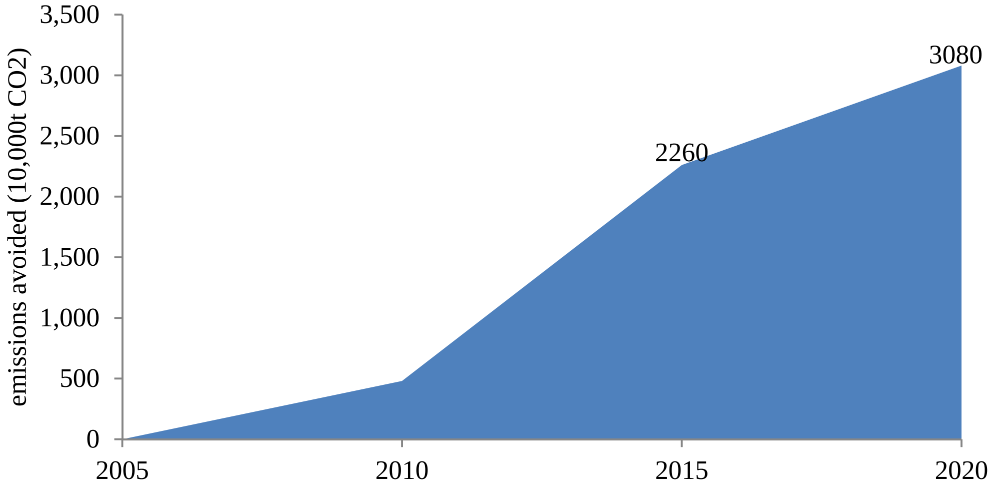
4.6.3 Policies and measures

- **Efforts to Promote Energy Conservation through Technical Progress and Industrial Restructuring of the Textile Industry**

Plans for energy conservation and emissions reductions for the textile industry are needed. These should encourage application of new technologies, advanced appropriate technologies and information technology; study and formulate the standards on the energy efficiency products and equipment, and further eliminate outdated industrial capacity by relevant improvements to market exit mechanisms; optimize its industrial distribution, upgrade its industrial access standards, and promote the optimization and upgrading of its organizational structure, product mix

and energy consumption structure; and implement the assessment and inspection mechanisms of energy conservation and environmental protection for fixed assets investment projects.

Figure 4-19: Potential CO_2 Emissions Reductions through the Promotion of Five Major Energy Conservation and Low-Carbon Technologies of the Textile Industry between 2006 and 2020



Source: LCIS Task Force analysis

- **Guidance in and Promotion of Improvement of Corporate Energy Management of Textile Enterprises**

To improve the energy conservation management of key energy-using textile enterprises, government agencies should urge these enterprises to establish and improve their energy management systems, develop their energy management mechanisms, prepare their standard energy measurement devices, arrange their energy management posts, employ their qualified energy management personnel and establish their energy conservation responsibility systems.

Efforts should also be made to guide and promote consistent for energy efficiency and low-carbon standards, and identify a series of benchmark enterprises in energy efficiency and low-carbon development. To strengthen the energy conservation management of small and medium sized textile enterprises, efforts should be made to explore new modes of energy supply in their cluster areas and industrial parks; and encourage energy conservation service providers to provide these enterprises with energy conservation services through energy performance contracting, leasing of energy conservation equipment and financing guarantee for energy conservation projects.

- **Establishment and Improvement of Supervision Mechanisms for Energy Efficiency and Emission Reduction of Textile Enterprises**

Responsibility systems for energy conservation objectives of textile enterprises should continue to be implemented; the statistics, monitoring, assessment and evaluation mechanisms for their energy conservation performance should be improved; regulators should strengthen the monitoring and inspection of the status of energy utilization and the elimination of outdated industrial capability of key energy-using

textile enterprises; and information on textile enterprises unable to effectively fulfil their energy efficiency and emissions reductions targets should be disclosed.

- **Role of Industrial Associations in the Textile Industry**

The industrial associations of the textile industry play an important role in facilitating energy conservation efforts of the entire industry. Efforts should be made to enable these industrial associations to act as a bridge, a link and a supporter by utilizing and facilitating these industrial associations in the basic management of energy efficiency and emissions reductions of the entire industry, and through facilitating their efforts to upgrade their capability in energy efficiency and emissions reductions services.

- **Facilitation of the Establishment of Public Service Platforms for Energy Efficiency and Emission Reduction of Textile Industry**

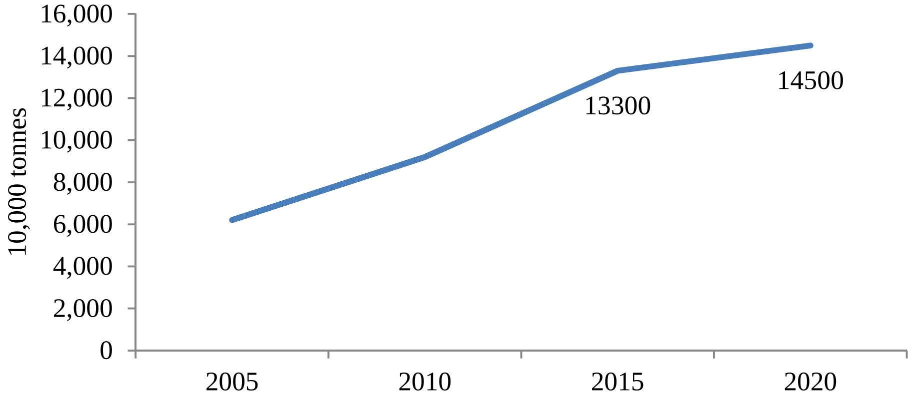
Government departments should help to facilitate the establishment of public service platforms, establish the information disclosure mechanisms and to facilitate the public service platforms to provide timely information on energy efficiency status, new technologies, processes and equipment for energy efficiency and emissions reductions, and advanced management experience at home and abroad, guide textile enterprises to explore their potentials and achieve their upgrades.

4.7 Papermaking industry

4.7.1 Current situation and development tendency of papermaking industry

China is the largest papermaker in the world, with about 3,700 paper and paperboard production enterprises. During the 11th FYP, although greatly impacted by the global financial crisis, the papermaking industry maintained rapid growth. In 2010, the total output of paper and paperboard reached 92 Mt. Compared to developed countries, the current average paper consumption per head of China remains very low and could therefore expand greatly in the future. By 2020, China’s total output of paper and paperboard is projected to reach 145 Mt.

Figure 4-20: Projected paper and paperboard production 2005-2020



Source: LCIS Task Force analysis

4.7.2 Approaches for the low-carbon development of papermaking industry as well as potential contributions

(1) Progress of low-carbon development in papermaking industry during the 11th FYP

Coal accounts for 73% of total energy consumption in this sector. During the 11th FYP, the papermaking industry took many measures in energy saving and low-carbon development, including: new construction, renovation and expansion papermaking projects; advanced pulping and papermaking technologies and equipment; the elimination of a big batch of outdated papermaking processes and equipment; growth and expansion in the wood pulp production line, waste paper processing and production line and papermaking machines; improvements to advanced papermaking capacity by over 70%. In 2010, the comprehensive energy consumption of paper and paperboard per unit product declined by about 20% compared to 2005.

(2) Approaches for the low-carbon development of papermaking industry in 2020

In the future, key approaches for energy conservation and low-carbon development of China's papermaking industry will include: increased elimination of outdated capacity; improvements to industrial concentration; optimization of the materials structure; development and promotion of energy-saving and low-carbon technology, process and equipment; and strengthening enterprise energy management.

i) Accelerate the elimination of outdated capacity

Outdated capacity continues to make up a large proportion of the papermaking industry, including small pulping production and small papermaking production with low energy efficiency and high emissions.

ii) Improve industrial concentration

In 2010, China had about 3,700 papermaking enterprises, more than 88% of which were small and medium-sized enterprises. Only 9 had a capacity over 1 Mt/year. In general, small papermaking enterprises in China use outdated technical equipment and have low energy use efficiency.

iii) Further optimize materials structure

The papermaking industry will focus on forestry-paper integration as a key development direction, strive to improve the proportion of wood fibre materials and reduce the proportion of non-wooden fibre papermaking. In addition, the waste paper recovery and use rate will be improved gradually.

iv) Develop and promote energy-saving and low-carbon technology

The following technologies and processes will be promoted in the pulp and papermaking industry: *extended delignification process in continuous cooking; high-yield pulping technology; biological technology; low-pollution pulping technology; oxygen delignification; elemental chlorine-free or total chlorine-free bleaching technology; closed screening technology; efficient waste paper deinking technology; water closed cycle technology; efficient waste water treatment and solid waste recovery processing technology; computer control technology for heat recovery; pulp and papermaking technical processes and management systems; and the adoption of new dehydration components, wide area squeezing, all closed cover and heat pumps in machines; thermo-electro combined production techniques.*

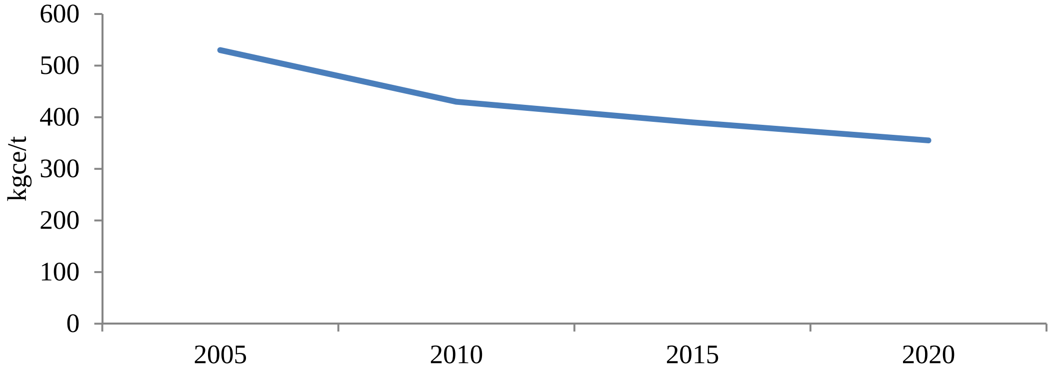
v) Strengthen enterprise energy management

Management will be strengthened through pilot projects and the establishment of energy saving and emissions reductions benchmark enterprises.

(3) Potential contributions of papermaking industry to low carbon development

By 2020, paper and paperboard energy intensity is predicted to decline by about 33%[94] compared to 2005 figures. This would avoid 25 Mtce of energy consumption per year, equivalent to 58 Mtce of CO_2.

Figure 4-21: Potential energy intensity improvement in paper and paperboard per unit product

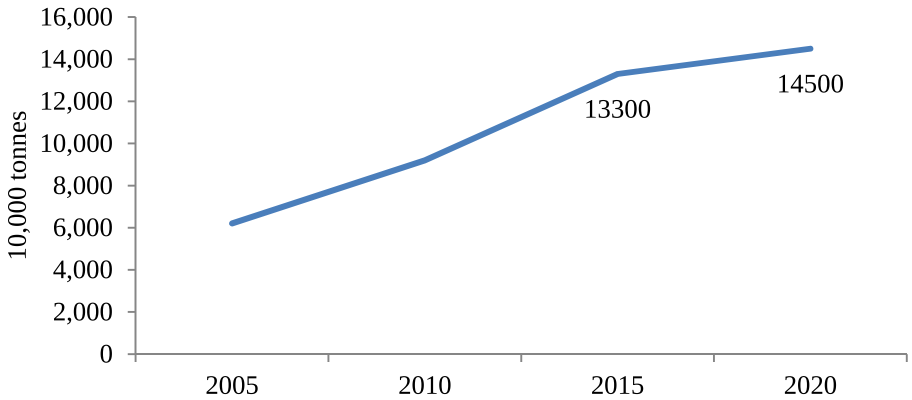


Source: LCIS Task Force analysis

(4) Analysis of promotion and application potential of low carbon technology in papermaking industry to 2020

4 major energy-saving and low-carbon technologies have been identified for the papermaking industry: energy saving and application technology for turbine vacuum system; papermaking energy systems analysis and scheduling information systems; efficient double disc pulp grinding technologies; and pulp and papermaking energy systems diagnosis and optimization technology. Research shows that if these technologies are efficiently implemented and widespread, they can induce energy savings of up to 13.34 Mtce and emissions reductions of 31 $MtCO_2$ in 2020.

Figure 4-22: Potential CO_2 emissions reductions due to promotion of 4 major papermaking energy saving and low carbon technologies (2006-2020)



Source: LCIS Task Force analysis

4.7.3 Policies and measures

1) Establish and perfect energy saving and emissions reduction laws and regulation

Energy saving and emissions reduction laws and regulation in papermaking industry should be introduced. In particular it is important to accelerate the development and revision of industrial energy consumption and water consumption standards.

2) Strengthen economic incentive policies for energy saving and emissions reductions

Support for financial and tax policies for the promotion of major energy saving and low carbon technologies.

3) Encourage and support energy saving and low carbon technology innovation in papermaking industry

Encourage the papermaking industry to build a platform for energy saving and low carbon technology innovation where technologies are jointly developed and results shared. Engineering centres should be constructed to provide technical support.

4) Guide and encourage intensive development of papermaking industry

Relevant government departments should guide and encourage papermaking enterprises to develop the scale and intensity of their operations through approaches such as closing, stopping, mergers, transfers, reshuffling and integration. Small papermaking enterprises with low energy efficiency and high emissions should be shut down to create space for enterprises with high energy efficiency and good business performance.

5) Intensify energy saving and the emissions reductions supervision mechanism

Responsibility systems for enterprises' targets should be strengthened and clarified; statistics collection and monitoring and evaluation systems improved; and monitoring and inspection of the energy utilization, performance and emissions of enterprises also strengthened.

6) Urge and guide papermaking industries to strengthen energy management

Urge papermaking enterprises to establish and perfect energy management system. Guide and promote key energy-use papermaking enterprises to carry out energy efficiency and low carbon benchmark activities and set up a batch of energy efficiency and low carbon benchmark enterprises. Strengthen small and middle papermaking enterprises' energy saving management.

5 THE ROLE OF THE EMERGING STRATEGIC INDUSTRIES

This chapter will discuss the contribution to low carbon industrialization made through development of strategic emerging industries. It will outline the current situation and the potential contribution to emissions reduction, as well as the policies and measures required in the seven strategic new industries: energy-saving and environmental protection; low carbon energy; low carbon energy vehicles; biotechnology; information technology; new materials; and the high-end equipment manufacturing industry.

5.1 Energy-saving and environmental protection

This sector includes a range of energy-saving, resource recycling, environmental protection and related technologies, equipment, products and services. During the 11th FYP period, the growth of the energy-saving and environment-protecting industry has accelerated significantly, with its average annual growth rate exceeding 20%. In 2009, according to incomplete statistics from industrial associations, the value of the industry was about RMB 1.9 trillion, of which 'energy-saving' constituted 18.4% (at RMB 350 billion), 'environmental protection' 28.9% (at RMB 550 billion) and 'resource utilization' 53.6% (at RMB 1,000 billion).

With expanding industrial scale, rapid deployment rates and increasing popularization of environment-friendly products and technologies amongst consumers, this industry is already boosting the process of low carbon industrialization.

Table 5-1: Output Value of Energy-saving and Environmental protection Industry in recent years

	2008		2009	
	Value(Billion RMB)	Proportion (%)	Value (Billion RMB)	Proportion (%)
Energy-saving Industry	270	19.1	350	18.4
Service Related	41.7	3.0	58	3.1
Environmental protection industry	480	34.0	550	28.9
Resource Utilization Industry	660	46.8	1000	52.6
Recycling and Reprocessing of Waste Resource and Material[95]	1158	8.2	145.3	7.6
Total	**1,410**	**100.0**	**1,900**	**100.0**
GDP，Billion RMB	34,050.7		39,798.3	
Share of China's total GDP %	**4.1**		**4.8**	

Sources: China Statistical Yearbook, China Energy Conservation Association, China Environmental Protection Industry Association, Chinese Renewable Energy Industries Association and China Environment Service Industry Association.

5.1.1 Prospect on energy-saving and environment-protecting industry in China

1) Huge market demand

Industrial waste material has grown rapidly during the past five years, with an average annual growth rate as high as 13%. However, the comprehensive re-utilization rate remains low, at around 70% in 2010.[96] The recycling of used products is booming, but

recycled non-ferrous metal still only makes up 24.3% of the total production of 10 kinds of non-ferrous metal in China.[97] The 2010 urban sewage treatment rate increased to 75.25%, but there are still 61 cities without sewage treatment plants, and virtually no sewage treatment facilities exist in rural areas. Landfill remains the main method for non-polluting garbage disposal, with the proportion of burn and compost being less than 20% - much lower than in Japan and South Korea.[98]

In 2010, energy consumption per unit of GDP dropped to 1.042 tonnes of standard coal per RMB 10,000, still lagging behind developed countries.[99] In the 11th FYP period, over RMB 200 billion was earmarked in the central budget for energy conservation and pollution reduction. The total social investment amounted to about RMB 2 trillion, about 2% of the total social investment in that period.[100] Investment in this area will be further expanded to fulfil its long-term strategic goals, and even calculated by the present 2.5% annual growth rate, the investment in the next 10 years is estimated to reach RMB 5.4 trillion.

2) New technologies to promote energy-saving and environmental protection

China already possesses a set of mature traditional technologies and equipment in this sector. It has started to develop R&D systems and generic platforms and is already producing some of the key industrialized technologies and generic technologies. Energy-saving technologies include TRT, low caloric value gas turbines, pure cryogenic residual heat power generation. Relevant environmental protection technologies include the incineration of waste and dried sludge in power plants. Some Chinese firms are internationally competitive in key technologies and equipment, including surface treatment technologies in remanufacturing, automatic production line for waste circuit board recovery, thermosetting plastics of electronic waste recycling, and refrigerants recycling technologies and equipment.

5.1.2 Energy-saving and environment-protecting industry and low carbon Industrialization

At present, Chinese enterprises still lag behind advanced foreign counterparts when it comes to energy efficiency in the production of major products (see Table 5-2).

The energy-saving and environmental protection industry can help heavy industry sectors to move towards a low carbon model - by reducing per unit energy consumption, promote resource re-utilization and cut costs. There are three ways to realize this transition:

- directly reducing energy consumption in the production process by adopting energy-saving technologies, products, equipment and management;
- reducing resource consumption and its impact on the environment by moving towards a circular economy and improving energy efficiency;
- producing energy-saving and environmentally friendly products and services that require fewer resources and raw materials during use and over their life-cycle.

Table 5-2: Energy Consumption of Major Industrial Products

	China			International Advanced Level	Gap (2005)		Gap (2009)	
	2005	2008	2009		Energy consumption	Proportion (%)	Energy consumption	Proportion (%)

Thermal power supply coal consumption (gce/kWh)	370	345	339	312	58	18.6	27	8.7
Steel comparable energy consumption for large and medium enterprises (kWh/t)	714	663	644	610	104	17.0	34	5.6
Electrolytic aluminum, AC consumption (kWh/t)	14680	14323	14131	14100	580	4.1	31	0.2
Copper smelting, total energy consumption (kgce/t)	780	564	548	500	280	56.0	48	9.6
Cement, total power consumption (kgce/t)	167	151	139	118	49	41.5	21	17.6
Crude oil refinery, total energy consumption (kgce/t)	114	106	106	73	41	56.2	33	45.3
Ethylene, total energy consumption (kgce/t)	1073	970	954	629	444	70.6	325	51.7
Synthesis ammonia, total energy consumption (kgce/t)	1650	1549	1521	1000	650	65.0	521	52.1
Caustic soda, total energy consumption (kgce/t)	1297	1154	1075	910	387	42.5	165	18.1
Soda ash, total energy consumption	396	345	306	310	86	27.7	-4	-1.2

(kgce/t)								
Paper and paperboard, total energy consumption (kgce/t)	1380	1158	--	640	740	115.6	518	80.9

Notes: See endnote # 101

Source: State Statistics Bureau, Ministry of Industry and Information Technology, China Electricity Council, China Iron and Steel Association, China Building Materials Industries Association, China Association for Chemical Energy Saving Technologies, Handbook of Energy & Economic Statistics in Japan (2010) by the Institute of Energy Economics, Japan, Journal of the Japan Institute of Energy, Iron & Steel Institute Japan and Korea Iron & Steel Association.

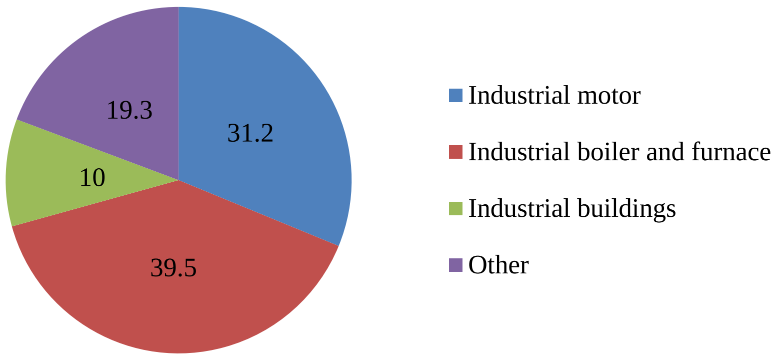
1. Reducing energy consumption in industrial production

Key areas of energy consumption within industrial production include: industrial power distribution, industrial motors, industrial boilers and furnaces, and industrial buildings (including air-conditioner and lighting), as shown in Figure 5-1.

The key challenges are as follows:

- the capacity and specification of the electric transformer and distribution line are not matched with their actual load, leading to low efficiency in the power supply and distribution system.
- the equipment configuration is imperfect: electricity consumption in industrial motor systems (including the electric motor, water pump, fan and compressor) takes up about 80% of the total electricity consumption in China, while the market occupancy of high-efficiency energy-saving motors is less than 3% and the operational efficiency of the electric motor system is generally 20% or so lower than that in developed countries.[102]
- The actual operational efficiency of industrial boilers (furnaces) is comparatively low, ranging from 15% to 20% lower than the average level of developed countries. The industrial boiler (furnace) accounts for more than 20% of Chinese coal consumption.
- The energy consumption of industrial construction is not given sufficient attention. Compared to domestic and retail, industrial buildings retrofitting with energy-saving technology requires more investment but produces a less significant effect. Encouraging enterprises to take undertake energy-saving measures is therefore difficult. At present the energy consumption of industrial buildings accounts for about 10% of the industrial energy consumption in China, and energy-saving buildings are relatively rare.[103]

Figure 5-1: Distribution of Energy Consumption in Process Of Industrial Production



Source: Calculated and Arranged according to Data from "Energy Statistical Yearbook in 2009 China"

Potential measures for promoting the energy-saving and environmental protection sector doing so are set out in detail below:

i. **Enhancing energy management at industrial end-use, including demand-side management, to reduce energy waste and equipment loss.** Suitable transformers or other power transforming equipment should be used. Systematic management of power distribution rooms located in different factories or on different floors can deliver efficiency savings while protecting equipment.

ii. **Deploying energy-saving equipment such as boilers and furnaces, motors, dragging equipment and waste heat and pressure utilization equipment, and energy-saving monitoring equipment.** In 2011, high-efficiency electrical motors are expected to reach 30% of total electrical motor sales, and the share will rise year on year in the future. Abandoning old electrical motors and increasing the share of high-efficiency electrical motors in new sales (annually increasing by 5-10% on average) will deliver rapid change: efficient models will account for 80% of the total installed equipment in these categories by 2020. On the basis of a 15% energy saving, the electricity consumption of high-efficiency electrical motors will be reduced by 750 TWh, equal to 568 $MtCO_2$.

The annual energy consumption of industrial boilers and furnaces in China is more than 700 Mtce, and the operational efficiency is 15-20% lower that the 'overseas advanced level'. If the operational efficiency of 70% of industrial boilers and furnaces is improved to the level as high as the present advanced level, 210 Mtce of energy consumption can be avoided, equivalent to 437 $MtCO_2$ respectively.

iii. **Driving up energy efficiency in new industrial buildings and through retrofitting.** This involves optimizing the design of factory buildings, fixing outer surrounding structure, and achieving widespread deployment of high-efficiency lighting devices and energy-saving air-conditioners and fans. Pilot projects exist in Shenyang have provided important lessons. If around 20% of existing industrial architectures can be retrofitted by 2020 and the energy consumption per building area drops by 15%, 14.9 Mtce of energy consumption will be avoided, equivalent to 345 $MtCO_2$.

iv. **Promoting the energy-saving service industry, building integrated service platforms and providing packaged services of energy-saving diagnosis, design,**

financing, reconstruction and operation for companies. There were about 800 energy-saving service enterprises in 2010 in China, with a total revenue of around 85 billion RMB, saving 10.7 Mtce of energy. The revenue of the energy-saving service industry is forecasted to climb by 23% per year, reaching 600 billion RMB by 2020 – 40% of the total revenue of the energy-saving industry as a whole. This will avoid 98.8 Mtce of energy consumption in industrial sectors, equal to 115 MtCO_2.

2. Developing a circular economy and promoting recycling of resources

A circular economy will require improvements in recycling facilities and waste recycling technology and the construction of related recycling services systems so as to improve the usage efficiency of renewable resources. In addition, innovation is needed in product design, for example to encourage remanufacturing, to enable products to be repaired and to use materials which can be sustainably sourced and disposed of. Detailed proposals are set out below:

i. **Accelerating the diffusion of essential resource recycling technologies and facilities.** This includes the recycling of tailings, smelting residues of major non-ferrous metal and waste products from the provision of new technologies. Facilities for separation, enrichment and comprehensive utilization of minerals, as well as high-efficiency clean disassembling technology and facilities for wasted machinery, electrical appliance and plastics are also needed.

ii. **Promoting the application of renewable resources in production and everyday life.** Solid wastes such as desulfurized gypsum, fly ash, coal and smelting residues can be used to produce new building materials; more recycled metal, rubber and plastic can be collected and used; Scrapped cars and other machines can be remanufactured and resold as new cars, or alternatively as car parts, engineering machinery, machine tools, as well as equipment for communication, transportation, drilling and military use. As set out in Section 3.2.3, secondary metal can save significant amounts of energy and CO_2.

iii. **Developing resource recycling services and improving the circular economy service system.** A key element is the improvement and integration of existing recovery systems in close combination with the distribution market. Service platforms are needed, bringing together research and development of remanufacturing engineering technology, safety analysis of reproduced products, and quality identification of remanufactured products through the establishment of waste recovery systems, using message-switching networks.

3. High-efficiency products and materials to save energy and resources

Energy-saving, material-saving and environmental protection products can avoid much unnecessary energy and resource consumption. Examples include household and commercial electrical appliances, lighting products, building materials and vehicles. The following measures are key to developing high-efficiency products and materials:

i. **Developing and popularizing high-efficiency household appliances.** These include: high-efficiency air-conditioners and refrigerator compressors, DC inverter compressors, DC inverter controllers, reinforced heat transfer technology of gas water heaters, solar water heaters and variable control energy-saving equipment; promoting high-efficiency products including air-conditioners, refrigerators, washing machines, electric cookers, water heaters and electric heaters.

According to China’s 2009 Resource Statistical Yearbook, the electricity consumption of household appliances is about 13.5% of the total. With the widespread adoption of household appliances in China, especially in rural areas, the proportion of electricity consumed by household appliances will rise. The proportion of energy-saving household appliances sold is currently about 15%-30% of the total, though exceeding 50% for certain appliances. Energy-saving household appliances make up less than 10% of total household appliances. Over the next ten years, the inventory of household appliances is projected to rise by about 5% annually in China, and the proportion of energy-saving household appliance will rise to around 40%. Assuming that each household appliance saves 30% electricity power, 67 TWh will be saved by means of energy-saving household appliances in China by 2020, equivalent to 50 $MtCO_2$.

ii. **Developing and promoting energy-saving commercial or public products.** These include: high-efficiency heat exchanger technology, energy storing devices, refrigerating and freezing technology, centrifugal impeller flow and pressurization technologies, and low-energy consumption mainboard, memory and power technologies; promoting unitary air-conditioning units, multi-connected air-conditioning units, chillier unit and external power adaptors; and disseminating high-efficiency energy-saving office supplies such as duplicators, printers and fax machines.

The electricity consumption of office buildings and other public buildings is only 55% of that of household electricity consumption, because public buildings are relatively concentrated so that the energy-saving campaigns are more easily carried out and because government departments have taken action to increase energy saving in public buildings. By 2020 carbon emissions are projected to have decreased by 27.9 Mt through adopting high-efficiency energy-saving products.

iii. **Developing and promoting high-efficiency energy-saving lighting products.** This means developing vital devices and core materials for semi-conductor lighting, such as gallium chloride material, and OLED materials and devices; developing general technology for semiconductor lighting industrialization such as high-power chips and devices, drive control and standardized module system integration; developing light source products such as ballasted lamps for ordinary illumination, metal halide lamps and high pressure sodium lamps, and relevant ballast.

Electricity consumption due to lighting is estimated to account for about 10-12% of the total in China. Around 1.4 billion incandescent lamps are in use in China now. During the three years from 2008 to 2010, nearly 350 million energy saving lamps were sold with the help of financial subsidies. If 150 million lamps are installed each year in the future, it will take 7-8 years to replace all the ordinary incandescent lamps with energy-saving lamps. According to a conservative estimate – where each lamp saves 50 kWh – 70 TWh can be avoided by the use of energy saving lamps by 2020 in China, reducing carbon dioxide emissions by 53.1 Mt.

iv. **Developing energy-saving and new-energy vehicles.** This includes developing new batteries for electric vehicles and new electromechanical coupling power systems for hybrid power vehicles, power system for vehicles and generating equipment, areas in which Chinese companies currently lack intellectual property rights. Efficiency can be pursued by promotig pure electric vehicles and hybrid power vehicles as well as internal combustion engine vehicles with a high fuel economy.

Annually 109 Mt of gasoline can be avoided by the deployment of energy-saving vehicles, equivalent to about 300 $MtCO_2$ emissions by 2020.[104]

v. **Energy-saving building materials and products, and upgrading heat supply.** This involves developing new wall materials such as thermal insulation, reinforced flash brick, gangue sintered brick and reinforced bearing blocks, energy-saving construction windows and doors and water-proof insulation systems for walls. Furthermore, solutions to the energy efficiency of buildings should be provided based on its specific heating or cooling supply system. By 2020, 113 $MtCO_2$ emissions can be avoided through these measures.

Table 5-3 summarises the potential for energy saving and environmental protection technologies to avoid energy consumption and CO_2 emissions.

Table 5-3: Specific Contribution of Energy-saving Environmental-protection Industries to Low-carbon Industrialization

Main links	2015		2020	
	Energy saving	Emission reduction	Energy saving	Emission reduction
	10,000 tce	10,000 tonnes of CO2	10,000 tce	10,000 tonnes of CO2
Reduce energy consumption in the process of industrial production				
high-efficiency electric motor	6400	14720	24700	56810
high-efficiency boiler (furnace)	8990	20677	20570	47311
Energy-saving industrial building	500	1150	1500	3450
energy-saving service	2250	5175	5000	11500
Develop recycling economy				
recycling of waste steel	6018	13842	8764	20157
develop and promote energy-saving and environmental protection products				
energy-saving household appliance	1422	3271	2164	4977
energy-saving public commercial products and office supplies	813	1869	1212	2788
energy-saving lighting	1815	4175	2310	5313
energy-saving environmental-protection vehicle	5950	13684	13043	30000

energy-saving building material	2300	5290	4900	11270
Subtotal of Contribution	41529	95516	96422	221772

Note: see Section 3.3 for details of the contribution of energy-saving and environment-friendly vehicles to low carbon industrialization.

5.1.3 Main Bottlenecks in developing energy-Saving and environmental protection industry

1) Weak technological basis for innovation

Production volumes of energy-saving and environmental protection equipment made in China are rising in most categories, including frequency converters, high-efficiency lighting equipments, dust collectors, desulfurizing devices and sewage disposal facilities. Some products, such as dust collectors and energy-saving home appliances, are now exported to other countries.

However, China still lacks crucial and generic green technologies with independent intellectual property rights. Key technologies, equipments and materials rely heavily on imports. While there are many manufacturers in China, companies engaged in R&D and services remain scarce and the added value of products and services remains low. For example, China is the largest manufacturer of lighting devices in the world, but its products are mainly at the low- or medium end of the market.

2) Imbalance in industrial structure

Among all manufacturers of environmental protection equipment, less than 5% are large companies, whereas the fixed assets of 85% companies are no more than 15 million RMB. Only 5 companies can handle more than 10,000 tonnes of waste per day to generate power, and the concentration ratio of the industry is lower than 8%. In 2010, there were more than 800 companies in the industry, but its development is sporadic with most companies offering only a single technology in their energy-saving services. Compared with the overall solution programs provided by large international corporations, these companies are apparent underdogs.

3) Sluggish structural reforms and supporting policies

Some local governments and relevant departments focus only on developing and introducing companies that yield time-saving benefits, leading to inadequate attention and investment in the energy-saving industry. Normally, most of the funds are invested in initiating new projects, which may therefore later be starved of funds when it comes to structural research and capacity improvement. In addition, external costs are not only made up of energy and environment costs. Relevant taxes and fees are low and hard to levy. At present, it costs only RMB 0.8 or less to treat each tonne of sewage. If plants were to deal with the sludge as well, the cost will rise to RMB 1.2 per tonne.

Existing measures in many cases do not provide sufficient incentive to change behaviour and investment patterns. In cities that charge for waste collection services, usually only 30-50% of residents pay for it. Environmental protection enterprises, like

other enterprises, are subject to 25% income tax. Measures to offset taxable income at a certain ratio of the investment amount or accelerated depreciation are rarely implemented.

4) Lack of private investment

Compared with developed countries, China's capital market and environmental exchange markets are immature: money raised directly from capital markets is limited, and the financing of energy-saving and environmental protection companies or service facilities is largely dependent on franchises and banks. Especially in the service area, up-front costs are high and the proceeds are relatively low. The investment cycle is long and may need to be supported by loan guarantees or other measures, which are not widely available. So far, not all banks approve of taking a franchise as collateral, making it very hard for some companies to obtain loans. Even worse, the business model of energy-saving and environmental protection companies is mostly one-track, meaning that their cash flow can easily be interrupted, leading to frequent capital shortages.

5.1.4 Policies and measures to promote development of the energy-saving and environmental protection industry

1) Short and medium term development plan for the industry and policy coordination

In accordance with the aim of the 12th FYP relevant departments should promulgate the *Short and Medium Term Development Plan for Energy-Saving and Environmental Protection Industry*, making clear the main objectives and corresponding policies and measures. Implementation of current policies and coordination among departments in charge should be strengthened, and plans at all levels integrated. The government should also issue policies to facilitate R&D in environmental protection technology, industrialization and trade, to accelerate independent innovation and technology introduction, to foster a number of leading companies with core competitiveness, and to accomplish rapid development in this sector.

2) Resource pricing and market incentives

Resource pricing should reflect supply and demand as well as the social and environmental costs of production. Water price reform is needed, with differential fees according to different types of water usage. Efforts will be made to set up a pricing mechanism for refined oil, which links the market with the price. The price peg between natural gas and alternative energy needs to be made clear. The resources tax will be moderately raised and the levying mechanism improved, so as to promote proper use of resources.

More energy-efficient products, equipment and buildings will need to be produced, and stricter regulations should be introduced to protect the environment and stimulate green technology markets. China should accelerate efforts in formulating energy labels and implementing energy-efficient standards for key products, improve energy audit systems, and introduce further restrictions on the discharge of industrial/domestic waste water and on the emission of air pollutant from coal power plants, industries and automobiles. China should also perfect supervision networks for energy-saving, enhance continuous online monitoring and control of environment, and set up an assessment platform for clean technology as well as a service platform for the development of a recycling economy.

The government should impose an environment tax and increased fines for polluting activities, intensify fee collection efforts for the treatment of waste water and domestic garbage, and severely punish those who violate the regulations. In order to deal with waste such as family appliances, electronics and automobiles, China should gradually implement the system of extended manufacturers' responsibility.

3) Introducing a strategy to promote the application of energy-saving and environmental-protection technology and improve technical levels

All relevant stakeholders should contribute to formulating a systematic strategy for promoting the application of energy saving, environmental protection technology and set up a mechanism to guarantee that the technology is accepted in the market.

Governments must provide guidance and policy direction, to increase the independence of enterprises in their R&D and application. They should encourage these companies—especially private ones—to take part in major national projects, support the establishment of a technology innovation system with enterprises as its centre, and facilitate the transfer and industrialization of outstanding green projects.

It is important to optimize the verification and product testing platforms for energy-saving projects, improve the standardized system for energy-saving and environmental protection technology, and implement a supervision system for green technological projects and equipment. China could establish a special institution to promote transferral of green technologies, such as energy-saving, environment-friendly equipment and services, so to eliminate structural, capital or informational obstacles in the transaction. It is also necessary to regulate the sales of green technologies. A sound market environment will facilitate R&D and application of technologies, equipment and products.

4) Increasing financial input and improve a diversified system for investment and financing

Investment in and operation of the green industry requires significant financing and central and regional levels in China. If environmental taxes proposed by the Task Force are levied, part of the revenue can be used to save energy and reduce emissions. Industry should also embrace foreign and private investment to enlarge the multiplier effect of fiscal capital and make better use of capital market.

5) Preferential taxes and support

Companies should be given tax incentives to make green investment and operational decisions. For enterprises with R&D functions, the tax preference should focus on technologies in the preliminary stages of development, through fee deduction and tax concession. In later stages of technology development, incentives should focus on reduced taxation. For companies offering operational services to green facilities, the governments could levy lighter turnover taxes, income taxes and land use taxes, and introduce investment deduction and accelerated depreciation in parallel.

5.2 Low carbon energy

5.2.1 Global development trends of the low carbon industry

1) Acceleration of innovation

Innovation in low carbon energy technology is gaining momentum. The maximum capacity of an individual wind turbine has risen from 30 kilowatts in 1980s to 5000

kilowatts at present, and the price for surfing the internet has decreased from 15.8 Euro cents per kilowatt hour to 4. The power generation efficiency of silicon-based solar photovoltaic has risen from less than 10% in 1990s to 17-18% at present. The industry has an 82% technological learning curve, which means that each time the scale doubles, the price is expected to fall by 18%. The price of wind power is likely to go down to 3 euro cent per kilowatt hour. The price of solar power will equal the price of thermal power around 2020 – a potential game-changer for the energy industry.

2) Low carbon energy industry is undergoing large-scale and rapid development

The low carbon energy industry is undergoing large-scale and rapid development. What was once a supplementary energy source becomes a mainstream alternative. During the past decade, photovoltaic solar power increased by 38% annually, and wind power by 28%. Wind power capacity installed in Europe accounts for more than 50% of the total global capacity installed.

3) Major countries pay great attention to the development of low carbon energy

Expansion of the low carbon energy industry is perceived to be a key lever to secure growth and jobs in the wake of the financial crisis, as well as being essential for responding to climate change. The US and EU as well as other major economies have increased investment in this area through economic stimulus packages and regular research budgets. 10% of the stimulus package of the US, 80 billion dollars, was for the development the low carbon energy. The European Union also intensified support for the research and development of the low carbon energy. For instance, the EU planned to spend up to 1.25 billion euro on a pilot project for carbon capture and sequestration technology.

5.2.2 China's low carbon energy resources and industry development

1) Abundant renewable resources in China

The technically developable installed capacity of hydropower in China is 540 GW, with an annual power generation capacity of 2470 GW - the highest in the world. With two thirds of the total territory enjoying over 2,200 hours of annual sunshine hours, there are abundant solar resources to be tapped. The annual solar radiation is higher than 5,000 MJ per square meter, equivalent to 170 kgce per square meter. There is 300 GW of usable wind power onshore, with another 700 GW available offshore. The current potential of biomass-converted power is equivalent to 500 Mtce. With the efforts of re-forestation and economic and social progress, the potential is expected to grow up to 1 billion tce.

2) Rapid progress made in the development and utilization of low carbon energy

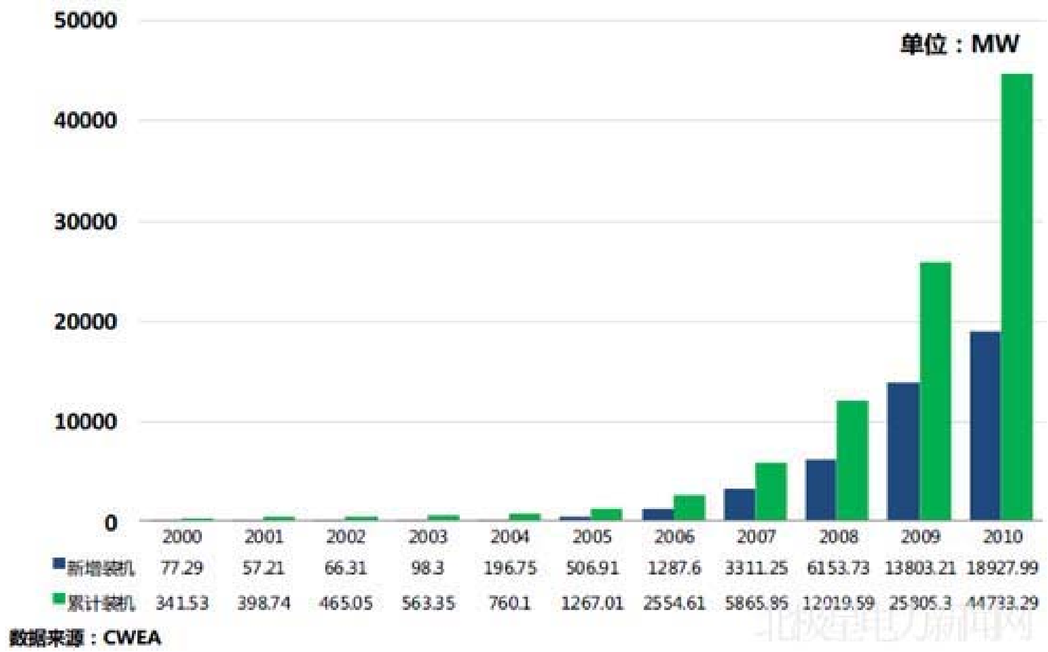
In recent years, wind power and other renewable energy have developed rapidly in China. By the end of 2010, hydropower reached 213.4 GW, and the installed capacity of nuclear power reached 10.82 GW. There are 26 nuclear powered reactors under construction with an additional capacity of 29.14 GW. The total integrated grid capacity of wind power reached 31.07 GW. (The installed capacity of wind power with completely erected turbines is 44.73 GW, see Figure 5-2).

The proportion of installed capacity of non-fossil power accounted for 26.5% of the total - 1.1 percentage points higher than in 2009. The cumulative power generated by non-fossil resources was 786.2 TWh, equivalent to 263 Mtce by coal-fired power

conversion, accounting for 8.11% of the country's total energy consumption. In 2010, solar water heaters covered 168 million square meters, while solar collectors covered a total of 40 million households with 150 million residents. Wind power capacity increased by 18.9 GW, accounting for half of the newly installed wind power capacity globally.

In terms of pricing, the on-grid wind power tariff dropped to 0.5 ~ 0.6 RMB / kwh. The solar power price went down much faster than expected over the last few years. In 2008, the officially approved on-grid solar power price was 4 RMB / kWh. But by March 2009, the average bidding price in the Dunhuang solar power project was down to 1.5 RMB / kwh, and the bid-winning price was 1.09 RMB / kWh. In the latest solar power project bidding, the winning bid price was 0.72 RMB / kwh.

Figure 5-2: Newly installed and aggregate installed capacity of wind power in China



Blue - Newly installed capacity

Green - Total installed capacity

Source: CWEA

3) Rapid expansion of low carbon energy industry

Domestic, large-scale manufacture of nuclear power equipment has made progress in China, reaching a production capacity of 6-8 sets of equipment annually. Wind power equipment manufacturing capacity also grew significantly, with the products from domestic manufactures and joint ventures accounting for 90% of newly installed capacity (see Table 5-4 below). In 2010, the annual production capacity of PV cell components reached 15GW, and the output was 8GW - a 100% year-on-year increase, accounting for more than 50% of the global share. Polycrystalline silicon production totalled 40,000 tonnes or so, meeting 50% of domestic demand, with an additional 6 Mt production capacity under construction. The annual added coverage of solar water

heaters reached 46 million square meters, accounting for more than half of global output.

Table 5-4: Top 20 manufactures of newly installed wind power capacity in 2010

No.	Manufacturer	Installed capacity(MW)	Market share
1	Sinovel	4386	23.2%
2	Gold Wind	3735	19.7%
3	East Turbine	2623.5	13.9%
4	United Power	1643	8.7%
5	Ming Yang	1050	5.5%
6	Vestas	892.1	4.7%
7	Shanghai Electric	597.85	3.2%
8	Gamesa	595.55	3.1%
9	XEMC Windpower	507	2.7%
10	China Creative Wind Energy	486	2.6%
11	CSIC (Chongqing) Haizhuang Windpower	383.15	2.0%
12	CSR Times	334.95	1.8%
13	Envision Energy	250.5	1.3%
14	GE	210	1.1%
15	Suzlon	199.85	1.1%
16	Hua Yi	161.64	0.9%
17	Yin Xing	154	0.8%
18	Windey	129	0.7%
19	SANY Electric	106	0.6%
20	Changxing Wind Power	100	0.5%
Others		**382.9**	**2.0%**
Total		**18927.99**	**100%**

Data source: CWEA

5.2.3 Development goals for the low carbon energy industry and the estimated contribution to energy conservation and emission reduction

1) Development goals

Non-fossil energy accounted for 8.1% of China's energy consumption in 2010. According to the 12h FYP, the proportion of should reach 11.4% by 2015. The proportion should increase further to 15% by 2020, with an installed capacity of 150 GW of wind power, 80 GW of nuclear power, and 20 GW of solar power, as suggested by the National Climate Change Program.

The current annual output of China's low carbon energy equipment industry is RMB 200 billion, of which photovoltaic cells industry accounted for RMB 70 billion and the industries of solar, wind and nuclear power contributed RMB 40 billion each. The goal is to increase the annual industrial output by one fold to over RMB 400 billion by the end of the 12th FYP. The low carbon energy industry is expected to bring about trillions of GDP growth every year, constituting a significant driver of economic growth.

With regard to industrial innovation capacity and competitiveness, more Chinese firms will need to create and protect new intellectual property, especially for key high value components, as well as making breakthroughs in the absorption of key technology such as third-generation nuclear power, high-power wind generation, and solar polycrystalline silicon manufacturing, during the 12th FYP period. By 2020, the low carbon energy industry is expected to display enhanced R&D capacity, and be a leader in advanced nuclear power, offshore wind power and third-generation solar technologies. As a result, industrial competitiveness will be refocused from low labour cost to high technical components and economies of scale, making the industry a vanguard sector in the national economy.

2) Contribution to energy conservation and emissions reduction

Based on the plans set out above, Table 5-5 sets out the potential to avoid energy consumption and emissions by deploying low carbon energy: By 2015, low carbon energy technologies will displace 467 mtce of energy consumption, equivalent to 1.15 $GtCO_2$. This is 500 Mt more than 2010 and will reduce carbon intensity by 3 percentage points. By 2020, it will avoid 720 mtce each year, equivalent to 1.8 $GtCO_2$, further reducing per unit GDP emission by 3-4 percentage points.

Table 5-5: Forecast on non-fossil energy development and evaluation on CO_2 emission reduction

	2010	2015	2020
Total energy consumption (100 Mtce)	32.4	41	48
The proportion of non-fossil energy	8.11%	11.40%	15%
Hydropower installed capacity (10,000 kilowatts)	21340	28000	43000
Wind power installed capacity (10,000 kilowatts)	3107	9000	15000
Nuclear power installed capacity (10,000 kilowatts)	1082	4000	8000
Solar power installed capacity (10,000 kilowatts)	60	500	2000
Alternative energy (100 Mtce)	2.63	4.67	7.20
CO_2 emission reduction (100 Mtce)	6.46	11.50	17.71

5.2.4 Challenges for the low carbon energy industry

1) Inadequate technology base

Today, Chinese firms do not produce all the core industry technologies, and key components are still dependent on imports. China's wind power capacity has increased dramatically, but R&D on new generator models is slow due to the introduction and assimilation of advanced imported ones. The control system and key bearings of wind generation equipment are good examples. China has a substantial solar cell industry, but domestic companies have not yet assimilated the technology for preparation and purification of polycrystalline silicon or the technology for recovering toxic by-products such as silicon tetrachloride, both of which are difficult to develop or introduce. The nuclear power generation, construction and operation capacity has seen significant improvement, but the overall design is based on a replication of imported models, and the design principles and know-how are still to be learned by Chinese companies. There is still a long way to go in the domestic manufacture of large forgings, main pumps and special materials.

The supporting system for technological innovation remains inadequate. Research institutions are scattered, mostly in various universities, lacking coordination. Furthermore, the industry is characterized by small enterprises with limited R&D capabilities, while the Chinese equivalents of large equipment suppliers such as General Electric, Westinghouse, Mitsubishi and Siemens are hard to find. Even large enterprises may be small- and medium-sized companies in developed countries when it comes to R&D capability.

2) Discipline and regulations required

There are currently few technical standards in the sub-sectors of wind power and photovoltaic power equipment manufacturing. The mandatory testing and accreditation regime has yet to be established, and the industrial technical threshold is lacking. This situation has brought two problems: enterprises initially rushed into the industry. Due to policy incentives and lack of an entrance threshold, the industry was inundated with newcomers. There are now over 70 wind power generator manufactures, the largest four of which have a total capacity of over 12 GW, and there are more than 30 polycrystalline silicon manufacturers. Lacking in core technology and innovation capacity, these companies entered into price competition at the expense of product quality and consistency.

Product quality has often been compromised. Due to the explosive growth of the industry, many products have only had a very short cycle from R&D to mass production, and so potential problems may not be fully exposed or effectively resolved. Huge volumes of products have therefore entered the market before sufficient testing, which may lead to large-scale equipment failure and significant losses.

3) Misalignment of low carbon energy concentration areas and load centres

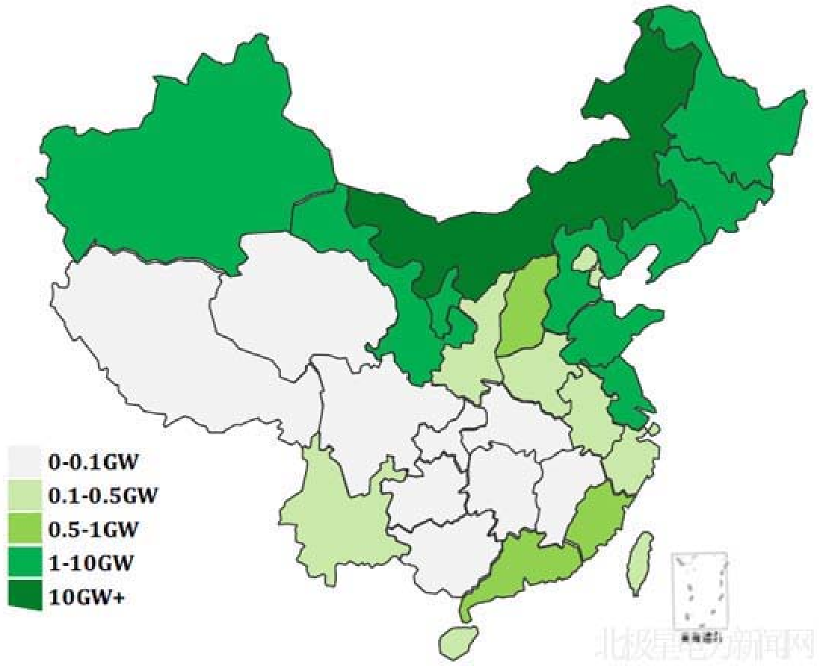
Low carbon energy resources are spread unequally and for some technologies the power generated from them fluctuates. The generated electricity needs to be spread over a large geographical area in order to limit the impact of fluctuation on the grid. China's low carbon energy resources, especially wind, is usually located far from the load centres, and requires large-scale power transmission. There are still bottlenecks, resulting in a high proportion of wind power in some areas, such as Jilin. In certain hours, power generated from wind accounts for 25% of the total load, which is

detrimental to the safe operation of power grid, and restrains further development of wind power.

4) Structural problems have resulted in idle capacity

The wind power industry had an installed capacity (with completely erected turbines) of 44.73 GW at the end of 2010, but the integrated grid capacity is only 31.07 GW. The huge idle capacity of the wind power industry is partially attributed to temporary factors, such as the comparatively slower pace of grid construction than power generation (see Figure 5-3). However, the fundamental cause lies in the industrial structure, including a lack of coordination between low carbon energy development and power grid construction, delayed transfer of the rising costs of power generation, and lack of mandatory requirements and supervision of power grid companies.

Figure 5-3: Aggregate installed capacity across provinces in 2010



5.2.5 Thinking on the development of low carbon energy industry

The development of China’s low carbon energy industry can be described as innovation-driven, rooted in local conditions and characterized by equal access and ‘two-way motivation’.

1) Innovation-driven

The speed and scale of low carbon energy development must be integrated with the development of the low carbon energy equipment manufacturing industry, particularly the improvement of technical innovation capacity. Financial and tax policies can be used to develop low carbon energy markets, but more attention must also be paid to the R&D, design, manufacturing and operation capacities.

2) Rooted in local conditions

Most European countries have taken a path of distributed utilization to some extent. In Germany, which has a total installed capacity of 23 GW, the majority of wind power comes from medium and small fields. The installed capacity of the largest wind power field is only 60,000 KW, and most wind power is directly connected to the

distribution network and digested in local areas. The US not only develops large-scale wind power, but also encourages the development of distributed energy such as small-scale wind power and household solar energy.

China should pursue a combination of large-scale and distributed development, rather than focusing only on large-scale power sources or grids. This means building wind and solar bases in regions with rich resources on a large scale, but also encouraging the construction of medium and small wind fields and the dispersed utilization of both. Furthermore, smart-grid capacity should be developed, the two-way power supply of distributed energy utilization systems implemented, and improve local digestion capacity improved.

3) Equal access

The establishment of fair access policies, technical standards and market mechanisms is an urgent priority, as is reform of the power system and improvements in the supervision of equal access to the power grid.

4) Two-way motivation

Price, finance and tax policies should be used to encourage investment in low carbon technology, but these subsidy policies will play two roles: First, the price of low-carbon energy will reduce over time as technology is deployed (technology learning). Second, it can motivate investors.

Since the implementation of bidding for wind power project contracts, competition has significantly reduced wind power feed-in tariffs. The wind power benchmark price, which is set according to regional resources, can avoid excessive competition, but significantly distorts the market. As technical progress is currently accelerating, it is hard for the government to set prices scientifically and reasonably, form efficient motivation for investors, promote technical innovation, improve efficiency and reduce cost. Low-carbon energy development should not in the long term be maintained by government subsidy. The current moderate subsidy is intended to make low-carbon energy economically competitive, and the price subsidy needs to be focused on the long-term objective.

5.2.6 Policy measures to accelerate the development of a low carbon energy industry

1) Establishing and publishing planning for low carbon energy development

The State Council has published the Decision on Speeding up the Cultivation and Development of Strategic Emerging Industries. Planning should be promulgated as early as possible, making clear goals at all stages, main principles, key tasks and policy measures.

2) Accelerating innovation

China’s low carbon energy research forces are dispersed and lack specialization and interdisciplinary integration. It is therefore important to establish open national low carbon energy research institutions. These will not only have general scientific research conditions and facilities – they will have capacity all the way from basic research to applied R&D, piloting and for testing and certification. The institute or institutes should be open to enterprises, universities and other research institutions and their function is to engage in basic and genetic technology R&D, test, experiment and

certification to address inefficient supply of generic technologies in low carbon energy industry.

To improve relevant policies and encourage independent innovation, the following measures should be adopted. First, existing effective technology policies should be fully implemented. The Adjustment and Revitalization Plan of Equipment Manufacturing Industry should be implemented as soon as possible. Investment guarantees could be provided for early products developed independently in China or insurance companies could be encouraged to provide cover in this area.

3) Standards, certification and inspection system

Design and certification standards are needed for wind/solar power equipment, in line with China's natural environment, resources condition and industrial basis. Construction of inspection and certification capacity will need to introduced at the same time. A unified wind power and solar power certification systems and compulsory product certification would help provide clarity to producers and consumers – this should be achieved as soon as possible, with participation from the government, power grid companies and power generation equipment manufacturers amongst others. The standards should refer to international standards and encourage equipment manufacturers to development friendly power grid technology and ensure power grid safety, but they should also give consideration to the current situation of the industry and allow time for domestic manufactures to adjust and capacity to be put in place.

4) Power grid and coordination of low carbon energy power supply planning

Accelerated construction of power transmission channels and network routes of low carbon energy projects is required. In particular, the focus should be on access lines for existing low carbon energy projects where there are connection difficulties, especially for wind power. Smart and interactive power distribution networks can be brought in for major cities such as Beijing and Shanghai. Low carbon energy storage and demand management can help to stabilize power grid fluctuation.

Coordination between low carbon energy power supply planning and power grid planning needs to be improved. After the separation of power generation and grid companies, the Discordance between plant and network is serious, and particularly apparent in the field of low carbon energy. To solve this problem, the first priority is to define the planning body. National departments in charge of energy are responsible for low carbon energy development planning and power network development planning.

The planning of grid companies and local governments should be synchronised with national overall planning. The second priority is to improve planning science. An important mechanism to improve scientific quality is multi-party participation by power source enterprises, power network enterprises and government planning departments.

5. Pricing mechanisms, management systems and the establishment of institutional environment suitable for large-scale development of low carbon energy

In order to meet the demand for large-scale low carbon energy development, the electricity price mechanism must be further improved. For large-scale low carbon energy projects with good resource conditions, the best way forward is to continue the

implementation of proprietary right bids and provide a reference for the government to set and adjust benchmark electricity price. For projects with distributed use and poor resource conditions on the other hand, low carbon energy benchmark feed-in tariffs can be implemented by regions to encourage enterprise investment and regulate pricing. In addition, the level of renewable energy resources must be considered, and the cost increase caused by low carbon energy development shared across the country.

Low carbon energy technology innovation and industry involves several departments, such as National Energy Administration, Ministry of Science and Technology, Ministry of Industry and Information Technology, National Development and Reform Commission, Ministry of Finance, Ministry of Environmental Protection, Ministry of Housing and Urban-Rural Development and National Standards Commission. In order to strengthen coordination among departments and management inefficiencies, China must strengthen the organization of and coordination among government departments and define the roles and responsibilities of each department.

6) Mandatory measures and economic incentives in the power sector

Low carbon energy development is insufficiently linked to power network enterprises, and there is a lack of incentive polices for power network enterprises to invest in low carbon. A renewable energy quota system for power network enterprises is therefore proposed, with a mandatory provision that the electricity purchased by power network enterprises must come from renewable energy. At the same time, it is necessary to adjust for the level of available renewable energy resources, address the cost increase caused by low carbon energy development and ensure that the profitability of power network enterprises is not narrowed unreasonably.

5.3 Energy efficient and electric vehicles

5.3.1 The international trend of efficient automobiles

1) Electrification and diversification

A major technological revolution is now underway in the global automobile industry. Electric vehicles have significant advantages over the internal combustion engine (ICE) and fuel cell vehicles, after taking into account multiple factors, such as comprehensive assessment of product functions, contribution to environmental protection and energy conservation and energy supply.

Japan leads in the field of Hybrid Electric Vehicles (HEV) and Japanese companies are focusing on the development of HEV before turning to pure electric cars. The Japanese government has formulated the development plan—The Next Generation of Automobiles, intending to increase the number of alternative energy vehicles to 13.5 million by 2020. To reach this target, at least 17 models of electric vehicles and 38 models of HEV should be developed by 2020.

With substantial and increasing strength in ICE technology, European companies are gradually making preparations for the future development of electric cars, while continuing to maintain their predominance in the ICE sector. In October 2009, the European Union released *European roadmap—Electrification of Road Transport*, giving more support to electric vehicles and plug-in hybrid electric vehicles. In August, 2009, the German government adopted its *National Development Plan for Electric Mobility (NEPE)*, pushing forward at the same time the development of

electric vehicles and PHEV, and planning to produce 1 million electric vehicles and PHEVs by 2020.

The US government sees the development of PHEV is as a first step towards mass use of alternative vehicles. It plans to devote 2.4 billion dollars to R&D and industrialization of PHEV and its key parts, aiming to have 1 million vehicles put in use by 2015.

2) Stimulated by relevant policies, electric vehicles are going through accelerated development.

As noted above, the United States, Europe and Japan have all increased policy support for alternative energy vehicles, including a major push forward on electric cars. The US has provided tax incentives for PHEVs, reducing tax by USD 2,500 to USD 15,000. Japan, from April 2009, began to give tax preference to electric automobiles and HEVs with a total annual tax reduction of around 210 billion yen. In April 2009, the UK adopted a new tax policy on the car industry, exempting electric vehicles from excise duty. Financial support such as credit aid has also been given to automobile manufacturers to accelerate the industrialization of electric vehicles.

Furthermore, the US's new regulations on improving automobile fuel economy and the EU's rules on average carbon dioxide emission of new vehicles all have posed strict restrictions on vehicle's oil consumption and carbon dioxide emissions for 2016 and 2020 respectively. If the manufacturers do not make use of electric vehicle technology, they may struggle meet these or future regulatory requirements.

Major US auto-makers including General Motors and Ford, and European giants such as BMW and Volkswagen, have followed in the steps of Japanese companies by increasing investment in the commercialisation of electric vehicles. Nissan Motors plans to put electric vehicles into the market on a large scale between 2012 and 2013. Mitsubishi, Renault, Toyota BMW and other auto-makers have also developed light electric cars, proposed to enter the market around 2012.

5.3.2 China's improvement in R&D and industrialization of low carbon energy powered vehicles

1) R&D over the last two FYPs has positioned China's electric vehicle companies for emerging global markets

The electric vehicle industry in China has developed strong foundations for commercialisation. With the support of two major energy conservation and low carbon energy powered automobile projects under the 10th and 11th FYPs, hundreds of domestic car manufacturers and related stakeholders – motor or battery producers and other parts makers, universities and research institutions – have acquired core electric vehicle technology, established a technological platform with independent intellectual property rights, formed a supportive R&D mechanism, and piloted the operation of small-scale whole-vehicle manufacture and commercialization in some regions. To date, over 160 models of electric vehicles have been listed in the China Auto Products Bulletin, around 30 state-level technological innovation platforms, such as state laboratories, have been instituted, and 42 electric vehicle-related standards have been formulated.

2) The electric vehicle industry is entering a stage of mass deployment

The first electric cars equipped with efficient, high-capacity lithium ion batteries were made in China. Chinese firms are building vehicles at advanced international levels in

terms of range, noise and cost. These firms have started to develop independent R&D and supportive industrial production capabilities of key technologies instead of replying on imports. Leading Chinese models currently require around 16.5 kWh per hundred km to run and have a top speed of over 120km/h, covering 180 km after one single charge. China's independent R&D of HEVs has been focused on key technologies such as idling, start-stop, speeding up, boosting, and brake energy recovery.

3) Chinese batteries are approaching the international advanced level

Chinese firms have independently developed a series of 6-100 ampere-hour nickel-hydrogen and lithium ion powered batteries for vehicles, making rapid improvements in power and energy density. The power density of lithium ion powered batteries has increased to 2500 watt per kilogram in 2008, up from 491 watt per kilogram in 2002, a four-fold increase. The battery module can be recharged around 1000 times before performance deteriorates.

Investments by Chinese battery enterprises have grown substantially in recent years. The larger battery manufacturers are growing rapidly and they now have the capacity to design and construct basic production facilities. China's annual production capacity of nickel-hydrogen and lithium ion batteries for vehicles were expected to exceed 360 MWh and 4 GWh respectively by the end of 2010. Assuming every electric vehicle was equipped with a 30 kWh battery (A-rated car with an endurance mileage of 200 km), over 150,000 electric vehicles were produced in 2010.

4) The infrastructure for electric vehicles has undergone initial development and fledgling networks have been formed in some cities

Domestic energy supply infrastructure for electric vehicles has been developed to meet the requirements for the experimental application of electric vehicles, with the completion of 98 charging stations of various kinds, 325 charging posts, 2 large-sized charging stations for electric buses, 62 charging tower for super capacitor bus lines, 3 hydrogen generation & refuelling stations and 3 moving hydrogen refuelling stations.

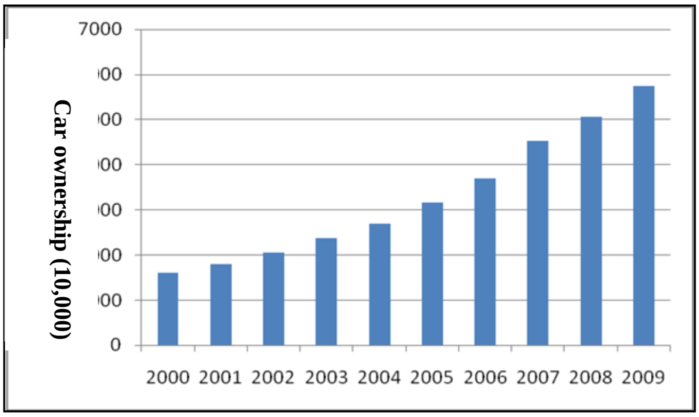
The city of Beijing increased investment in recharging infrastructure to meet a target of 1,050 electric buses by the 2010 Olympic Games. The city of Shanghai had also introduced 1,000 alternative energy powered buses by 2010, and the city also has one rapid-recharge station, 147 charging posts, 62 charging towers for super capacitor bus lines and 2 hydrogen refuelling stations inside the World Expo Park. The Shenzhen municipality has selected 19 bus stations for the implementation of charging facilities, with 5 of them already completed and in operation. Also, the city of Wuhan has built about 30 electric vehicle charging stations, forming an electric bus charging network.

With the implementation of the 2009 program 'Thousands of Low Carbon Energy Powered Vehicles in Ten Cities', the potential opportunities for electricity companies has been given much attention. The National Grid Company, China Southern Power Grid, Potevio Company and other energy enterprises have taken part in the construction of electric charging infrastructure around the state's development strategies of low carbon energy powered vehicles.

5.3.3 The transformation to low carbon makes new demands on the development of china's energy-conserving and low carbon energy powered vehicles

In recent years, as living standards improve and the national economy develops rapidly, the number of vehicles owned by Chinese citizens continues to rise rapidly. In 2000, the total number of private automobiles stood at 16.09 million and by 2009 the figure had reached 57.42 million; a threefold increase over eight years, with an annual growth rate of 15.2%, as shown by Figure 5-4. In the decades to come, the number of private automobiles will continue to grow at a very high rate. The total number of vehicles is forecast to reach 153.36 million in 2020 and 240.5 million by 2030.

Figure 5-4: Automobile ownership (from 2000 to 2009)



The rapid increase of automobiles poses great challenges to China's energy conservation and emission reduction goals. In terms of energy consumption, the percentage of China's automobile fuel consumption on the overall oil consumption continues to rise, having reached 29.3% in 2008 up from 25.1% in 2005.[105] Based on current fuel economy levels, and assuming that the automobile growth and average annual mileage pattern trends continue, China's automobile oil consumption will reach 333 Mt by 2020, and over 500 Mt by 2030.

A tonne of conventional petroleum (as opposed to oil from tar sands etc.) currently produces about 3 tonnes of CO_2. If this remains the same, China's vehicle emissions by 2020 will be four times those of 2005. At 10% a year, this is a similar growth rate to GDP. Given that the 40-45% carbon intensity target for 2020 (compared to 2005) requires an improvement across the economy in terms of energy per unit GDP, it is clear that energy conservation and emission reduction in the use of automobiles must be implemented as quickly as possible.

5.3.4 The contribution of energy-saving and alternative energy automobiles to energy conservation and emission reduction

Policy makers need to consider three categories of energy and emissions saving vehicles. First, conventional ICE vehicles can deliver savings through high-efficiency in engines, car design optimization and light-weight materials. Second, hybrid technologies can further improve efficiency when combined with ICE technology. The final option is the pure electric vehicle, or plug in hybrid electric vehicles (PHEV) which use oil to extend their range. The following is a forecast of the role

these kinds of cars will play in energy conservation and emission reduction in 2020 and 2030.

1) Contribution of efficient ICEs

Conventional cars remain the mainstream of the automobile market but their oil economy will continue to improve. Hybrids will become increasingly popular, but turnover of vehicles happens every few years, so the impact by 2020 may still be limited. It is therefore projected that ICE vehicles will be 88% of automobiles on the road by 2020. Their fuel efficiency will have increases by over 30% by this time (as compared with that of 2005, the same hereafter).

Compared to a scenario in which vehicle performance does not improve, ICE vehicles will therefore reduce fuel consumption by about 25% (88% * 30% = 26.4%).

By 2030, the market share of ICE vehicles will drop to around 55% but these remaining ICE vehicles will be 40% more efficient than today. Overall, this will reduce vehicle energy use by around 20% compared to a scenario where ICE vehicle technology had not improved (55% * 40% = 22%).

2) Contribution of HEVs

By 2020, HEVs are likely to make up 9% of vehicles on the road. Compared with today's ICE vehicles these will reduce consumption by 40% in 2020, saving about 4% of overall automobile fuel consumption (9% * 40% = 3.6%).

By 2030, HEVs will gain in popularity, accounting for 35% of automobiles. Innovation will mean that they reach perhaps a 50% reduction in fuel consumption compared with today’s ICE vehicles – thus avoiding 17.5% of automobile fuel use (35% * 50% = 17.5%).

3) Contribution of electric vehicles and PHEVs

Compared to HEVs, electric vehicles and PHEVs is not mature technology. By 2020 they will account for only 3% of vehicles. Electric vehicles are powered entirely by electricity, making their oil-saving ratio 100% (if oil is not used for power generation). PHEVs can also rely entirely on electric power for a short distance inside urban areas, but are powered by combustion while running outside the city or on expressways. On average around 90% of oil will be saved by EVs and PHEVs in the year 2020 – a 3% reduction in automobile fuel consumption (3% * 90% = 2.7%).

CO_2 emissions from electric vehicles largely depend on the electricity generation mix and efficiency. By 2020, if coal-fired power has a 70% share and some plant are using IGCC technology, estimated life-cycle CO_2 emissions brought by the consumption of electricity of electric vehicles will be around 50% of the CO_2 emissions compared to today’s ICEs. Therefore the life-cycle emission savings due to EVs and PHEVs will be around 1% (3% * 90% * 50% = 1.35%).

By 2030, with the further development and maturing of battery, motor and electric control technologies, EVs and PHEVs will account for 10% of automobiles on the road. Oil-saving will approach 100% as technology advance reduces the need for range extension using fossil fuels. These vehicles will therefore reduce fuel use by about 10% in total by 2030 (10% * 100% = 10%) compared to today’s ICE technology. If coal fired electricity account for 60% of the electric power by this time, all plant have adopted IGCC technology and some have adopted CCS, the life-cycle emission reductions due to EVs and PHEVs will be around 7% (10% * 100% * 70%

= 7%).

4) The sum of various vehicles' contribution to energy conservation and emission reduction

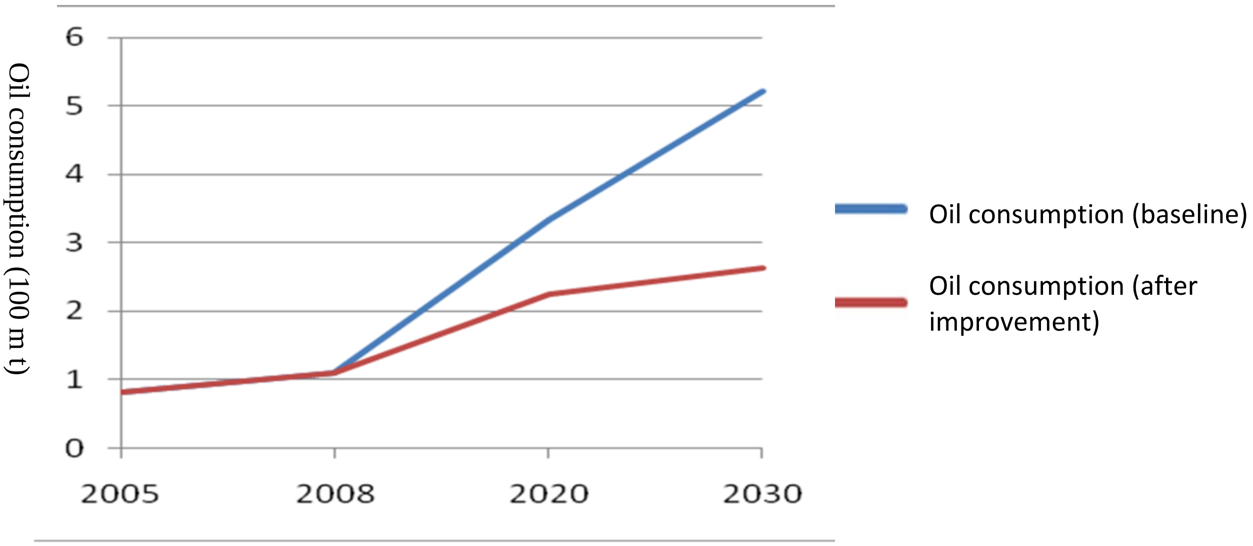
The projected numbers in the previous section are summarized in Table 5-6:

Table 5-6: Emission reduction prediction of energy-conserving and low carbon energy powered automobiles

		2020	2030
Vehicle ownership	Number of vehicles (10,000)	15360	24050
	Conventional vehicles	88%	55%
	HEVs	9%	35%
	Electric vehicles	3%	10%
Fuel savings by category compared with today's ICEs	Efficient ICE vehicles	30%	40%
	HEVs	40%	50%
	Electric vehicles	90%	100%
Sum contribution to oil-saving	Efficient ICE vehicles	26.4%	22%
	HEVs	3.6%	17.5%
	Electric vehicles	2.7%	10%
Sum contribution to emission reduction	Efficient ICE vehicles	25%	20%
	HEVs	3.6%	17.5%
	Electric vehicles	1.35%	7%

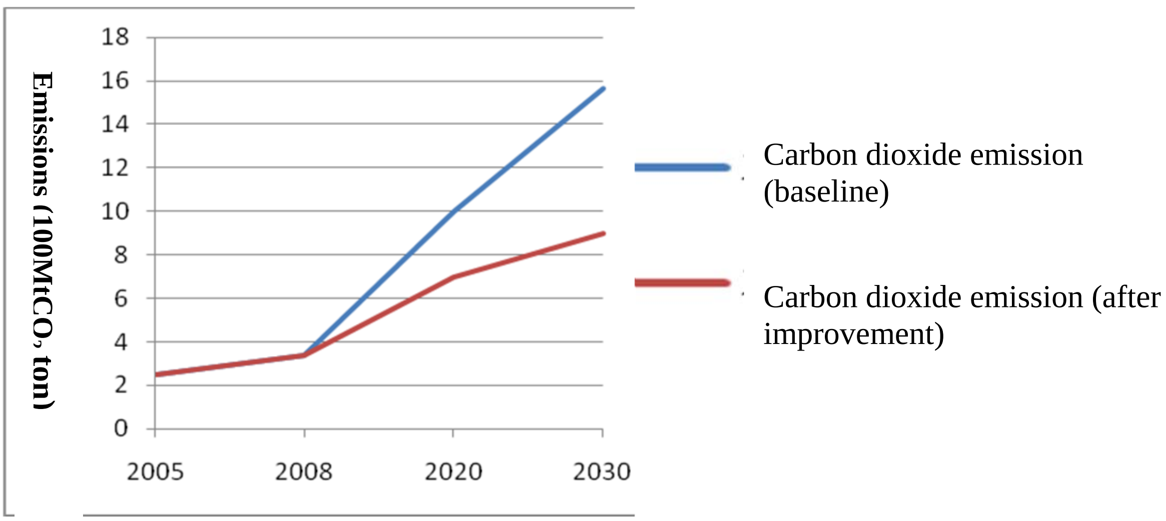
In total, innovation across the three vehicle types could therefore reach around 33%, with emissions reductions of 30% in 2020, compared with 2005. In 2030, fuel savings will reach 49.5% with CO_2 reductions of 44.5%. This is equivalent to around 109 Mt and 300 Mt of oil respectively, as compared with the baseline. By 2030, oil consumption will have decreased by 256 Mt, and emissions by 666 $MtCO_2$. Figure 5-5 and Figure 5-6 show the contribution to energy conservation and emission reduction by the development of oil-saving technology for conventional automobiles and the popularity of low carbon energy-powered vehicles.

Figure 5-5: Energy-conserving and low carbon energy powered automobiles' contribution to oil-saving



Source: LCIS Task Force analysis

Figure 5-6: Energy-conserving and low carbon energy powered automobiles' contribution to carbon dioxide emission reduction



In the short term, the advancement in oil-saving technology for ICE vehicles will make a large contribution. In the long term, however, it will be harder to find improvements in conventional vehicles and HEVs. In contrast, electric cars will emerge over time and become popular as technology develops and matures. Figure 5-7 presents in detail the different contributions of the three categories of vehicles to oil-saving and emission reduction.

Figure 5-7: Contributions to oil-saving by three kinds of vehicles

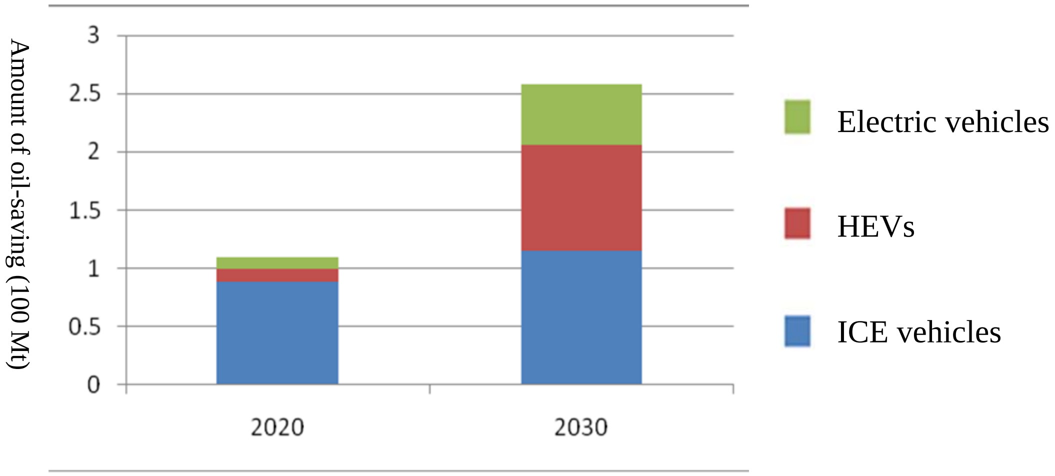
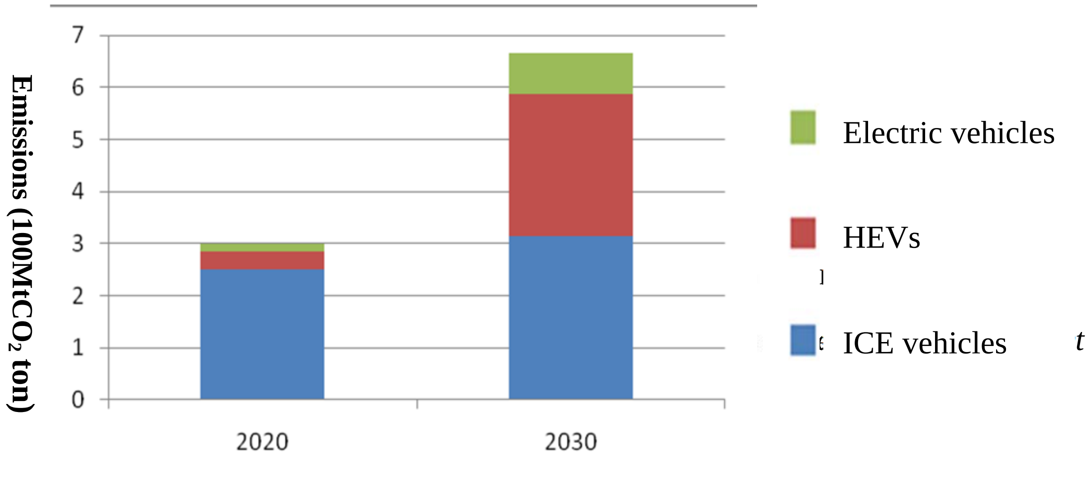


Figure 5-8: Contributions to emission reduction by three kinds of vehicle



To be consistent with the low carbon economy objective, the Chinese automobile industry will need to deliver on efficient ICEs and electric vehicles.

At present, the oil economy of China's passenger vehicles is about 8 liters per hundred kilometer, 1 litre higher than Europe's average level in 2006, and 2 litres higher than Japan's current level. This means that achieving today's international best practice levels alone can bring about over 20% of oil-saving and emission reduction – and much more innovation is to come.

In the long term, electric vehicles should become the major focus for the development of the automobile industry. However, the demand on technology of electric vehicles is also the highest – they are more difficult to promote than HEVs as they lack the conditions for large-scale diffusion in the short term. As a result, at least for the next 20-30 years, HEVs will remain an important transition technology for the auto industry's progress towards low carbon.

In addition, China's primary energy structure must be improved. CO_2 savings from electric vehicles depend on rapid progress in decarbonizing the power sector and making it more efficient.

5.3.6 Policies and measures for the development of low carbon automobiles

1) A roadmap for China's development in low carbon energy automobiles

China should make electric vehicles the major strategic direction for the transition of its auto industry.

This means focusing on breakthroughs in powered batteries, motors, and electric control technology, and promoting the industrialization of electric vehicles and PHEVs. HEVs valuable transition technology – they should be promoted in the near future and promoted on a large scale, so that vehicle oil economy can be improved.

2) Speeding up industrial development plans for low carbon energy-powered automobiles

The government should speed up the formulation of industrial development plans for low carbon automobiles, and make clear the aim, industrial plan and policy measures.

To promote the orderly development of the industry, China must not only guide the local and social investment actively, making full use of enterprises, but also refrain from rushing headlong into action which might cause low-level investment and duplication of infrastructure.

Instead, the industrialization of low carbon energy-powered vehicles should follow a step-by-step strategy, taking into account the degree of technological advancement across different stages as well as the market demand. Periodical objectives should also be set out concerning the main functions of powered batteries and cost cutting. Furthermore, the construction plan of charging stations should be integrated organically with urban planning and the electricity grid plan.

3) Setting up a special program for the technology and industrialization of low carbon vehicles

The biggest challenge for the development of the industry is forming domestic innovative capability. The government should organize the implementation of a major state-level project plan specially designed for electric vehicles technology and industrialization. This should integrate short-term and long-term R&D on core technologies, take into consideration both products and projects, and speed up the formation of innovative systems and innovative mechanisms for the industrialization of electric vehicles.

China should also establish special funds for the development of the low carbon automobile industry. It should mainly support R&D into core technologies of batteries, motors and electric control; begin basic and scoping studies of the new generation of battery material; and realize the autonomy of equipment manufacturing, particularly batteries, diaphragms and cathode materials. Furthermore, Chinese firms must make technological advances in whole-set electric or control techniques, advanced internal combustion engines, high-efficiency gearboxes, light-weight materials and other generic technologies, and make breakthroughs in difficult areas of industrialization technology.

4) Establishing policy mechanism that combines incentives with constraint

The initial development of the low carbon energy powered automobile industry cannot move forward without the encouragement and support of national policies. The relevant government agencies should examine the formulation of new support policies

for the development of low carbon energy-powered vehicles in the areas of industry, finance, tax and investment.

The following issues should be considered: the implementation of average oil economy policies for companies and time/date based restrictive measures for corporate vehicles with high oil consumption and high emissions; alteration of taxation methods based on emission volume and weight – to be replaced with tax incentives based on oil consumption; and differential licensing for electric vehicles and conventional cars and policy incentives based on the use of different licenses.

In addition, the government should encourage the service sector to participate in the building and operation of charging facilities for electric vehicles, offering interest discounts for the building and procurement of charging stations and facilities. It is important to encourage innovation and experiments with various types of charging patterns and business models (such as changing batteries) and the local governments must set up model areas for the application of electric cars. China must, meanwhile, study the formulation of pricing policies for electricity that can motivate, guide and encourage electric vehicle users to make use of electricity at off-peak periods.

5.4 ICT

ICT is a powerful engine for social development in the 21st century. With the emergence of a new generation of ICT industry and increasing constraints posed by resource and environmental challenges, ICT not only has the potential to act as an important driving force behind China's economic development, but also as a crucial means to push forward the development of a low-carbon economy and address environmental issues.

5.4.1 The crucial role ICT plays in pushing forward the development of low-carbon economy

1) The information and communications industry consumes a huge amount of energy. Through the upgrading of technology, it can lower its carbon emissions.

In the past, pollution from the ICT industry has been widely ignored. However, both the manufacturing and use of ICT products consume huge amounts of electric power and release a substantial amount of CO_2. In 2007, the IT research and consulting company, Gartner has confirmed that the CO_2 emissions from ICT account for 2% of total emissions – a figure that equals that of the airline industry. PCs, servers and outside electronic parts are amongst the largest consumers, accounting for huge CO_2 emissions within their production and supply chains. In 2008, the Climate Group, on behalf of the Global e-Sustainability Initiative (GeSI), and McKinsey & Company released the 'SMART 2020: Enabling the Low Carbon Economy in the Information Age'. This report had similar findings, predicting that the ICT industry's emissions would increase from 500 $MtCO_2$ in 2002 to 1.4 $GtCO_2$ by 2020.

In 2007, ICT production and use were responsible for emissions of 190 $MtCO_2$ in China, 2.5%[106] of total national emissions. In 2010, there were 64 mobile phones per 100 people, a rapid increase from 41 in 2007. It is predicted that by 2020, 70% of China's population will own PC, compared with 10% in 2007. If current trends of energy efficiency remain unchanged, by 2020 the ICT industry's emissions are predicted to reach 415 $MtCO_2$, accounting for 4% of total emissions. If televisions and other home appliances are taken into consideration, emissions from China's ICT

industry will account for 5%[107] of the global ICT industry by 2020. As a result, China cannot afford to ignore this issue. Technological upgrading should be promoted and CO_2 emissions reduced in the production and application process of products.

2) Improved ICT technologies can greatly improve the energy efficiency of the traditional industries

The 'SMART 2020' report released by the Climate Group in 2008 estimated that the application of ICT in other industries could improve energy efficiency and emissions reductions by up to five times. By 2020, ICT could reduce global CO_2 emissions by 7.8 $GtCO_2$, equivalent to 15% of the total amount under 2020's business-as-usual scenario. From an economic perspective, energy efficiency in ICT could save up to €600 billion (USD 946.5 billion).

A range of research has been undertaken on the role of the ICT industry in reducing CO_2 emissions. The International Data Corp (IDC) suggested that the application of improved ICT could potentially reduce emissions by 1.4 $GtCO_2$ by 2020. Through this saving alone, China could achieve its target of a 40% reduction in emissions. In addition, the World Wildlife Fund and the China Mobile Communications Corporation co-released a study in 2010 estimating that, in conjunction with proper policy, ICT could reduce China's emissions by 615 $MtCO_2$ by 2020 and Xie Mengzhe et al (2010) stated that by 2020 this figure could reach 1.4 Gt.

Table 5-7 - Analysis of ICT's worldwide potential in energy efficiency and emissions reductions

Research institutions	Energy conservation and emission reduction potential	Energy conservation and emission reduction ratio	Major opportunity areas
GESI/Climate Group (2008) SMART 2020: Enabling the Low Carbon Economy in the Information Age		5:1 (carbon emissions)	Smart grid Smart building Smart logistics Smart motor engine Dematerialization (including tele-office)
European Commission (2008) IC technologies' influence on energy efficiency	By 2020, IC technologies can save 32% of Europe's planned energy consumption.	7:1 (energy consumption) 3:1 (carbon emission)	Construction energy consumption (control of heating, ventilation, air-conditioning)

Ecofys/（WWF）(2008) First global IT strategy of carbon dioxide reduction：reduce carbon dioxide emission by over 1 Gt through transformation	From 1 Gt to 8 Gt carbon dioxide equivalent (high, middle and low three scenarios)		In-car IC technologies (smart transportation) E-commerce and dematerialization Smart building IC technologies Application on industrial energy conservation Through smart plan to realize transformation of transportation means
IDC	Emissions reduction target of 5.8 $GtCO_2$ by 2020 proposed by member state of G20, equivalent to 25% or above of the total emission of these countries		Building (energy management, tele-office) Electric power (smart grid) Transportation (smart logistics, green travel, navigation, energy-conserving vehicles) Industry (dematerialization, smart motor engine)
US National Commission on Energy Policy (2009) semi-conductor technology： the hope for innovation for the productive force of American energy	Through the intensive application of semi-conductor technology, the target energy consumption can be expected to be lower by 27% by 2030.	1:10 (energy consumption)	Electricity supply and management E-commerce and telecommunication Smart motor engine LED and smart illumination system Transmitter and controller The application of alternative energy Smart grid

3) ICT technology can enable China to to develop a low-carbon economy, achieve industrial transformation and position itself for global markets

After the global financial crisis, the world's major countries have declared development of low carbon energy and a new generation of information technology important strategic measures to revive their economies and positions in the global marketplace. By 2015, the global green IT service market is predicted to reach USD 5 billion.

China's new generation of ICT occupies a relatively competitive position globally. Chinese firms can capitalise upon this opportunity by investing in its growth and development, making use of China's huge market demand and talent base.

5.4.2 Carbon emissions reductions potential of ICT technologies

1) Smart logistics

The transport industry is a large emitter of greenhouse gases, accounting for 14% of the global total – a large percentage of which comes from transportation and storage.

ICT can help optimize logistics, reducing transport emissions by up to 16% and storage emissions by up to 27% worldwide. This could help to reduce global emissions by 1.52 $GtCO_2$ by 2020, equivalent to savings of €280 billion (USD 441.7 billion).

Within the EU, targets have been set to maintain CO_2 emissions of new cars below 120g/km, a 25% decrease from current levels. Within this figure, technical measures could account for reductions of up to 110g/km; the remaining 10g could be achieved through the application of ICT and materials. This would include, for example, of a smart and innovative transport system, including smart engine management, smart vehicle safety system, smart real-time transportation management, driver information systems and an integrated logistics system.

The World Wildlife Fund and China Mobile concluded that with improved ICT services and collaboration between operating enterprises, the public and the government in China's highway logistics industry, the empty load rate could drop from 30% to 15%, with emission reduction opportunities of up to 128 $MtCO_2$ by 2020 and up to 207 $MtCO_2$ by 2030.

2) Smart Building

On a global scale, the construction industry ranks second to the manufacturing industry in terms of energy consumption. However, new smart building technologies are expected to reduce emissions by 1.68 $GtCO_2$ by 2020, equivalent to about USD 340.8 billion. A North American study indicates that if ICTs were applied in improving building design, construction and management, a potential 15% reduction in greenhouse gas emissions could be achieved.

The annual electricity consumption of China's buildings is 4000-5000 kWh, between 22% and 24% of the total electricity generation, and its electricity consumption per floor area is 26-27 kWh/m2. This is 2-3 times that of the developed countries. Countries in the west have been at the forefront of developing new technologies for smart buildings and, therefore, have a significant advantage; the market for smart construction products is also monopolized by foreign enterprises. Consequently, emphasis in China is currently placed on improving R&D using advanced ICT for smart buildings, with independent intellectual property rights. These technologies include network technologies, such as realty management technologies based on broadband and multi-network integration technologies, IC technologies, such as video conferencing, and smart technologies, such as NexWatch and Parking Control.

3) Smart Grid

The smart grid concept combines a modern, highly integrated grid, in-depth advanced measuring and sensor technology, ICT and control technology. The grid would be characterized by safety, reliability, economy, high-efficiency, high environmental standards, protection and self-healing. By making the grid smarter, emissions could be reduced by 2.03 $GtCO_2$ by 2020, equivalent to USD 124.6 billion.

The smart grid has major strategic importance for China's development of a low-carbon economy. Recent research shows that if China could fully reform the traditional grid by 2020, energy consumption could be reduced by 220 Mtce, equivalent to 500 $MtCO_2$, with significant reductions in other pollutants (see Table 5-8).

Table 5-8: The energy reduction & emission reduction efficiency of the development of smart grid in China (2020, unit: trillion ton)

Specific links	*Energy*	*Carbon dioxide*	*Sulfur dioxide*	*NO_X*	*TSP*
Line loss reduction	210	445	5	2	4
Fuel consumption for electricity generation reduction	6100	12932	134	61	104
Electricity consumption reduction	12000	25440	264	120	204
Low carbon energy and renewable energy	4000	8480	88	40	68
Electric vehicles	--	2100	--	--	--
Aggregate	22310	49397	491	223	379

China's smart grid remains in the exploration and pilot phase and its future development will rely on leapfrogging to advanced ICT technologies. These technologies requiring R&D in key areas, including: communications and sensor technologies, accurate parameters measurement technologies, automatic control technologies and decision support technologies.

4) Smart motor engine

According to research by the Climate Group, if China begins to make full use of ICT to improve vehicles and improve the energy efficiency of industrial equipment, then by 2020 reductions in emissions could amount to 970 $MtCO_2$, saving USD 107.2 billion.

5) Smart Work

Advanced communications tools, such as the internet, can help spread rush hour traffic, bring flexibility to workplaces and reduce the need for business travel. Globally, if 5% of commuters could shift to tele-working and 15% of business travel could be replaced by e-conferencing, 100 $MtCO_2$ of emissions could be avoided by 2020.

Based on statistics released from the WWF and China Mobile, China's emissions reductions through tele-work could be up to 298 Mt and 340 Mt of CO_2 in 2010 and 2020, respectively; and through an increase in e-conferences, up to 12 Mt and 123 Mt of CO_2 reductions could be achieved in 2010 and 2020, respectively.

5.4.3 Challenges for the application of ICT to promote a low-carbon economy

In September, 2010, the Decisions on Speeding up the Nurturing and Development of Strategic New Industries by the State Council, marked the new generation of ICT as a strategic new industry in China. By applying ICT in traditional energy-intensive industries, energy efficiency can be improved and emissions reduced. However, this will lead to increased demand on the ICT industry; China must, therefore, first address current problems within ICT.

1) The R&D and manufacturing capability of sensor equipment and smart control equipment is relatively weak

Smart equipment, such as sensors and routers play a key role in optimising industrial processes (environmental performance, but also quality and cost) and managing supply chains efficiently. Other key technologies enable the tracking and monitoring of products in what is sometimes called the 'internet of things'. These include Radio Frequency Identification (RFID) chips, which are used to identify, track objects and record other information, infrared sensors, laser scanners and GPS. At present, China is relatively weak in R&D and manufacturing in this area. More investment is needed in skills and research to further push forward the R&D and production of the new generation of ICT facilities.

2) Improvements to internet-related technology

China should leapfrog to the next generation of internet technologies and protocols (for example, rapidly incorporating IPv6), support the development and application of core technology and software and speed up the development of new high-speed broadband networks.

3) Consistent standards and planning

For sensors, routers and other smart control equipment to achieve automatic management and control functions in the various traditional production sectors, a consistent data format must be adopted to ensure the compatibility of different facilities. Thus, to push forward the application of ICT in traditional industries, China should actively develop the unification of internet standards, the data interface standard, and a systemic solution plan.

5.4.4 Policy measures to utilise ICT in the low-carbon economy

1) Clarify the strategic position and increase policy support

ICT should be viewed as having a critical role in the transition to an energy-efficient and environmentally-friendly society. With this in mind, more resources are needed for innovation, preferential finance and other support to the industry.

2) Insist on independent innovation and reinforce the technological R&D

The ICT sector has a huge opportunity to develop a competitive advantage in the international industry and technology sectors, but domestic innovation capacity will need to be rapidly enhanced.

3) Launch the model application and improve the assessment mechanism

To push forward R&D and commercialisation of green technologies and products, government departments should identify key issues, carry out pilot programs, establish a comprehensive assessment mechanism, conduct analysis on the applicability and market demand of ICT technologies that cater to the development of low-carbon economy, and overcome developmental bottlenecks.

4) Reinforce multilateral cooperation and consolidate the formulation of international standards

The formulation of ITC standards in telecommunications, products and technical requirements will affect the ability of ITC technologies to contribute to low carbon industrialisation. China should strengthen governmental guidance, fully utilize trade associations and industrial alliances, motivate enterprises to actively formulate and

perfect the technical standards system, conduct research into the products green manufacture standards system, gradually improve industrial standards and influence the formulation of international standards.

5) Developing the ITC skills base

China must improve its further education system and retraining schemes, in order to talents with a specialized knowledge background and techniques. Through close cooperation with institutions of higher learning, such as program cooperation, technology R&D and consultancy services, China could make full use of incubators inside scientific parks and universities, driving production with learning and research and pushing forward the construction and development of ICT.

6) Open up international cooperation and explore new cooperation patterns

China should facilitate wide-range cooperation between governments, international corporations and high-tech enterprises of advanced countries, make use of the enormous potential for the development of China's low-carbon economy, and speed up the application and transformation of advanced international technologies. This should enable reductions in time and capital costs for the development of China's green ICT industry, improve technological and management levels, and improve the overall strength of China's green ICT industry.

5.5 Bio-industry

5.5.1 The basis of and prospects for the development of China's bio-industry

1) A relatively good basis for development

China is a leader amongst developing countries in life sciences and biotechnology. Its industrial capabilities in biotechnology have improved substantially, the bio-medicine and bio-agricultural sectors have reached a certain scale and numerous new bio-products and industries are developing rapidly. In addition, China is rich in bio-resources and talents engaged with biotechnology research, both from abroad and Chinese.

2) A broad prospect of the market

Based on conservative projections, by 2020 China's biomedical market is expected to reach 4 trillion RMB, its bio-manufacturing to reach 1 trillion RMB, bio-agriculture - 500 billion RMB, bio-energy- 3000 billion RMB and bio-environmental-protection - 100 billion RMB. Overall, the market scale of the bio-industry will be about 6 trillion RMB.

3) In a period of strategic opportunities

Compared to other sectors the global bio-industry is relatively open to new entrants. China's bio-industry, in particular, has the smallest gap in terms of technology, talents and scientific research base, plus rich bio-resources, making it the most promising area to realize leapfrog development.

5.5.2 The potential contribution of the bio-industry to low-carbon industrialisation

The 'bio-economy' concept is a green, low-carbon and sustainable model of economic development. The production and consumption of raw materials for bio-manufacturing act to both reuse and store CO_2 and the system is cyclical, recycling the majority of its products.

In a bio-refining technological system is a new manufacturing model that uses renewable plant-based materials as the feedstock for a range of energy and industrial products. Sugar, fat, organic waste and even industrial exhaust gases and CO_2 can serve as raw materials to produce chemical products similar to those produced by oil-refining, including basic chemical material Plant-based plastics, fibres and rubber products are gradually entering into the market. It is estimated that 90% of traditional oil chemical products can theoretically be made by bio-refining – and according to a 2009 strategic report by China's Administrative Program, by 2030, 35% of chemicals and other industrial products will be produced from bio-manufacturing processes.

Due to the use of renewable resources, the life cycle of bio-manufactured products greatly reduces CO_2 emissions. WWF estimate that by 2030, industrial bio-manufacturing technology could avoid 1-2 $GtCO_2$ per year globally.

Bio-manufacturing, therefore, has the potential to address the shortfalls of oil chemical manufacturing, achieve long-term sustainable production, simplify the production process, reduce energy and material consumption and decrease environmental pollution.

For China, the active development of bio-manufacturing, increasing the percentage of green, low-carbon and renewable bio-chemical production and reorganizing the petro-chemical industry makes great strategic sense for both sustainable development and low carbon industrialisation.

5.5.3 Problems need to be solved urgently to accelerate development of the bio-industry

1) Weak independent innovation capability

The US, Europe and Japan account for 59%, 19% and 17% of global biotechnology patents respectively. In contrast, developing countries, including China, account for only 5%. Among the 380 genetic project medicine and vaccine products of 25 types from 13 classes approved to enter the market in China, only 21 products of 9 types from 6 classes are novel – the rest are copies.

2) Industrial organization

Bio-enterprises are generally small scale in China and the industry's low concentration and disorderly competition have led to low profitability and weak accumulation capabilities. As a result, currently profits and development are hard to achieve.

3) Lack of funds

Today, any of the largest global pharmaceuticals will typically invest more in bio-medicine each year than China's annual R&D budget in this area. Furthermore, China lacks a domestic risk investment mechanism for start-up enterprises, making it hard to acquire financial support during the initial and industrialization phases of new enterprises.

4) Poor commercialisation of scientific results

Due to a disconnect between technological innovation and the wider economy, and the weak link between pilots, expansion and integration, less than 15% of biotechnology innovations are successfully commercialised in China; and under 5% in the western districts.

5) The market environment needs to be standardized

Procurement and bidding processes for medicines are not standardized; product and technical standards for bio-energy, bio-agriculture and bio-based materials are not consistent; and the technological products market is not mature.

6) Inappropriate systems and mechanisms

Reforms in institutions and systems in China are lagging behind and are currently unable to satisfy the requirements of large-scale industrialization. The key areas are: scientific research and innovation; medicine and health care; investment and financing; product evaluation; pricing; market access; government procurement and enterprise assessment.

In addition, some issues, such as the loss of biological resources and the encroachment of alien species, pose great hidden dangers to bio-safety.

5.5.4 The strategic aim and main thoughts on accelerating the development of bio-industry

1) Strategic aim

By 2025, the global bio-industry will be relatively mature. These products and approaches will be widely used in the industrial sector. China's bio-technology innovation will be close to developed countries. Chinese firms will hold IPR in key technologies and will produce major bio-technology products capable of satisfying the basic needs of the public

The bio-industry should aim to be one of the important pillar industries of the national economy. With the emergence of an array of international bio-enterprises with cutting-edge innovative capability, the export sector of bio-industry can capture a large share of the global market, and China can establish a position as a global bio-industry giant, bio-technology leader and pioneer in the bio-economy.

2) Key issues for biotechnology

i). Increased attention from the state to developing the bio-industry

It is imperative that China speeds up the formulation of 'State Plans for Medium and Long-term Development of Bio-industry (2010-2030)' and 'Plans for Medium and Long-term Development of Bio-economy', marking the industry as a key pillar in China's development strategy.

ii). Innovation and deployment of an array of key and cutting-edge bio-industry technologies

Well-developed programs with good market prospects, such as those in bio-agriculture and bio-medicine, should be urgently selected and supported to accelerate industrialization and stimulate innovation in key technologies, techniques and products. The application of technologies that are already industrialised should be

expanded. Demands from society and other sectors for bio-industry must be evaluated and an array of cutting-edge bio-technologies developed and implemented.

iii). Improvements in the independent innovation capability of the bio-industry

The government can support strong bio-enterprises by establishing high-level R&D institutions; the creation or reform of state engineering laboratories and research centres; and improving the engineering and systemic integration capabilities of scientific research. China should also push forward industrial capacity building, such as state-level bio-technology public laboratories, pilot bases, financing platforms and talent cultivation platforms. A high-end generic technology platform should be formed with strong enterprises at its core, supporting higher educational institutions and science research centres, and pushing forward the building of a bio-industrial technological innovation alliance.

It is important that the links between industry and education are strengthened, and an effective implementation mechanism led by enterprises, higher education institutions and scientific research institutions be established, in order to achieve cooperation in applying bio-technological findings.

iv). Induce relevant elements to converge on bio-industrial bases and forge an efficient bio-industry chain

To speed up the development of bio-industrial regional clusters, China should select districts with a good existing industrial base, strong innovation capability, a track record of commercialisation and openness to building several state-level bio-industrial bases with unique styles based on the principles of overall planning – bringing into full play comparative advantages, differentiated guidance and steady improvement.

Bio-enterprises and the relevant bodies in central and local government should be encouraged to cooperate, facilitate a rational division of labour and effective integration, optimize their industrial chains, reduce their operational costs and improve their response capabilities.

v). Foster and develop a series of strong bio-enterprises

Following principles of "government guidance, market mechanisms and leading enterprises integration", growth in leading enterprises should be supported, encourage mergers or acquisitions of R&D institutions with core technologies domestically and worldwide, and nurture domestic bio-enterprises leaders that have relatively stronger innovation capability and international competitiveness.

China can also support the development of several high-tech medium and small bio-manufacturing enterprises with special technical features and flexible mechanisms. China should assist the big bio-distribution enterprises, encouraging them to actively explore the global market, and support the service outsourcing enterprises to integrate with the global R&D chain of the bio-industry.

5.5.5 Policy measures to advance the bio-industry's development

1. Strengthen leadership and group coordination

Leading industrial groups should be set up to coordinate and adjust the developmental targets and policies of the bio-industry, increase the synergy among different sectors and make use of good policies and administrative resources to develop the bio-industry.

2. Integrate government resources and strengthen support efforts

China should integrate the Government Technology Plan Fund, Scientific Research Basic Condition Building and other funds, increase financial input and set up the State Bio-industry Development Fund.

Subsidies could be granted to bio-products facing high costs in the initial stage of industrialization – but where future cost reductions are anticipated – or those that cannot achieve full marketization, and relevant preferential policies must be studied and formulated by combining the reform direction of state taxation. Bio-enterprises registered inside China should benefit from preferential policies on corporate income tax. Currently, young bio-enterprises in their first two years of acquiring profits, can enjoy a preferential policy on income tax.

3) Improve the financing environment and widen financing channels

The establishment and development of bio-technology start-ups and investment institutions, and an industrial investment fund should be encouraged. Bio-enterprises raising capital through the capital market should be supported. Adopting the principles of "independent appointment, independent standard and independent assessment" in the domestic venture exchange, China should increase the percentage of direct financing, make full use of state policy banks, support enterprises borrowing money from banks using patent technologies as a warranty, and give full support to bio-enterprises with independent patent technologies and promising market prospects.

Specific financial products and a Bio-industry Investment Fund should be established by the government. A risk investment and state-level technology-based SMEs innovation fund is also encouraged, with particular focus on SMEs developing biotechnologies and industrializing research findings in China.

5.6 Advanced materials

'New materials' refers to recent and emerging materials with superior performance and special functions that traditional materials do not possess, or traditional materials with improved functions due to new technologies, techniques and equipment.

They can be divided into metal; non-organic non-metal; organic; and composite new materials, according to physical and chemical attributes. In terms of function they can be divided into advanced technology; high-efficiency structure; and structural performance (strength, flexibility etc.); and integration of materials. according to function; and electric information, space and aeronautic, low carbon energy, energy efficient, environmental and bio-medical new materials, according to their application area.

5.6.1 The new materials industry has a broad market prospect

China's economic and social development has rapidly increased demand for low-cost, efficient, smart, light weight, and environmentally-friendly new materials. With the upgrading and reform of traditional industries, the rapid development of new high-tech industry, and raised living standards, China is currently in an important stage of accelerated industrialization and urbanization, stimulating rapid development of the new materials industry and enormous demand potential.

China's new materials industry grew to about 600 billion RMB in 2008; broken down, new chemical materials account for 110 billion RMB; non-organic non-metal materials account for 70 billion RMB; black metal new materials account for 120

billion RMB; and non-ferrous and precious metals, and rare earth new materials account for 230 billion RMB. During the 12th FYP and in the future, the new materials industry will witness accelerated development, with an average increase rate of over 20%. By 2020, the output value of the new material industry is expected to exceed 5 trillion RMB.

5.6.2 The influence of the new materials industry on low-carbon industrialization

The importance of the new material industry's influences on low-carbon industrialization can be divided into the following aspects:

1. New material can assist and support the strategic new industries, pushing forward low-carbon industrialization.

The new materials industry is a critical supplier and enabler of the other emerging industries: energy-efficient & environmentally-friendly industry, low carbon energy, low carbon vehicles, high-end equipment manufacturing and bio-industry are all dependent on progress in materials science.

The development of solar power, for example, is tied the development of polycrystalline silicon industry, a key primary material used in solar panels. The high-end equipment manufacturing relies on advanced structural materials, such as high-quality special steel, new alloy material and engineering plastic. A range of improvements to carbon fibre, aramid fibre, UHMW polyethylene fibre, other high performance fibres and compound materials, and research on general basic material, can be undertaken through the development of superconductivity and smart materials.

2. Closer integration between the new materials industry and traditional industry

Light weight and strong new structural materials, including high-performance compound fibres and light metals, such as aluminium, magnesium, titanium and their alloys, have great advantages in terms of energy conservation and emissions reductions in aerospace, automobiles, communications, transport, marine, construction and other industries.

4. **Reconstruction of new material can improve the efficiency and recuce emissions from building materials**

By 2020, the newly increased housing will add nearly 30 billion m^2 of floor space. If the scale and level of energy consumption in construction remain unaltered, by 2020, the annual energy consumption is predicted to be equivalent to 1.2 trillion kWh of electricity and 410 mtce, almost three times that of the current level.

Huge energy inefficiencies – over 70% - result from heat loss from the outer protective structure, with 50% lost through windows and 28% through the outer wall. Building materials determine to a large extent the energy efficiency of buildings; new building materials, with their high-performance, multi-function and smart features, are, therefore, crucial for improvements in this area.

5.6.3 The main challenges faced by the new materials industry

1) Divisions between manufacture, study and research makes it hard to utilize scientific findings.

Chinese firms and universities have been very active in R&D related to new materials in recent years. New materials projects and research have won many annual National Technology Awards and, at present, Chinese theses on new materials technology are ranked among the top worldwide. China still lags behind many developed countries in the commercialisation of new technology.

This is partly the result of investment in higher education and scientific research institutions being focussed primarily on the R&D of new materials, rather than their industrialisation. However, it is also due to enterprises – some restricted by inappropriate infrastructure or insufficient funds, some inexperienced with no long-term development plans – depending on well-established technologies, with a lack of enthusiasm for cooperation with universities to industrialise their products. As a result, many scientific findings stagnate at the laboratory stage, rarely achieving commercialisation.

2) The market is dominated by state-owned enterprises and government agencies, making it risky and costly for the private sector to invest.

R&D in the new materials industry has been dominated by the government. Due to support requirements for state-owned capital in the government's development plans, policy incentives rarely benefit private companies engaged in the R&D and industrialization of new materials. This increases investment risk for the private sector, reduces their reform and innovation activities and, as a result, hampers the readjustment patterns of different industries. Improvements to investment and financing policy mechanisms and equal treatment of all funding sources are, therefore, key factors for the rapid expansion and development of the new materials industry.

3) The technological level is low and the industrial chain is weak

China's new materials industry has made few technological advances even as it has grown in revenue. In 2005, for example, output increased exponentially with no improvements in efficiency.

4) The industry is highly dependent upon foreign markets.

The new materials market has not been developed sufficiently and demand is not strong. However, because domestic enterprises do not have strong processing capabilities, shortages of middle to high range new materials exist and China still has a huge domestic import substitute demand. For example, in the production of polycrystalline silicon used in solar panels, China had to import the raw materials from abroad and then export the products, playing the role of processor and relying on foreign markets at each end of the supply chain.

5) Policy support is weak and a long-term developmental plan is needed.

Although the state has continuously supported the new materials industry, the independence of every policy-based plan and their lack of cohesion as a whole, has greatly undermined their successful implementation. Additionally, participating parties do not communicate and exchange ideas on the problems occurred in policy

implementation, casting a negative influence over the industrial layout and effective configuration of resources.

Policies have either been introduced without sufficient lead-time, as information cannot be communicated quickly and smoothly, making it difficult to reach the higher-level government; or the industry's development has been affected by the government's lack of long-term plans, with no clear picture of the inherent issues facing the industry.

6) The accreditation system and industrial standards are not well-established.

The management of China's material industry is in the hands of many different parties and the management mechanism is relatively disorderly. Many industry standards have been created by different government agencies instead of industrial associations in accordance with international standards, and the similarity of enterprises and their need for global market integration have not been fully considered. Furthermore, the management role of the government has been weakened by the departmentalization of power and lack of policy mechanisms, leading to ineffectual communication and cooperation between enterprises, schools and R&D institutions. This has led to disjointedness between R&D and the market, causing further difficulties for the formulation of industrial standards.

5.6.4 General ideas and development of the new material industry

China's continued economic and social development should be supported by a major strategy pushing forward structural adjustment and upgrading traditional industries, focusing on improvements to independent innovation in the new materials industry, and breakthroughs in high-performance new materials.

China should push forward the development and commercialization of the new materials industry with good market prospects, strong leading power, a good development base and domestically-generated IPR. Integrated development between the new materials industry and the traditional raw materials industry should also be promoted, in order to substantially improve the industry's competitiveness in international markets.

2) Developmental target

In the 12^{th} FYP and beyond, China must establish a new materials industry with strong innovation capability and an appropriate scale; build several, self-sustained industrial bases for new materials with prominent advantages; and foster a series of pioneering, competitive enterprises.

5.6.5 Policy measures to speed up the development of the new materials industry

1) Development strategies for the new materials industry

The state should set clear development strategies for the new materials industry. Based on past plans and incorporating a global perspective, China should implement a national development strategy, giving full consideration to the development, supply and use of new materials. Appropriate long-term plans for the development of the new materials industry should be set, core technologies and equipment to address the industry's development bottleneck be proposed, and policies to solve the core issues in managing industrial standards be implemented.

2) Integration of innovation in research to improve the commercialization rate of scientific findings

New materials are innovation and knowledge intensive products, with rapid renewal development and intense international competition. China should improve integration between research innovation and industrialization; focus on absorbing and introducing advanced technologies; conduct independent innovation; and gradually realize the integration between R&D, production and application. To achieve improved performance, multi-functionality and cost-reduction, primary research is needed to guide the process of R&D and manufacturing.

3) Reform government management of industrial innovation and maintain a sustained innovation capability

Currently, as governments promote the development of new materials, attention is paid primarily to increasing GDP and relevant tax incomes from private, placing industrial innovation as a lower priority. China is able to attract foreign investment, but is unable to implement and sustain a regional innovation system supporting national development.

To achieve effective regional innovation, therefore, China cannot rely on the accumulation of advanced elements from different regions, but must develop systemic, effective coordination and efficient operations with regional characteristics. As a result, the responsibility of regional governments is to create regional features and strengthen the exchange, communications and networking of innovation identities. Governmental innovation should be readjusted to maintain and sufficiently support sustainable industrial innovation.

4) Increase support for private investment

China's government should also support the private investment and R&D that has developed over the last decades through policies and market-based regulation consistent with principles of scale efficiency and competition.

6 A POLICY FRAMEWORK FOR LOW-CARBON INDUSTRIALIZATION

Low carbon industrialization is at the core of developing a low-carbon economy, and also a main approach to promote the transformation of China's mode of economic development.

China can advance low carbon industrialization in multiple policy areas, including developing development program of low-carbon Industrialization, improving pricing systems for energy and principle resources, constructing fiscal and taxation policy systems in promoting low-carbon economy, improving market mechanism and technological innovation.

The framework, set out below, will help deliver China's development goals while recognising its industrial characteristics and drawing on international experience.

6.1 Components of the policy framework

6.1.1 Logic behind the policy framework for promoting low-carbon Industrialization

(1) Formulate relevant policies according to the 2 major approaches - technology improvement and restructuring. This can improve energy efficiency, enhance the comprehensive resource utilization rate, strengthen technological R&D, promote industrial restructuring and upgrading, increase products' added value and optimize the energy supply structure.

(2) In order to develop a suitable policy framework for low-carbon industrialization, unfavourable policies should be disregarded whilst supportive policies should be consolidated and improved. These changes should be conducted according to new requirements and new policies should be developed.

(3) Different policies have different spheres of influence and may interact with one another. It is, therefore, necessary to appropriately select means of policy, coordinate different policies and foster synergy to avoid contradiction and conflict that weakens policy effect.

(4) As a tool kit of multiple policies, the policy framework should coordinate all policies. Firstly, the government and market mechanism should work together. This requires the government to formulate relevant laws and economic policies and, additionally, to value, promote and guide the market mechanism. Secondly, incentives and binding measures should work together to better realize accommodation of the two.

6.1.2 Policy options for promoting low-carbon Industrialization

In order to address difficulties in the low-carbon transition, poor technology levels and innovation, unsound market mechanisms and defects in policies related to price, finance, taxation, laws, regulations and standards, key policies are:

1. Policies related to laws and systems, including formulating development plans for low-carbon industrialization and improving systems of laws, regulations and standards.

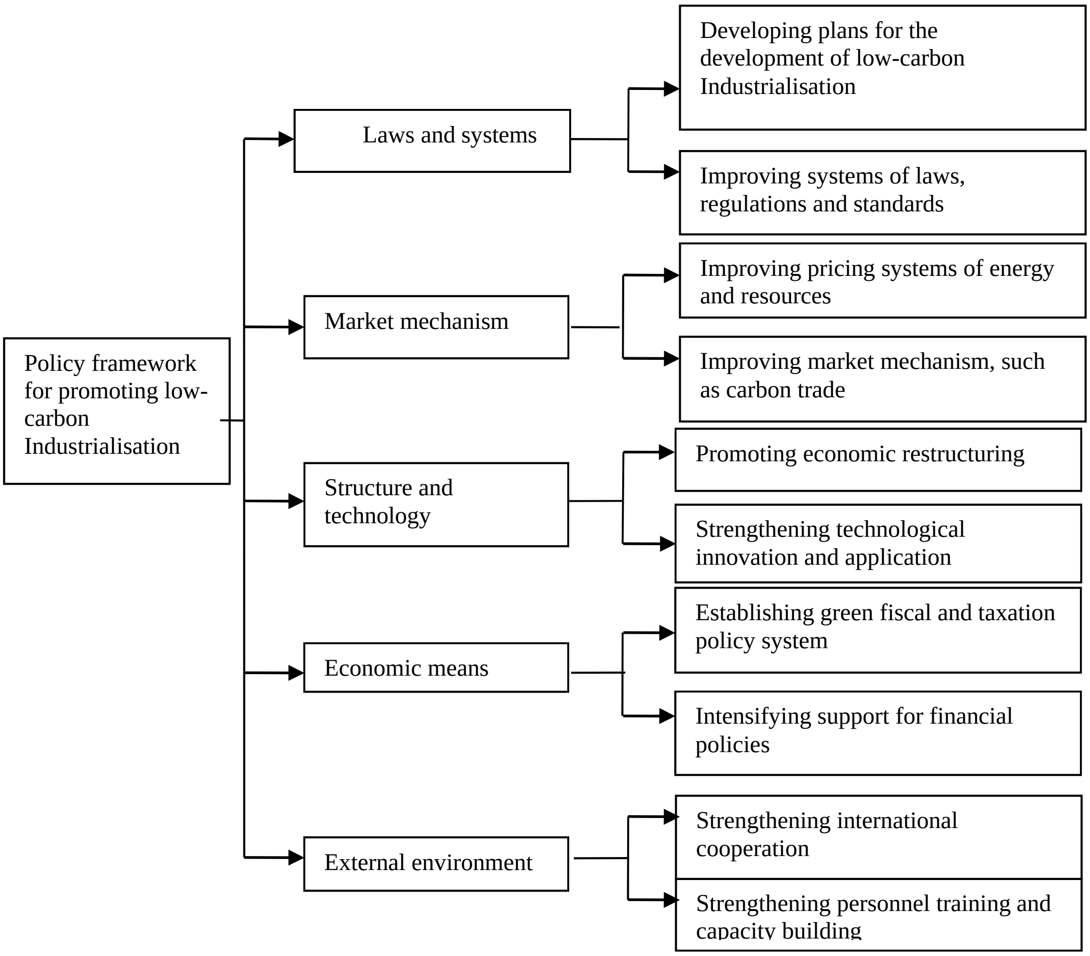
2. Policies related to market mechanisms, including improving pricing systems of energy and principle resources, and market mechanisms, such as carbon trade.

3. Policies related to restructuring and technological innovation, including promoting economic restructuring and strengthening technological innovation and application.

4. Economic Policies, including speeding up the establishment of green fiscal and taxation policy systems and intensifying support for financial policies.

5. Policies related to the external environment, including strengthening international cooperation, personnel training and capacity building.

Figure 6-1: China's policy framework for promoting low-carbon Industrialization



Source: LCIS Task Force analysis

6.2 Policies for promoting low-carbon industrialization

6.2.1 Planning the development of low-carbon industrialization

By setting out development plans, low-carbon industrialization can be identified as a main approach to promote the transformation of the mode of economic development and grounding in a broader context.

1. The form of the low-carbon industrialization development plan (LCIDP).

The LCIDP could be incorporated within existing policy documents (the national socioeconomic development plan or the plan for the development of low-carbon economy). Alternatively it could be established as a new, dedicated development plan. Through the FYP planning process, phased development targets, key areas and required policies for low-carbon industrialization could be identified.

2. The targets for the development of low-carbon industrialization.

China's existing binding carbon intensity target specifies a reduction in CO_2 per unit of GDP of 40-45% by 2020 compared to 2005. Emission reduction targets for secondary industry and certain energy-intensive sectors could be introduced as part of

the delivery of this overall target. In addition, requirements for industrial restructuring and technological innovation should be identified.

3. Main approaches, key areas and policy guarantee for the development of low-carbon industrialization.

Safeguarding mechanisms, such as relevant economic policies, should be formulated to ensure the smooth implementation of the LCIDP.

4. Relationship between the Low-Carbon Industrialization Development Plan and other plans.

The LCIDP should be aligned and coordinate with plans such as the 12th FYP, The Energy Plan, The Plan of Technological Innovation and the Plan for Emerging Strategic Industries in order to shape an operable policy.

6.2.2 Economic restructuring

A genuine low-carbon economy cannot be built unless the mode of economic development is transformed. Optimizing industrial structures through eliminating outdated production capacity, developing a modern service industry and emerging strategic industries will promote the development of low-carbon industrialization.

1. Eliminating outdated production capacity

i) Efforts should be made to continue to implement the fiscal incentives and appropriate exit and compensation mechanisms for the elimination of outdated production capacity. Differentiated regional fiscal support policies should be adopted in consideration of the uneven economic development and financial strengths of different regions. For underdeveloped regions, the central finance should further scale-up the special funds and transfer payments to incentivize the elimination of outdated production capacity. For regions where conditions permit, supporting funds could be arranged according to local situations, in order to increase support.

ii) Efforts should be made to integrate economic, legal, environmental and all other necessary administrative tools and make full use of the current policies, such as fiscal subsidies, favourable taxation and land development transfers. In addition, asset compensation, personnel placement and other issues related to the elimination of outdated production capacity should be addressed and support should be given to all regions to conduct the relevant work.

2. Developing emerging strategic industries

i) Set up a special fund for the development of emerging and strategic industries. The central finance authority should integrate the current special funds for industrial development, industrial R&D, research-into-use, electronic development, integrate circuit R&D and others. In addition, it should set up a fund for the development of strategic and emerging industries. Funding priority should be given to infrastructure inside emerging industries, key projects, R&D, public service platforms and innovating capacity. Local financial authorities should also set up industrial development funds targeted at local priorities.

ii) The government could provide funds for start-ups and equity investment through stock participation. China should set up a pilot government fund for investment in start-ups and emerging industries, guide and lead private investment into young and innovative enterprises. China should improve and implement relevant policies, and guide and encourage the private sector to make investment in emerging strategic

industries. Efforts should be made to establish and improve supporting policy and supervision systems, and create optimum conditions for insurance companies, social security funds, corporate annuity administrative institutions and other investors to participate in funds for start-ups and equity investment.

iii) Improve tax incentive policies both for technological investment and research-into-use, and in reference to tax reform and categories. These policies should take into account difficulties in commercialization at the early stage of product development, from the perspective of motivating innovation, guiding consumption and encouraging the development of new types of business. The government should design and improve the transfer tax, income tax and other supporting policies according to each specific industry's needs, mobilizing private resources.

iv) Improve financial policies. Financial institutions should intensify support for the emerging strategic industries; develop relevant services and financial products; establish suitable credit management and loan variety systems; advance innovations in financial products, such as intellectual property collateral financing and industrial chain financing; and develop new types of financial services. Through establishing a multi-tier guarantee system encompassing fiscal funding and private funding, China should make use of government discount loans, risk compensations and other favourable policies to promote financial institutions to intensify support for the development of emerging strategic industries. The capital market can be encouraged to support the financing of emerging strategic industries, including via the Growth Enterprise Market system. In addition, the development of the over-the-counter market should be encouraged and the needs of start-ups at different stages of development should be recognised. The bond market should be developed to expand financing channels for enterprises in emerging strategic industries.

3. Developing a modern service industry

i) A special fund for the development of a modern service industry should be set up to provide subsidies and loan discounts for key projects, including those in finance, modern logistics, high-tech services and business services and promote to the integration of advanced manufacturing industries. Fiscal subsidies, government discount loans and incentive policies should be used flexibly to guide private investment into technological and information services, and to better exercise the leveraging effect of public finance.

ii) Efforts should be made to implement the favourable policies released by the government related to the business tax and income tax in the service industry. Given the fact that the service industry was incorporated into the expanded incidence of VAT taxation, efforts should be made to appropriately identify the tax burdens and improve the systems.

iii) The modern service sectors that are within the scope of government procurement, such as information systems and energy-saving service, could directly use this approach to support their development.

iv) Other policies include expanding financing channels for enterprises in the service industry and supporting eligible enterprises to list and issue bonds. Key service sectors should be able to enjoy the same prices of electricity, water, gas and heat as secondary industry. Efforts should be made to expand land supply to the service industry and land returned by manufacturing enterprises should be used for the development of service industry on a preferential basis.

6.2.3 Innovation and application of low-carbon technology

1. Propelling breakthroughs of low-carbon technology

China will need to deploy both basic and frontier technological research in order to become competitive in low carbon technology. For example, breakthroughs can be achieved in fields such as carbon capture & sequestration (CCS); alternative technologies; minimization, recycling, reclamation and energy utilization technologies; bio-technology; and the new material, green consumption and ecological restoration technologies.

2. Public R&D institutes and experimental platforms

China should accelerate the construction of research platforms for basic, frontier and generic technologies to strengthen the capability of original and integrative innovations. Public R&D institutes and experimental platforms hold a very important position in the supporting system of technology innovation, especially for the research and development of structural and generic technologies, industrial and national research programs.

In the energy field, it is suggested that a national low carbon energy research institute is set up, possessing both general research facilities and facilities to conduct pilot plant tests. This would enable it to be qualified for the whole research process, from basic research to technological development, experimental demonstration, detection and authentication. The institute should be open to enterprises, universities and other research institutes. It would aim to solve the problem of insufficient supply capacity of generic technologies in low carbon energy industry via its R&D activities, piloting, testing and authentication. At the same time, support should also be given to the construction of an enterprise technology centre, a technology development platform and a technology innovation service platform for enterprises.

3. A technology innovation system centred on the private sector

The private sector must be at the core of China’s technology innovation system – the system should integrate industries, universities and research institutes. This could be further boosted by more technological resource support from the government, as this would attract and guide more capital input and innovation from a variety of sources. China should encourage large enterprises to increase R&D input and stimulate innovation in small and medium-sized enterprises in order to allocate them increased responsibility. Furthermore, China should develop new models for scientific research organizations by funding and a Strategic Innovation Association comprised of enterprises, research institutes and universities, which allow entrepreneurs and leading scientific talents to play a key role in technology innovation.

4. Industrialization of low carbon technology innovation

The “Adjusting and Revitalizing Plan for Equipment Manufacturing Industry” should be put into practice, a risk compensation mechanism for using the first domestic equipment should be established, and insurance companies should be encouraged to target important domestic technical equipment. Fiscal measures, such as interest subsidies, assurance and premium, should be maintained and preferential tax policies should be put into practice to encourage technology innovation. Support for low carbon experimental demonstration, for example consumption of new low carbon products, should be improved, as well as the pilot and demonstration of CCS through fiscal and taxation policies.

6.2.4 Improving the pricing system of energy and major resources

The energy pricing system should be reformed so that prices reflect market supply and demand, resource shortages and environment damage. This will promote structural adjustment, resource conservation and environmental protection.

The following reforms should be undertaken: market pricing in competitive energy fields and supervision of natural monopolistic sectors according to clear regulations; ensuring that the external cost and resource consumption of energy along the supply chain are fully reflected in energy prices. Energy subsidies should be gradually removed – instead, vulnerable groups can be supported instead through the fiscal system and other measures. In the meantime, 'invisible subsidies' should be made transparent.

Detailed policies for different energy resources:

(1). Coal: A resource tax should be introduced to internalize the external environmental and social costs of coal production and use, moderately increasing the price.

(2). Power: electricity price reform should continue, towards the goal of market-set tariffs. Direct electricity trade between large consumers should be enabled, and a bid-based tariff pilot should be carried out. A ladder-type electricity pricing policy should adopted for residential electricity consumption. An independent transmission and distribution pricing mechanism should also be formed. This will gradually reduce cross-subsidization and create conditions suitable for the implementation of bilateral power trade. The additional costs of renewable energy deployment should be spread across the system, improving the cost-sharing mechanism.

(3). Oil and Gas: price reforms for refined oil products should continue and the government should optimize the oil and gas price mechanism – this should be linked to the international market to increase price flexibility.

(4). Urban heat supply: China should encourage and support energy-efficient combined cooling-heat-power (CCHP) projects, popularize individual heat/cooling metering systems, advance heat charge reform and provide appropriate subsidies for their purchase. In addition, heat charge subsidy reform should be enforced as soon as possible, in order to convert "invisible subsidies" to "open subsidies". The pricing policy should reflect the principle of "higher consumption, higher bills" – China can gradually establish an effective heat supply pricing mechanism.

6.2.5 Optimizing relevant market mechanisms

In addition carbon taxes, China can also make full use of market mechanisms, international carbon credits and improved energy management to reduce costs and maximise the benefits of emissions reduction.

1. Establishing a carbon emissions trading system

A carbon trading system should be established, aimed at controlling greenhouse gases and domestic carbon emissions. This should be focussed towards entry into the international carbon emissions market.

i) The system should be developed on a step-by–step basis, and in a planned and orderly way. At the same time, this project must be combined with China's carbon emission reduction per unit GDP 2020 goal and the wider goal of low carbon development; A relative measure, such as carbon intensity, could be adopted instead

of an absolute measure, though for some industries, such as power and aircraft, the latter could be considered.

ii) A carbon trading platform should be established, along similar lines to existing environmental commodity exchanges and building on lessons learnt from international carbon trade systems. Carbon trading centres that are currently undergoing development without full and prior understanding of emissions trading should be more closely regulated. The approach taken should recognise China's development situation – for example, capacity building should be strengthened following pilot tests in the following areas:

a) capacity building in statistical and online monitoring systems, including emission measurement, report and inspection; b) encouraging China's financial services industry to play an important role and regulation of carbon trading, in order to create a transparent, open and fair market environment; c) training programs to familiarize relevant personnel with trade regulations and pilot testing.

iii) The carbon emissions trading system and carbon tax mechanisms should be coordinated. Europe provides a potential model: in some countries energy-intensive enterprises have a choice between emissions trading and a carbon tax if they fail to achieve their reductions goals.

2. Utilizing the Clean Development Mechanism (CDM)

China should continue to accept support from developed countries – for example in the form of carbon finance, technology cooperation and capacity building. Access to the Clean Development Mechanism and the voluntary emissions reductions market would exist in parallel to the carbon trading system described in the previous section, with due regard for additionality. The CDM should be utilised not only to achieve international funding, but also to catalyse the transfer and diffusion of energy saving and emissions reductions technologies. In China, use of the CDM will be affected both by future trends in international carbon markets and their relationship to emissions reductions goals for 2020 and beyond.

Specific measures include: a) rapid CDM development with effective measurement the emissions reductions potential; b) encouraging domestic enterprises to access the CDM; c) adjusting China's CDM price management system and the establishment of an effective coping mechanism to adapt to the new international situation;

3. Optimizing market mechanisms for energy saving and low carbon development

i) Promote the use of energy management contracts in cooperation with the energy-saving service industry.

ii) Encourage enterprises to sign a voluntary energy-saving agreement. Energy-intensive industries should set ambitious goals in order to advance energy efficiency, both in the industry as a whole and nationally.

6.2.6 Building a green finance and tax system

The key green fiscal policies proposed by the Task Force to support low carbon industrialisation are set out in Table 6-1 below:

Table 6-1: Green Fiscal Policies

Support for energy conservation	**Support for low carbon energy deployment**	**Support for low carbon technology R&D**
Establish a national 'special fund for energy conservation'	Increase the size of the 'development fund for renewable energy'	At least 5% of public R&D expenditure should be focused on basic and applied low-carbon technology
Reductions in the corporate tax rate for energy-saving and environmental-friendly projects	Wider use of concessional loans and new advice for banks on their loan policies for renewable energy	Tax benefits for enterprises to offset their R&D investments
Subsidies for high energy efficiency consumer products	Subsidies for solar power and small-scale wind power for homes	Government support for large scale industrial pilots
Enlarge the range and proportion of energy-saving products purchased by the government including energy service agreements	Reduce import tariffs and value added tax on renewable energy technology and equipment	Harmonise financial support policies of energy conservation R&D and deployment.

More detailed recommendations on greening the fiscal system are set out below:

1. Finance and tax support for energy saving

ii) Investment in energy efficiency can be increased, with support of the central government, in the following ways: incentives for technological upgrading; special funds for the elimination of outdated production capacity; public procurement and stricter buildings energy performance standards for government and the public sector; and subsidies for the promotion of energy-efficient lighting products. A Special National Fund for energy-saving should be set up to form a standardized and stable investment channel and to focus the government's financial investment in promoting social energy saving. Special Funds for energy saving should also be established at provincial or city level. These should focus on energy-intensive provinces in mid- and west-China.

ii) Improve existing financial subsidies for energy efficiency and emissions reductions on a sector-by-sector basis. This could involve new funds, incentives and subsidies to suit independent operational conditions, including investment, production and/or consumer subsidies. The implementation and supervision of these subsidies should be strengthened to enhance their operability and efficiency. Improvements in information management have enabled more accurate assessments of the energy and carbon impact of products along the supply chain – in this area, regulatory oversight should be improved, with more spot-checks and data analysis; with strict punishments for any organisations accessing subsidies without delivering on the appropriate environmental benefit.

iii) Improve and expand existing tax policies on energy saving. Reductions in corporation tax are already available for energy-saving and environmentally-friendly

projects: three years with no corporation tax and three years' with a 50% reduction. In addition, reductions in business income tax and other policies to promote energy efficiency and the circular economy could be introduced for enterprises that produce and manufacture energy-saving equipment and products. For consumers, a consumption tax could be collected on sales of energy-intensive products, such as filament lamps and household appliances, to narrow the price gap between energy-intensive and energy-efficient products and promote energy-saving products.

iv) Ensure that government procurement supports markets for low-carbon, energy-efficient products and services. Key dimensions include: enlarging the range of energy efficient products purchased; purchasing certified products; and demonstrating the benefits to the public, including cost savings. In parallel the certification of energy-saving and green products should be strengthened.

China has applied to join the WTO's Government Procurement Agreement (GPA) several times, but has so far its proposals have not been accepted. Under the GPA, countries commit to open up public procurement to competition, including from foreign firms. In order to avoid prejudice and inconsistencies in the government's purchase list, China should consider the introduction of "standardized approach" or other government purchase models.

Finally, energy-saving services should be included within the scope of government procurement as well as products and equipments, and governmental agencies should consider the energy-efficiency of service providers as part of the selection process. The Energy Conservation Law needs to be revised in this light. Government agencies could select some services and products to purchase as pilots; these actions should then be decentralised and expanded to other areas across China as soon as possible.

2. Finance and tax support for low carbon energy development

i) The development fund for renewable energy, as specified in the Law on Renewable Energy, should be implemented as soon as possible. The fund's management should be activated, investments of financial capital should be increased, its recipients specified and a better capital guarantee system should be established. This will ensure the sound and rapid growth of the renewable energy industries.

Financial subsidy policies in the renewable energy sector should be adjusted to reflect the different issues and needs for the different types of renewables - and relevant standards and conditions of the subsidies should be further specified. In addition, banks should be advised to adjust their loan policies: increasing the availability of loans, allowing preferential interest rates and expanding financing channels for renewable energy. New subsidy policies should be adopted, including for solar roofs on households and small-scale wind power.

China's inter-regional system of transfer payments and ecological compensation should be improved. This will promote the coordinated development of renewable energy, encouraging trade between provinces and regions. China should consider the overall life cycle - the industrial chain and the interest chain - design supportive policies for finance, tax and government purchases, and strengthen coordination among these policies.

Fourth, for the renewable energy sector, the value-added tax should be reduced, preferential policies on income tax should be adopted and import tariffs should be reduced.

ii) Improve financial and tax policies supporting the development of cleaner coal. China should support clean coal technology, provide guidance for market forces to invest in this sector and mobilize enterprises to master and promote clean coal technologies with a market-based orientation through subsidies, government purchases and preferential tax policies.

iii) If the ambitious expansion plans for nuclear power in China are to be achieved, the private sector will need to be encouraged to invest via a range of loan guarantees, preferential loans and other financial subsidies. Attention should be paid to tax and price policies at the different stages of the nuclear power industry, including R&D, project design, operations and maintenance, fuel processing and waste disposal. In addition, training, service industries and equipment manufacturing enterprises will need to be developed.

iv) The external costs of energy development, conversion and utilization should be fully reflected in the price of energy products. The principle of cost transparency applies to nuclear power (from the costs of nuclear accidents to decommissioning and waste management), as well as the coal industry and renewables sector.

3. Finance and tax support for innovation and application of low-carbon science and technology

i) The R&D budget for low-carbon technologies should be increased. In the national R&D fund, more than 5% should be used for R&D of the fundamental and applicable low-carbon technologies.

ii) Tax incentives for enterprises to increase their R&D and technological innovation should be provided. Tax incentive policies that can promote technological progress, such as the potential to offset taxable income with R&D expenses, should be implemented. Tax incentives should also be provided where projects are demonstrating low carbon technology cooperation with foreign firms.

iii) Encourage the expansion of low-carbon technology and energy-efficiency projects. Investment in technological transformation of the traditional industries is needed - for example, replacing oil with alternative energy resources, cogeneration, residual heat utilization and energy conservation in buildings. Particular focus should be given to technological innovation in energy-intensive industries. Government funds should be arranged to support and lead the expansion and application of energy efficiency technologies and industrial pilots; the possibility of establishing and improving a long-term investment mechanism to promote the low-carbon industrialization should be evaluated. In addition to large-sized enterprises, financial policies should support the expansion and application of various low-carbon technologies with business value among small and medium -sized enterprises based on their individual characteristics.

iv) Coordination between financial support policies for energy-efficient technology, R&D and low-carbon industrialization should be strengthened to enhance the cost-effectiveness of public investments.

4. Supporting low-carbon transportation and construction

i) Public transport in urban areas with low energy consumption and carbon emissions should be supported. Investment in public transport should be increased and an urban rail transport system and inter-city high-speed railway should be built to form a

diversified urban public transport system. This will reduce direct energy consumption and help to optimize the city functions and layout. In addition, public transport costs should be decreased though financial subsidies and car parking fees should be increased to encourage travel by bicycle, rail and bus.

ii) Financial and taxation policies and measures to encourage energy-efficiency in buildings should be supported. More subsidies should be offered for green buildings and investment in renovation of public buildings by energy service companies should be increased.

iii) Financial support policies to improve the urban energy supply should be increased. Funding should be directed to cogeneration and central heating projects and subsidies should be provided for heat supplying enterprises.

5. A carbon tax is needed to support low-carbon innovation and the large-scale deployment of low carbon technology

A carbon tax would encourage investment in low-carbon technology innovation and assist the large-scale application of technologies to reduce CO_2 emissions, helping China to fulfil its environmental responsibilities as a developing country.

Carbon taxes and emissions trading should be applied side-by-side in China. The carbon tax can achieve emissions reductions more rapidly in the short term and will provide a clear signal for investment. Taxes are more transparent and can be applied more comprehensively. For example, in the EU land-based transport is not included in the EU ETS but it is subject to energy and carbon taxes. Emissions trading will support the long-term objectives of systemic low carbon development in line with market conditions. However it will take time to perfect a fully-fledged, effective trading system that covers all sectors and is ambitious enough to realign investment incentives towards low carbon transition.

Key dimensions of the carbon tax are as follows:

i) Methodology for calculating and applying the carbon tax: Carbon tax is closely related to other energy taxes. The carbon content in fossil fuels, based on current resource tax and consumption tax, could be the foundation for tax imposition; a carbon tax could be either imposed alongside the consumption tax and environment tax, or regarded as an item of environment tax. The government should consider converting the taxes currently imposed on fossil fuels into taxes that take account of their carbon content, rather than adding new carbon taxes. This would be in line with the tax reform principle of “broadening the tax base and simplifying the tax system”.

iii). The rate of carbon tax. Carbon tax will have a great impact on some energy-intensive industries. In order to prevent the adverse impact of carbon tax on the international competitiveness of Chinese industries and the living standard of low income groups, the carbon tax should start from a low tax rate. A low rate in the short-term, such as RMB 10 per tonne of CO_2, will have a limited negative impact on the economy. This could then be raised significantly over time in line with China’s economic and social development. It is also necessary to establish a dynamic adjustment mechanism of carbon tax incidence, including forecasts of tax rate raises. These should be based on the actual development of China’s economy and society and the demand for international coordination, so that carbon taxes can play an important role in urging enterprises to reduce emissions.

The Task Force evaluated a carbon tax scenario – with a cascading tax rate adopted during the 12th FYP and the 13th FYP periods, under a 45% carbon intensity improvement in 2020 compared to 2005. The modelling identified an appropriate carbon price level to meet the carbon intensity targets. The carbon price is shown in Figure 6-2 and Table 6-2 below. If a cascade tax rate is adopted, the carbon tax level is about 75 RMB/tonne in 2015 and 135 RMB tonne in 2020.

Figure 6-2 - Carbon price level during the 12th FYP and the 13th FYP with a 45% reduction target of carbon intensity

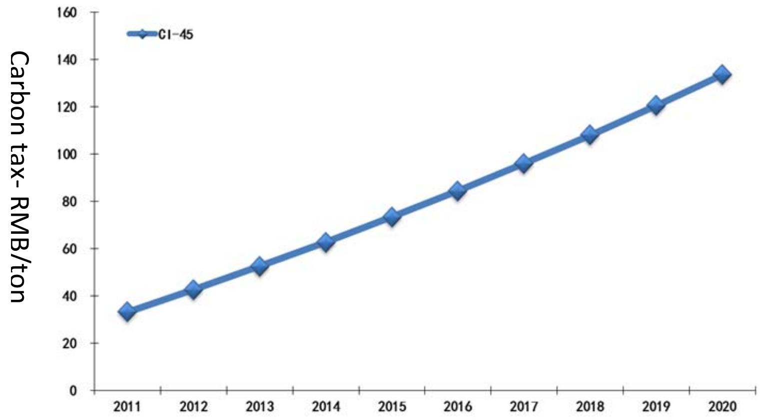


Table 6-2: Primary Design of CO_2 Tax Rate [1]

Tax rate	2012	2020
Carbon tax (RMB per tonne of CO_2)	10	40
Raw coal carbon tax (RMB per ton)	19.4	77.6
Crude oil (RMB per ton)	30.3	121.2
Gasoline carbon tax (RMB per ton)	29.5	118
Diesel carbon tax (RMB per ton)	31.3	125.2
Natural gas carbon tax (RMB per 1000 cubic meter)	22	88

Notes: 1) In the model, the carbon tax is imposed in 2012; 2) The formula for different tax rates are: RMB 1 per tonne of CO_2 = RMB 1.94 per tonne of coal= RMB 3.03 per tonne of crude oil = RMB 2.95 per tonne of crude oil = RMB 3.13 per tonne of crude oil = RMB 2.2 per 1000 meter^3 of natural gas.

Source: LCIS Task Force

iv). Carbon tax incentives. In order to prevent a negative impact on the international competitiveness of China's industries and reduce the resistance of carbon tax imposition, China should consider the possibility of designing a package of supporting policies and measures relevant to tax incentives and conducive to

industrial transformation. China could establish a tax revenue reduction and exemption and rebate mechanism in the energy intensive industries. But in return these industries would need to sign a binding energy conservation and emission reduction agreements to a certain standard with the Chinese government. Second, tax reductions and exemptions should be offered to enterprises that have reduced emissions with technologies and exceeded the standard.

vi) Utilization of carbon tax revenue. In principle, revenues from carbon taxation can be earmarked for specific low carbon or other projects or added to national budgets like other tax revenue. In either case, the carbon tax should be included in the central budget management system to ensure good financial management. The absence of earmarking does not mean that financial investment in low-carbon economic development, energy conservation and emissions reductions is weak. However, a carbon tax as a specific tax category is closely related to combating climate change and achieving low-carbon economic development. China may consider the possibility of earmarking so that part or all of the carbon tax revenue is used for sustainable development.

A summary of the key elements of carbon taxation are set out below in Table 6-3

Table 6-3: Elements of the carbon tax system

Elements of tax system	Basic regulations
Tax payer	Organizations and individuals who directly emit CO_2 to the natural environment due to consumption of fossil fuels.
The range and objective of taxation	Those CO_2 emissions discharged by fossil fuel consumption in production, operation and daily life into natural environment. In the long term, the CO_2 caused by individuals using fossil fuel in daily life should also be included in the taxation objectives; but recently, the CO_2 from family is also temporarily exempted from taxation, except for those caused by individuals using finished oil such as gasoline and diesel.
Tax calculation basis	Estimate emission amount, based on the fossil fuel consumption of tax payer. CO_2 *emission=fossil fuel consumption* × *emission factor* Fossil fuel consumption level refers to the volume of fossil fuels consumed in companies' production and operation to emit CO2, including coal, natural gas, gasoline, diesel and etc, which are calculated according to companies' account record; the emission factor is determined by the types of fossil fuel and related parameters.
Tax rate	It will be fixed rate according to the amounts. In the initial implementation of a carbon tax, it can take low tax rate as a starting level, like RMB 10 / tonne of CO2 Conversion of carbon tax rate: RMB 1 per tonne of CO2=RMB 1.94 per tonne of coal=RMB 3.03 per tonne of crude oil=RMB 2.95 per tonne of crude oil=RMB 3.13 per tonne of crude oil=RMB 2.2 per 1000 cubic meters of natural gas.
Taxation stage	The taxation will be designed to be charged in the consumption stage of fossil fuel. But according to the real situation of taxation management, in the initial implementation of a carbon tax, the tax on coal, natural gas and

	finished oil will be charged during the exploit and production of fossil fuel energies; in the future when taxation management situation permits, the tax on finished oil and natural gas could be charged in the process of whole sales and retail, and tax for coal could be charged in consumption of energy intensive enterprises.
Tax preference	**Tax incentives :** (1). In the initial implementation of carbon tax, define the what kind of industries can enjoy the preferences according to the demands of the national macroeconomic policy and economic restructuring, and offer those energy intensive industries which have large influences (some pillar industries according to China's relevant industrial policies and macro economy) certain tax exemption in a certain period (2). Offer tax exemption to those enterprise which actively use technologies to reduce and recycle CO_2 and reach certain standards.
Other elements of tax system	The regulations on tax deadline, tax payment place and other system elements（omitted）
Tax revenue attribution	It is suggested that carbon tax revenue be shared by central government and local government, with sharing proportion of 7:3.
The use of tax revenue	Take carbon tax revenue into budget management. Meanwhile, increase the fiscal investment on energy saving, environment protection and climate change debate.

6. Fiscal reform

i). Resource tax reforms have to date focused on oil and gas in the west of China, calculating tax according to price. China should increase resource tax rates according to the linkage mechanism (which considers price, tax, fees and rent); a fixed tax on key resources, such as coal, should be calculated according to quantity; and reforms should be carried out country-wide. The resource tax system must be designed to reflect the specific nature of each resource category and the demands of resource conservation and environmental protection.

ii) Levying an energy tax and increasing the cost of energy usage will guide energy consumption behaviour. A higher tax rate should be applied to high energy-consuming products like existing finished oil and large vehicles. Since the implementation of fuel tax reform, China's finished oil tax rate has already increased; now the consumption tax rate of finished oil should be increased according to other energy tax reform. In addition, the tax range should be expanded to cover resource- and energy-intensive products, which are not currently taxed and do not meet appropriate energy performance standards.

iii) Actively implement environmental taxation. China should improve the charging system and increase the collection rate for pollutant discharges. At the same time, on the basis of the existing charging system of pollutant discharges, it should levy environment tax (or pollutant discharges tax) on pollutants, such as waste gas, water and solid materials. Environmental taxation should be increased appropriately, so that environmental and social costs are reflected in the prices of energy and other products.

iv). Existing vehicle and vessel taxes will in future be charged according to emissions levels per kilometre, and taxes on sales of large passenger cars will be increased.

China should improve the motor vehicle tax policy by combining it with tax charges on other aspects of motor vehicles. Existing tax policies restricting exports of energy-intensive products should also be continued, including cancelling and lowering export tax refund rates, and levying export taxes on some energy-intensive products. To minimise effects on exports and economic development, China should widen the scope of these policies and decrease energy exports via energy carriers.

6.2.7 Increasing financial support

Putting carbon-finance development into the policy framework of national climate change and low-carbon economy development, making carbon finance a key policy tool to promote low-carbon industrialization.

1. Green credit policies and policy support for carbon emissions reductions

Preferential loans should be provided to carbon emissions reductions projects, support the low-carbon enterprises and related programs in priority, which will ease the bottleneck of resources, control environmental pollution and reduce greenhouse gas emissions. In addition, carbon-rights secured loans and provide financial support for CDM projects should be promoted; the financial services sector can actively develop credit-guaranteed financing and offer preferences in loan audit, release, repayment deadlines and interest rates; and establish special loans for the purchaser of carbon emissions quotas.

2. Low-carbon capital markets.

Support should be provided to enterprises that prioritise the development of low carbon technologies and low carbon economy so that more can be listed, for example, on the Growth Enterprise Market stock exchange in Hong Kong, including small and medium sized enterprises. In addition, proposals from qualified low carbon enterprises or projects to issue corporate bonds, company bonds, short-term financing bills and other debt financing instruments should be prioritized; active support should be given to financial institutions to issue "low-carbon bonds" in order to enhance investment in some long-term and large-sized low carbon industries; training and development of low-carbon trust funds should be developed; and private equity funds, venture capital, social capital and international aid donations encouraged to operate in this area.

3. Innovation in carbon finance products

Through cooperation with banks, insurance institutions and investment institutions, the government could accelerate the use of financial derivatives and products, including carbon trading, options and futures which support the low carbon economy. This should enrich the market, satisfy various investor requirements to hedge and avoid risks, and promote rapid growth in low carbon financing.

4. Policy support for carbon finance

The government should announce laws and regulations related to carbon finance as soon as possible, and improve the carbon trading law and supervision framework; and establish and perfect the climate change database and carbon risk evaluation criteria to create a friendly policy environment for stable development of carbon finance. In the meantime, it can provide supportive policies for financial institutions’ earnings from carbon finance business.

6.2.8 *System of laws, regulations and standards*

Improve the laws, regulations and standards related to low carbon economy and ensure that they are enforced, in order to better promote the development of low-carbon industrialization.

1. Laws and regulations promoting carbon emissions reductions

In order to encourage the development and use of low carbon energy, the government should prioritise the strengthening of legislation responding to climate change; lay down the Law on Responding to Climate Change; properly modify and perfect the existing laws related to climate change and environmental protection; and announce supporting laws and regulations as soon as possible. It should also formulate, promulgate and implement a Law on Energy, revise the Law on Coal, Law on Electric Power, Law on Energy Conservation, Law on Renewable Energy and other laws and regulations accordingly.

Supporting regulations in the Circular Economy Promotion Law to promote the development of circular economy should be drawn-up, in addition to the Agriculture Law, Forest Law, Grassland Law, Land Administration Law and other relevant laws. This will improve the productivity of agriculture and forestry and increase their carbon storage capacity. Plans to protect and expand forest, farmland and grassland, forbid cultivation of poor land and prevent destruction of wildwood, grassland and cultivated land for any reason should be implemented.

The key regulatory proposals of the Task Force are set out in Table 6-4 below:

Table 6-4: Key regulatory measures

1.	Introduce a “Top Runner” program for key industrial equipment and energy-consuming products
2.	Strengthen energy-efficiency standards for industrial equipment with high energy consumption such as draught fans, water pumps, voltage transformers, and motors.
3.	Review and potentially tighten efficiency standards for major energy-consuming products such as household appliances, lighting fixtures, office equipment, and motor vehicles
4.	Introduce energy efficiency labels and certification across a wide range of energy-saving products, based on a new standards carbon footprinting methodology
5.	Revise standards for the energy efficiency of buildings
6.	Establish standards for temperature control (heating and cooling) in buildings
7.	Assess and review energy efficiency standards for fixed asset investment projects

2. Developing standards for energy efficiency and low-carbon products

Standards to control temperature in buildings should be finalised, relevant to different climates across China; performance standards for the energy efficiency and energy consumption of major industrial equipment are needed for key technologies, such as

draught fans, water pumps, voltage transformers and electromotors, and major energy- intensive products such as household appliances, lighting fixtures, office equipment and vehicles. When revising the standards of energy efficiency or carbon emissions, China should consider adopting Japan's method of "Top Runner" - the energy efficiency or emissions of enterprises with best performance in the last term will serve as the standards of the next term.

China should also set an energy efficiency label and improve the certification of energy-saving products, expanding the scope of the Mandatory Energy Efficiency Labelling System. The system of carbon footprint labelling and low-carbon product certification should be developed, social awareness should be increased to guide the consumer behaviours and enterprises should be encouraged to speed up the development and research of low emission products.

3. Implementing energy efficiency standards

New, remodeled, and expended fixed asset investment projects should go through an emission reduction review procedure (to assess their carbon and energy reduction impact) before being examined by planners. Projects should not be approved if the procedure has not been followed. Large-scale public buildings and commercial residential buildings should be subject to strict inspection processes –if these buildings fail to reach mandatory standards they should be not be approved for use. The system of monitoring, index and evaluation of energy saving and emission reduction should be improved, strengthening assessment procedures and the system of rewards and penalties.

4. Sectoral targets for energy-intensive industries

Over the past five years, China has focused on regional targets for energy intensity and action by local government. Moving forward, some policy challenges, such as standards and technology platforms for innovation, can only be tackled effectively at national and sectoral level.

Energy-intensity targets should be introduced for seven heavy industry sectors: electricity, steel, building materials, petrochemicals, non-ferrous metals, textiles and paper and pulp. Potential energy-intensity targets are displayed in Table 6-5. These are based on detailed analysis by the Task Force, taking into account the experience of China's industry during the 11^{th} FYP period and assessments of the technical and practical potential to upgrade each sector. Extensive discussions were conducted by the Task Force, with industry bodies as well as academic experts.

Table 6-5: Selected energy intensity improvement potentials for heavy industries

	Energy intensity in 2005	Decline by 2015 (%)	Decline by 2020 (%)
Electricity Thermal efficiency of electricity generation (gce/kWh)	370	13.5	16.2
Steel			
Crude steel kgce/t	741	12.3	15.3
Petrochemicals			
Ethene kgce/t	1081	11.5	14.5
Synthesis ammonia kgce/t	1774	12	17

Caustic soda kgce/t	1351	20.9	25.7
Soda ash kgce/t	530	20.9	25.7
Calcium carbide kgce/t	2095	15.5	19.5
Building materials			
Cement kgce/t	149.2	27.3	31.3
Non-ferrous metals			
Electrolytic aluminium kWh/t	14575	6.2	15.2
Textiles			
Chemical fibres kgce/t	743	18.4	23.3
Paper-making			
Paper and paperboard kgce/t	525	25.7	31.4

6.2.9 International cooperation

International cooperation – for example, in low carbon technology and innovation, capacity building and finance – should be encouraged as a key aspect of low carbon industrialisation in China.

1. More cooperation with developed countries

China should encourage cooperation with developed countries in key areas of low carbon industrialisation. Technology cooperation at the research, piloting and deployment phases would increase scientific and technological levels and innovation capacity in China. An international platform for technology exchange and cooperation should be established to facilitate these processes.

2. New system in international cooperation

Through international cooperation on climate change, strategic policy dialogues should be improved. The focus should be on pragmatic cooperation in scientific research, R&D, piloting and capacity building.

3. Cooperation in other areas

More training is needed to increase skills levels, especially on the CDM. China can work to strengthen partnerships between a wide range of actors: developed countries, international organizations, research institutes, enterprises, NGOs, and associations. Practical cooperation activities can be promoted in academic research, experience sharing and capacity building.

6.2.10 Strengthen talent training and construction

To strengthen talent training and construction in low-carbon economy, a systematic approach is needed.

1. Talent-training in low carbon areas

Support should be provided to low-carbon research projects, new colleges and universities and talent training bases on effective mechanisms within, as well as closer cooperation among industries, universities and research institutes. Publicity and professional training of enterprises and governments in the low carbon area should be improved and talent training channels widened. Effective mechanisms for talent motivation and competition should be developed and construction and integration of

talent forces with strong independent innovation ability, outstanding professional skills and international influence should be undertaken.

2. High-level overseas talent

Skilled labour in low carbon industry should be encouraged into China from other countries, via new or improved preferential policies, incentive mechanisms and assessment systems. The flexible introduction mechanism combining talent, intelligence and projects should be improved, and methods such as consultation, lectures and technical cooperation could be used to introduce new talent.

3. Strengthen popular awareness of low carbon science.

The low carbon economy should be an important part of improving the public's scientific awareness. This could be achieved via the establishment of a publicity mechanism integrated with government, media, enterprises and the public; and activities to popularize scientific knowledge nationwide, and improve the awareness of enterprises and the public in low carbon economy.

6.3 Policy roadmap

Based on details of phased goals of low carbon industrialization in 2020, the above policies should be employed to promote low carbon industrialization and make clear policy choices at successive phases.

The key policies required to implement a Low Carbon Industrialization Strategy in China are set out below, separated into actions for the 12th and 13th FYP periods.

Table 6-6: Policy implementation road map and key policy priorities

Phase I **2011–15**	1) Sectoral targets for energy-intensive industry are designed and introduced 2) Support for strategic emerging industries is scaled up, especially on innovation that will be important for their development by 2020 and 2030 3) China's energy pricing system and subsidies are reformed 4) A carbon tax is introduced 5) Pilot emissions trading schemes are started in some regions and industries 6) A 'top runner' program is designed and implemented 7) China's low carbon pilot areas use targeted fiscal and tax policies and credit support to accelerate investment, supported by the national government 8) There is tougher enforcement of energy-efficiency standards in industry and buildings 9) The coverage of mandatory labelling for energy and emissions is expanded and carbon footprinting methodology is approved

Phase II **2016–20**	1) Innovation is increasingly targeted at advanced, transformative technologies and materials needed to maintain competitiveness in the 2020s 2) Energy prices are set according to the market 3) Carbon tax rates gradually increase, encouraging low carbon investment 4) Green taxation makes a growing contribution to China's fiscal revenue 5) The top-runner program is in its second phase, now covering a wide range of industrial, commercial and domestic technology categories 6) A national carbon emissions trading system is introduced 7) A fully-fledged carbon finance system is achieved 8) Carbon footprinting and labelling are promoted, giving much greater visibility to energy and emissions performance for consumers

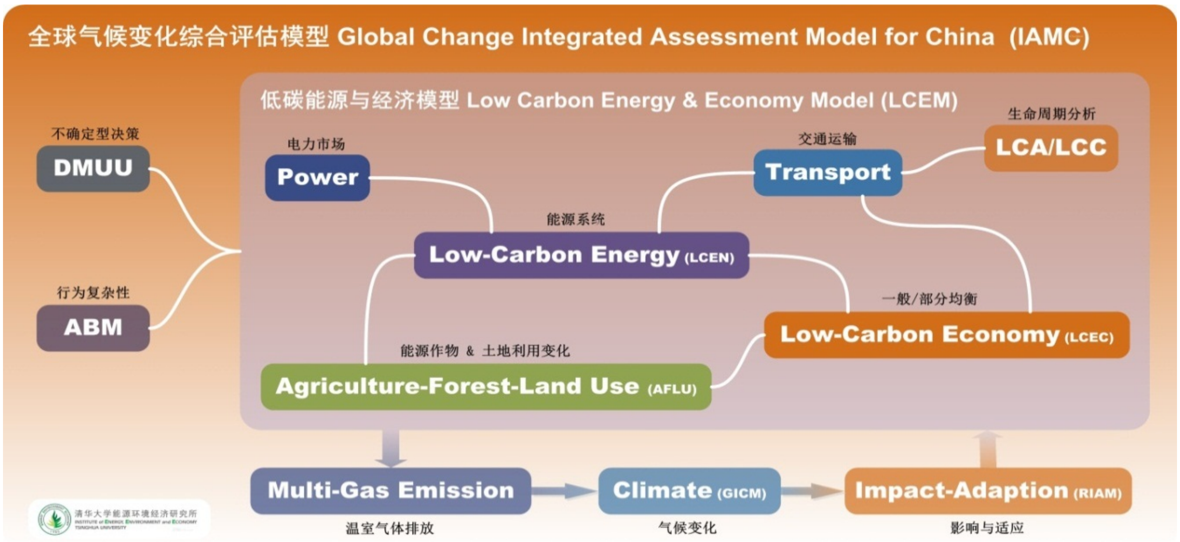
7 APPENDIX: BACKGROUND ON SCENARIO ANALYIS AND MODELLING

In order to study the impact of meeting the 2020 carbon intensity target on economy, industry, energy consumption and other aspects, the Task Force applied the 'Low Carbon Energy & Economy Model' (LCEM). This was established by the Institute of Energy, Environment and Economy at Tsinghua University. This appendix provides additional background on the modelling and scenarios work referred to throughout the LCIS Task Force report.

Introduction of LCEM

LCEM is a low carbon development 'integrated assessment model' coupled with three sub-models (LCEC, LCEN and AFLU). The base year is 1999 and the simulation period is 2005-2020. It is a global model and in this research, it mainly addresses issues within China. The integrated model framework is shown in Figure 7-1.

Figure 7-1: Global Change Integrated Assessment Model for China (IAMC)



LCEC (Low Carbon Economy Module) is a general equilibrium macro-economy growth model. It aims to evaluate the economic cost of different policies and measures to deal with climate change as well as the influence on economic growth and social benefits. LCEC is an intertemporal optimization model, with social benefit optimization and intertemporal consumption as the goal.

LCEN (Low Carbon Energy Module) is a bottom-up energy technology model. Terminal energy demand is divided into 8 sectors: agriculture, industry (high energy consumption industry and other industries), transportation (freight transport, passenger transport and international shipping) and buildings (commerce and housing). Specifically, high energy consumption industry includes steel, building material (cement), oil refining and petrochemical industry, papermaking, chemical engineering, aluminium and non-ferrous metal smelting and others, and its energy service includes boilers, heat treatment, mechanical drive, electrochemical treatment, material supply and other uses. Commercial building sector energy services include

heating, refrigeration, hot water, lighting, office equipment and other services. Domestic building sector energy services include heating, refrigeration, hot water, lighting, electrical equipment and other services.

LCEN includes detailed independently-running sub-models of electricity generation technology and electricity market competition, communications and transportation technology and market competition sub-models.

AFLU (Agriculture-Forest-Land Use Module) is a simplified agricultural technology model used to study the greenhouse gas emission of agricultural sectors such as agriculture, forestry and husbandry, greenhouse gas emission of land use changes, generation of biomass energy and its influence on land resource use, crop production, forest carbon sinks and others.

The simulation of industrial sector adopts TECGE, including 8 modules: production module, price module, income module, consumption and deposit module, investment and capital accumulation module, trade module, environment module and market equilibrium module; it can be divided into sectors such as agriculture, industry (nonmetallic mineral product industry, petroleum processing, coking and nuclear fuel processing industry, non-ferrous metal smelting and calendaring processing industry, ferrous metal smelting and calendaring processing industry, chemical material and chemical product production industry, chemical fibre production industry, papermaking and paper production industry, textile industry and other industries), energy (coal, oil, gas and power), transportation (railway, civil aviation, water transport, highway and pipeline), building industry and service industry.

Definition of China's LCIS

China's low carbon industrialization scenario is defined as follows:

(1) **Reference scenario:** social and economic development trends and technical change before 2005 continues, no extra emission reduction targets and policy incentives;

(2) **Target scenarios based on carbon intensity**: These are restrained by specific carbon intensity improvements in 2020 versus 2005 (40%, 45% and 50%, referred to as CI40 etc.) and other key policies such as the non-fossil energy development target (15% by 2020) and forest carbon sink target (40 million hectares in 2020). The carbon intensity improvement is assessed both with and without land use change (FF&I and FF&I&LULUCF). These scenarios use the same social and economic parameters and the same rates of technological improvement as the reference scenario.

(3) **Technology scenario**: this takes the CI45 Target Scenario but applies different rates of technological improvement (in terms of unit energy consumption and emissions) across the energy intensive industries (CI-45TL, CI-45TM and CI-45TH i.e. low, medium and high).

(4) **Policy scenario**: this takes the CI45 Target Scenario but applies a carbon tax that increase in a cascade during the 12^{th} FYP and the 13^{th} FYP periods.

(5) **Integrated scenario** this takes the CI45 Target Scenario but incorporates aspects of energy price change.

Assumption of main social and economic conditions of China

1 Population and urbanization

The population of China remains steady growth. The total population of China will reach its peak around 2030. The population is likely to increase to 1.41 billion during the 12th FYP and to 1.44 billion by 2020; but at the same time, the labour force participation rate will tend to decline slowly during the 12th FYP and may fall from 60% in 2005 to 59% in 2015 and 57% in 2020.

During the 12th FYP, the urbanization rate is expected to increase to about 54% and it will reach about 63% by 2020; during the 12th FYP, urban households will number 266 million, the household size will be about 2.84 people per home, and the average living area per household will reach 92.3 m^2; rural households will number 178 million, the household size will be about 3.65 people per home, and the average living area per household will reach 138.7 m^2.

2 Economic growth rate

China's social and economic development target is that GDP and GDP per capita in 2020 both quadruple that of 2000. During the 12th FYP, annual growth of GDP will be maintained at 7-9%, with an average of 8.6%; during the 13th FYP, the annual growth of GDP will be at 6-8%, with the average of 7.2%. Calculated at constant price of 2005, China's GDP of 2010 will reach RMB 36 trillion, with a GDP per capita of more than RMB 25,000; during the 12th FYP, China's GDP will reach RMB 50-55 trillion, with GDP per capita of more than RMB 35,000-39,000; by 2020, China's GDP will reach RMB 67-80 trillion, with GDP per capita of more than RMB 46,000-56,000.

Table 7-1 - Social and economic parameters

	2005	2010	2015	2020
Population (million)	1,308	1,360	1,408	1,440
Rate of urbanization (%)	43	49	54	63
Labour force participation rate (%)	60	61	59	57
Urban				
Residents (million)	562.44	666.4	757.5	907.2
Household size(persons/household)	2.96	2.88	2.84	2.8
Household number (million)	190	222	266	288
Rural				
Residents (million)	745	694	533	533
Household size(persons/household)	4.08	3.8	3.65	3.5
Household number (million)	183	190	178	181

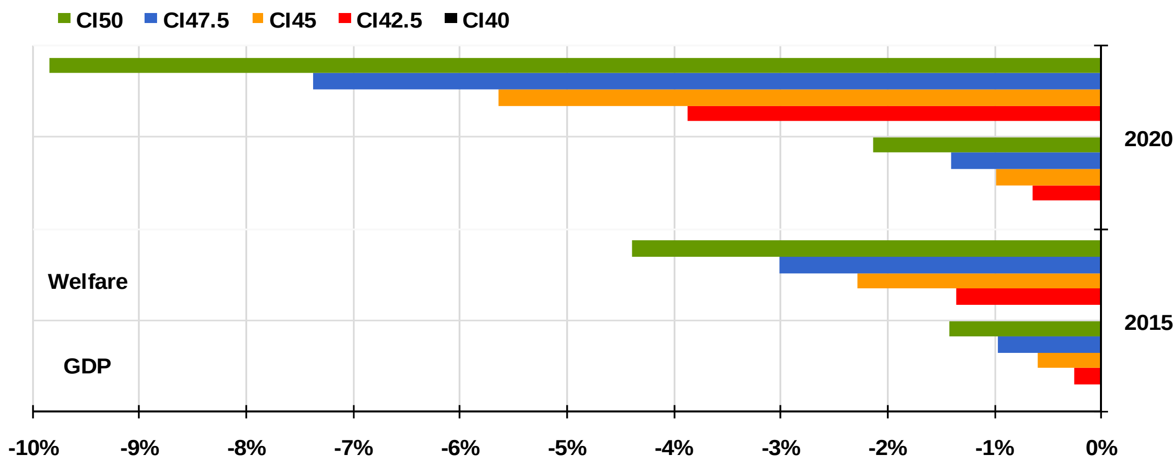
Cost analysis of different scenarios

1. Welfare loss of consumers

Different carbon intensity policy targets will influence economic and social welfare. With the 40% reduction target as benchmark, the 40-45% reduction target of carbon intensity has less than 1% influence on both 2015 and 2020 GDP, and the influence

on welfare (or consumption) is about 1-5%, which is shown in Appendix 1. If stricter carbon intensity reduction targets are implemented (such as 50%), the GDP loss of 2015 and 2020 will reach 1.4% and 2.1% respectively, and the welfare (or consumption) loss will reach 4.4% and 9.8% or so. It is important to note that these are overall as opposed to per-year figures.

Figure 7-2: Influence of different carbon intensity policy targets on economic and social welfare

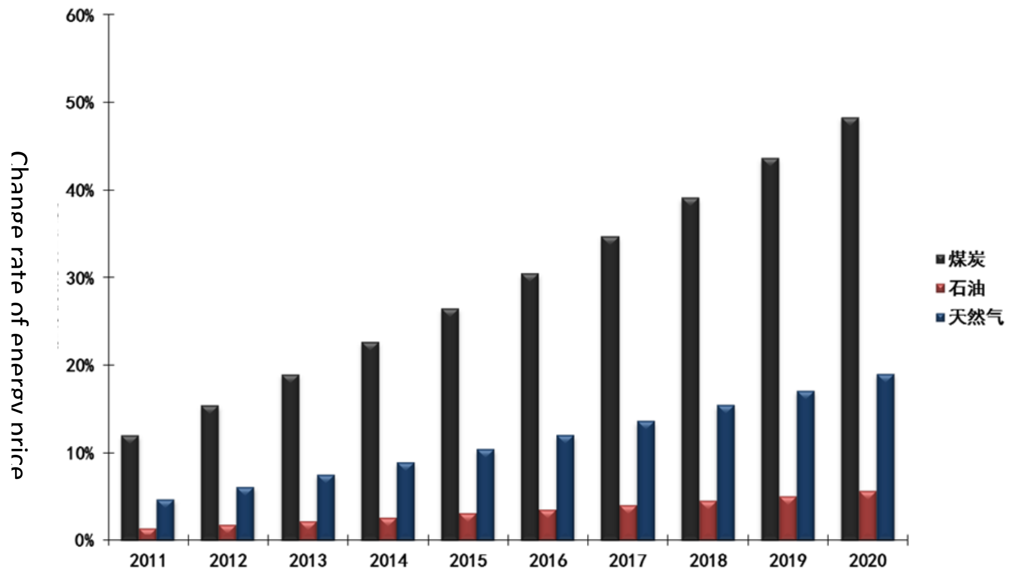


Source: LCIS Task Force analysis

2. Change of energy price

Under CI45, the price level of energy products increases relative to reference scenario: coal, oil and gas prices will rise by about 26.5%, 3.1% and 10.4% in 2015, respectively, and about 48.3%, 5.6% and 19.0% in 2020, respectively.

Figure 7-3: Energy price level during the 12th FYP and the 13th FYP, with a 45% reduction target of carbon intensity



Source: LCIS Task Force analysis

This Task Force Report is submitted to CCICED
with the Co-Chairs' approval

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[84] 1. Output of Hydropower, photovoltaic cell and methane accounting for global proportion is estimation.
2. Direct geothermic utilization includes ground source heat pump, bath, swimming, and regular geothermic heating as well as greenhouse, aquatic product, industry and snow melting etc. Ground source heat pump accounts for 49% of direct geothermic utilization in the world and 41% in China. (Statistics from 2009)
3. In China, methane is mainly for domestic use in rural area and is produced by medium and large scaled methane projects, while in the U.S, methane is largely produced at refuse landfill and cattle farm.

[85] 1. In the calculation of comprehensive energy consumption, both at home and abroad, electricity consumption is converted to coal consumption for power generation uniformly.
2. Gap stands for how many %age points higher China is than international advanced level.
3. For coal consumption of thermal power supply, the figure of China comes from the average value of units over 6MW and that of international advanced level comes from the average value of Japan's 9 major electricity companies. In China and Japan's power source structures of 2006, coal-derived electricity accounts for 81.33% and 26.03% respectively, while electricity produced from oil and gas makes up 1.97% and 34.68%. Comparable energy consumption of steel is mainly for large and medium-sized enterprises in China, whose output accounted for 86.2% of the total in 2010. International advanced level was South Korea's average value in 2005 and Japan's average value in 2010. Canadian company Alma represents international advanced level of electrolytic aluminium power consumption and Middle East stands for international advanced level of comprehensive ethylene energy consumption. These countries use ethane as raw materials while China uses naphtha.

[86] 1. The comprehensive energy consumption of the steel industry refers to larger and medium-sized steel enterprises, which contributed 86.2% to the total steel production in 2010.
2. The comprehensive energy consumption of power consumption is calculated with coal consumption in power generation.
3. In the volume of production, the production of oil refining refers to the processing amount of crude oil; the production of glass sheets is calculated in weight cases, and the rest in Mt.

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[89] The one thousand high energy consuming enterprise refers to those enterprise which participate in "energy saving movement in one thousand enterprises", with annual comprehensive energy consumption more than 180 thousand tce and most of which are high energy consuming industrial sectors. In 2006, National Development and Reform Commission and some relevant departments started this movement, aiming to save 100 million tce energy accumulatively in 11th FYP period.

[90] Those 79 kinds of existing industrial energy conservation technologies include: 18 in electricity (4 are advanced thermal power generation technologies) ; 11 in steel; 15 in building materials; 17 in petrochemical industry; 9 in non-ferrous metal; 5 in textile; 4 in papermaking

[91] The investment requirement in promotion and application of energy efficiency technologies in energy intensive industrial sectors only take those added cost for increasing energy efficiency into account.

[92] Electricity consumption in the comprehensive energy consumption of per tonne steel production is converted to the equivalent value.

[93] Electricity consumption in the comprehensive energy consumption of cement production is converted to equivalent value.

[94] In comprehensive energy consumption of paper and paperboard per unit product, electricity is converted according to equivalent weight method

[95] These statistics only cover enterprises above designated scale.

[96] Source: from China Statistical Yearbook.

[97] Source: from Secondary Metal Branch of China Nonferrous Metals Industry Association.

[98] Source: China National Development and Reform Commission.

[99] Source: from statistics released by State Statistics Bureau.

[100] Xie Zhenhua, press conference of the Information Office of the State Council, November 23rd, 2010.

[101] 1. International advanced level refers to the average level of advanced countries.
2. Total energy consumption of major products in China and abroad adopts standard coal to calculate electricity consumption. Since 2007, China applies coal consumption of power generation (about 350 gce/kWh) in China Energy Balance Sheet, while Japan, representing international advanced level, calculates with 350 gce/kWh.

3. In terms of coal consumption of thermal power supply, China only counts generators with over 6MW capacity while Japan calculates the average value of nine major power companies. Electricity consumption and heat consumption of oil-fired and gas-fired power plants are lower than thermal power plants. In 2006, coal, oil and gas takes up 81.23%, 1.46% and 0.51% respectively in the electricity generating resources mix, while those figures for Japan are 26.03%, 10.58% and 24.1% respectively. Service power consumption rate for Chinese power stations is 5.93% and that for Japan is 3.86%.
4. The comparable energy consumption of steel in China only refers to large and medium enterprises. In 2008, 70 large and medium sized steel companies produces 83% of the country's steel. 1990, 2000 and 2008 "international advanced level" is represented by Japan, and the 2005 figure is the average level of 31 South Korean companies.
5. The 1990 and 2000 total energy consumption of ethylene is represented by Japan, while 2005 and 2008 is the average level of Middle East countries. China and Japan mainly use naphtha as the raw material of ethylene production, while Middle East Region utilizes ethane.

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[103] Source: "Survey and Analysis on Typical Industrial Architecture and Thermal Engineering in Shenyang" by Wang Hongwei, "Industrial Architecture" Issue S1, 2010

[104] .See the third section of this chapter about the calculation detail about contribution of energy-saving environmental-protection vehicles to low-carbon Industrialisation

[105] The ratio is a result of total consumption of petrol and diesel divided by the overall oil consumption.

[106] Xie Mengzhe, ICT's potential contribution to China's achieving the developmental goal of low-carbon economy, 2010

[107] Xie Mengzhe, ICT's potential contribution to China's achieving the developmental goal of low-carbon economy, 2010