China's Low Carbon Industrialization Strategy

1 Introduction

1.1 Why China needs a low carbon industrialization strategy

To enhance the prospect for competitive and sustainable growth in 2020 and beyond, and to deliver the "12th Five-Year Plan" objectives, China should act now to develop a comprehensive, innovation-based low carbon industrialization strategy.

Today, China's energy-intensive① industries remain critical to the national economy. Ongoing rapid industrialization and urbanization will be accompanied by growth in the heavy chemical industries, and the expansion of the iron and steel, vehicle manufacturing, shipbuilding and mechanical engineering industries, all of which require a large volume of materials and energy. In China's rapidly expanding economy, industry accounts for roughly 70% of energy consumption, and the bulk of total greenhouse gas emissions.

Upgrading the efficiency of the heavy industries in China will continue to be critical for controlling demand and reducing environmental impact. However, according to the "12th Five-Year Plan", emissions from heavy industry in China will increase until at least 2020, even if challenging energy-intensity targets are introduced for each sector. In the next few years, China can lay the groundwork for a more transformative phase of industrialization in the 2020s and beyond, driven by technological breakthroughs, restructuring of the economy and institutional reform. Through such measures, absolute emissions reductions can be achieved in some sectors in the 2020s.

Moving to a low carbon economy is of critical strategic importance for China's future growth prospects, as has been made clear by its senior leaders. Innovation is already a priority for China, whether for upgrading old industries or to support new, technology-rich sectors. Research and development (R&D) investment as a share of GDP will climb to 2.2%

① In this report, China's national energy intensity is defined as "energy consumption divided by GDP" (tonnes of coal equivalent / GDP). In individual sectors, energy intensity is defined as "energy consumption per tonne of production" (tce / tonne) or alternatively as "energy consumption per unit value added" (tce / RMB). Carbon intensity is treated in the same way as energy intensity: i.e. at the national level it is defined as "greenhouse gas emissions (in CO_2e) divided by GDP".

by 2015 – up from just 1% ten years ago. But much more can be done to build a strong, inclusive enabling environment. Shifting to an innovation-driven society will require a dynamic education system, flexible institutions and enhanced international cooperation.

Achieving the goal of industrial restructuring is no mean feat, especially in the wake of the global economic downturn and high and volatile energy prices. Employment pressures make it harder to speed up structural adjustment in the short term by closing inefficient production capacity. On top of this there are sharp regional variations in the extent of industrialization, with China still needing to accomplish large-scale development in its western region.

Meanwhile, the global outlook for competitiveness is changing: The state of manufacturing has become a key indicator of success for developed countries as their governments seek to stimulate economic recovery. Chinese firms are competitive in meeting burgeoning global demand for low carbon technologies such as renewable energies, electric vehicles and green information and communications systems. According to China's "12th Five-Year Plan" these low carbon sectors have the potential to become pillar industries in the next ten years, together contributing around 15% of GDP. Meeting this goal depends on refocusing China's industrial assets and upgrading its capacities for technology innovation. Finally, 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.

Governments and businesses increasingly recognize that those who are moving fastest in the transition to a low carbon economy are likely to gain a significant competitive advantage. According to HSBC, the low carbon energy market reached USD 0.7bn in 2009 and is set to grow to between USD 1.5 and USD 2.7 trillion in 2020.[①] The key policy question is how states and markets can harness their industrial assets to stimulate opportunities in low carbon economic activities and energy efficiency.

With low-cost labour and inexpensive resources, China's manufacturing sector currently enjoys an unbeatable competitive edge in many products. However, rising costs of labour and resource and environmental constraints mean that China's traditional low-end industry is starting to lose its advantage over those of other countries, especially its Asian neighbours. Even so, the average salary of China's manufacturing workers is still only a small percentage of that in developed nations – and its huge domestic market and well-established industrial chain and infrastructure are still attractive for investors.

Upgrading heavy industry will not mean the elimination of labour-intensive industries, but rather a focus on producing more high-tech, higher-value products. Achieving absolute

① HSBC, 2010. *Sizing the climate economy*. www.research.hsbc.com/midas/Res/RDV?ao=20&key= wU4BbdyRmz&n= 276049.PDF reductions in consumption for such products will take significant effort and will not happen overnight. Labour-intensive industries are also the backbone of the economy in parts of the country, and China will continue to develop them to take in a significant quantity of rural labour.

1.2 A solid foundation for low carbon industrialization

There is no doubt that China has the capacity and the need to become a global leader in sustainable development and environmental technology innovation. Chinese leaders have long recognized that a more sustainable model of development is required given the global resource constraints and environmental impacts.①

The "11th Five-Year Plan" saw a step change in China's policies on energy and environmental protection, especially the energy-intensity target – an improvement of 20% by 2010 compared to 2005. Industrial sectors, the major focus of policy, collectively avoided 339 Mtce of energy demand by adopting new technologies, contributing 54% of the total energy saving during the period. Although overall energy consumption continued to grow strongly, the energy intensity of key sectors such as coal-fired electricity generation, cement, ammonia and chemical fibers came down by 9.5%, 24.5%, 17.3% and 30.6% (see Table 1).

Table 1 Progress on energy conservation in the "11th Five-Year Plan"

	Energy intensity			Production in 2010 (Mt)	Energy conservation during the "11th Five-Year Plan" period (Mtce)
	unit	2005	2010		
Steel	kgce/t	760	701	627	37.0
Aluminium	kWh/t	14 575	13 979	16	3.3
Copper	kgce/t	780	500	5	1.3
Cement	kgce/t	167	126	1 877	76.9
Glass sheets	kgce/weight case	22.0	16.3	663	3.8
Oil refining	kgce/t	114	100	423	5.9
Coking	kgce/t	156	117	388	15.1
Ethylene	kgce/t	1 073	950	14	1.7
Ammonia	kgce/t	1 700	1 464	52	12.2
Caustic soda	kgce/t	1 297	1 006	21	6.1
Soda ash	kgce/t	396	317	20	1.6
Calcium carbide	kWh/t	3 450	3 340	14	0.6
Chemical fibres	kgce/t	743	517	30	6.7
Total					172.1

Source: LCIS Task Force analysis.

① Feng Zhijun, David Strangway et al., 2008. *CCICED Task Force on Innovation and Environmentally-friendly Society: Action Plan.*

In the last five years, China has also emerged as a key player in renewable energy. Starting from a low base in 2004, its annual investment in renewables looks set to overtake the EU's in the next couple of years, and it deployed more wind-power capacity in 2010 than any other country. It has also become the leading manufacturing base for both wind-power technology and solar photovoltaic cells.

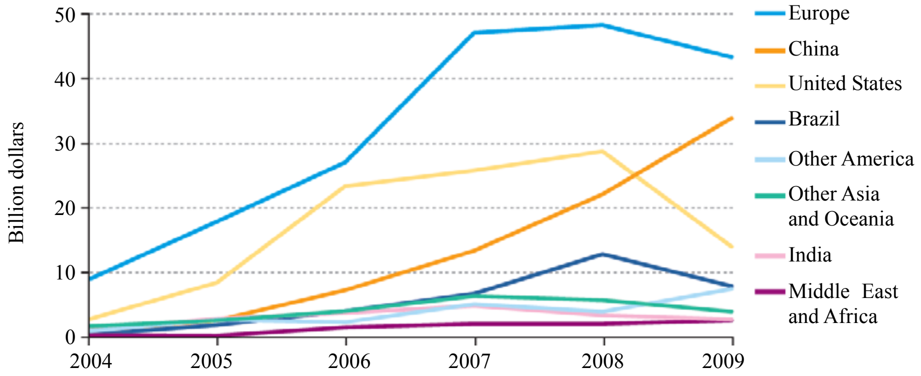

Figure 1 Annual investment in renewable energy assets by region

Source: IEA, 2010 (BNEF data).

If it is to capitalise on these advantages to secure and develop its low carbon industry, China needs to upgrade its domestic innovation base radically. Only a significant strengthening in this area can ensure China's ability to generate the range of options and the flexibility needed to thrive in coming years. R&D, deployment and associated infrastructure, as well as continued investment in key sectors, will play a vital part. However, China must also act more broadly, building up education and human capital at all levels and stimulating a culture of innovation across society.

Importantly, no one country will hold the key to the low carbon economy. Collaboration on the development and supply chains of important technologies will be crucial for companies seeking to gain a technological edge and penetrate global markets. Moreover, domestic policies alone are unlikely to support the global public good aspects of low carbon innovation; multilateral action is required to provide incentives for additional national actions, drive international collaboration and help correct critical market and policy failures.[①] China must maintain a vision of open innovation and investment to ensure the necessary flexibility.

① Shane Tomlinson, Pelin Zorlu and Claire Langley, (2008). *Innovation and Technology Transfer Framework for a Global Climate Deal*. E3G and Chatham House.

1.3 The low carbon economy – a new form of development model

Rapid industrialization is integral to the growth strategies of many developing countries, many of which guide public and private investment into primary and secondary production – whether in steel, shipbuilding or metal-processing. Environmental and resource constraints will, however, make it increasingly difficult for emerging economies to follow this traditional pathway. The path to low carbon industrialization will necessitate the creation of new development models, driven by more sustainable, less resource-intensive growth.

Industrial sectors contribute significantly to the problem of greenhouse gas emissions. 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, i.e., chemical, petrochemicals, iron and steel, cement, paper and pulp, and other minerals and metals, account for more than two-thirds of this amount.

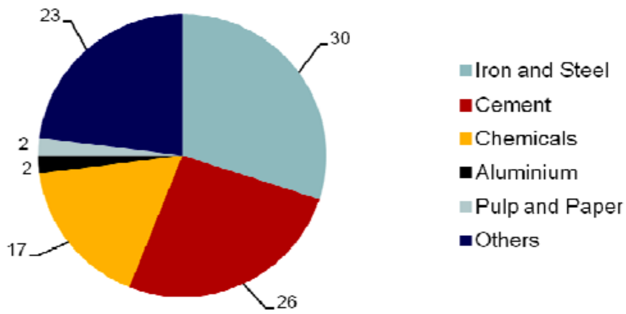

Figure 2 Contribution of global industrial CO_2 production by industry

Source: IEA, 2009.[①]

Yet these sectors are also a key part of the solution, as industry adapts to meet new product demands from a decarbonizing economy. The transformation to a low carbon economy will entail not only a retooling of existing manufacturing processes, but a more systemic change in industrial structure. This will need to combine a shift from carbon-intensive to knowledge-intensive sectors; a focus on low carbon goods; infrastructure to support lower carbon transport and services across the economy and a shift towards more energy-efficient manufacturing processes to reduce the remaining carbon footprint of industry. Systemic change involves more than just replacing a set of technologies; it must comprise a much broader network of technological chains, physical infrastructure, user

① IEA, 2009. *Energy Technology Transition for Industry.* International Energy Agency. Paris.

practices, markets and regulatory systems.

China will need a variety of different low carbon models to reflect the diversity of its regions in terms of income, geography, resource availability and general level of technological development. For example, Shanghai's income level is 10 times that of Guizhou, and part of China's central and western regions still have a significant labour surplus.

A pro-poor low carbon industrialization strategy must address the reality that China is still a developing country, and that regions currently relying on heavy industry will need a different approach from those with modern industries. With low carbon industrialization, the combination of upgrading traditional industry while fostering higher-value, cleaner sectors can contribute much to a more balanced regional development, which is itself a priority in the "12th Five-Year Plan". Moreover, the impacts of climate change and environmental degradation will add to the burden of poverty if left unchecked.

1.4 Low carbon industrialization is a pillar of the low carbon economy

In 2009 China announced a carbon-intensity target for the first time. If achieved, the amount of carbon dioxide emitted per unit of GDP will fall by 40%—45% by 2020, compared to the 2005 level. Figure 3 shows what happens to absolute carbon dioxide emissions under different scenarios for carbon-intensity improvement. Even in the 50% case – going beyond China's existing target – overall CO_2 emissions continue to rise strongly between 2015 and 2020. An important question for China is when overall energy consumption and emissions will peak. Nevertheless, achieving the 45% reduction target would save about 8.5 $GtCO_2$ per year in 2020 relative to a 40% reduction.

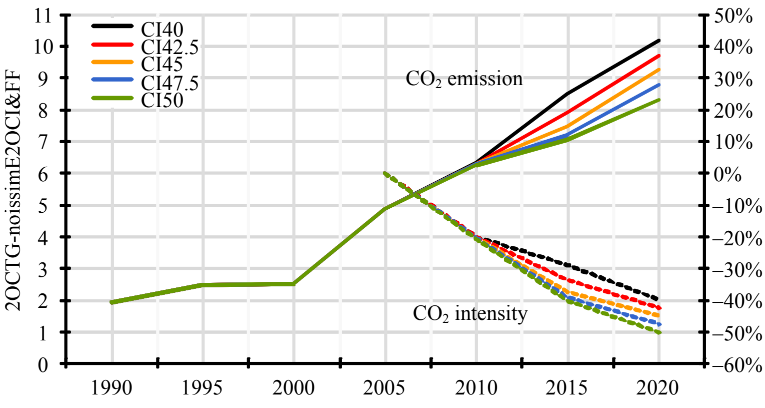

Figure 3 Impact of China's carbon intensity reductions on CO_2 emissions

Source: LCIS Task Force analysis.

The impact of energy intensity on emissions is highly sensitive to GDP assumptions. In Figure 3, annual average GDP growth rate is maintained at about 8%～9% during 2011—2015, and at about 7%～7.5% during 2016—2020.①

There are four key reasons why low carbon industrialization is critical to achieving a low carbon economy in China, including meeting the 40%～45% target.

1.4.1 Industry is a major consumer of energy and emitter of CO_2

According to the International Energy Agency, a third of the world's energy consumption and 36% of 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. Overall, the energy consumption by industry globally has increased 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 such as steel and petrochemicals is unlikely to fall rapidly over the next decade and beyond – the decisive period in the global response to climate change.

1.4.2 Heavy industry sectors will still be important for China's economic development by 2020 and 2030

If challenges in the industrial sectors can be addressed, the overall performance of China's economy will be put on a secure footing. In the next decade, as the Chinese economy and society continue to develop with gradual industrialization and urbanization, China's energy-intensive industries are expected to expand in varying degrees, resulting in a continuing increase in energy consumption and greenhouse gas emissions from these sectors.

1.4.3 LCI will play a significant role in the transformation of China's economic pattern

Analysis by the Task Force shows that achieving the 40%～45% carbon intensity reduction target will rely on innovation. This is partly because improving energy efficiency using existing technology will become progressively more challenging as China's industry approaches the best available standards.

① Scenarios were also produced for the CCICED Low Carbon Economy Task Force in 2008. The 50% improvement shown in Figure 4 results in a similar level of emissions in 2020 to the "enhanced low carbon scenario" in the report of the LCE TF, while a 45% improvement falls roughly half way between the LCE TF's "business as usual scenario" and "low carbon scenario".

1.4.4 Global economic trends after the financial crisis – the resurgence of manufacturing

Following the global economic downturn, many countries hope to seize the opportunity to develop new low carbon technologies. For China, the occasion provides a major opportunity to improve global competitiveness. The financial crisis of 2008 confirmed a global trend in the making over the past decade – that of shifting economic power across the globe, and the rise of several emerging economies as major geo-economic actors. In 2010, China overtook Japan as the world's second largest economy in terms of nominal GDP, even though, at USD 3,678, its per capita GDP is still one-tenth of Japan's.

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 2009,① the EU adopted *Europe 2020: A Strategy for Smart, Sustainable and Inclusive Growth* in June 2010,② and Japan announced details of its *New Growth Strategy by 2020* in June 2010 and approved it in January 2011③ (see Box 1).

Box 1 Japan's New Growth Strategy
In mid-2010 the Japanese government announced 21 National Strategic Projects for the revitalization of the country in the 21st century. These projects affected a wide variety of sectors: energy, transport, urban construction, manufacturing and healthcare, to name but a few. Under the subheading of Green Innovation, three specific projects have been proposed: (1) Expansion of Japan's renewable energy market: ① Expanding the purchase of renewable through the feed-in tariff system; ② Introducing smart grids to make the system more efficient and enable greater integration of renewables; ③ Promoting the construction of renewables through the creation of implementation zones; ④ Providing financial assistance to strengthen finance mechanisms; ⑤ Stimulating demand for heat from renewable energy. (2) Future Cities Initiative: ① Creating a world-leading 'future city' through future-orientated technologies, schemes and services; ② Implementing a comprehensive package of policy measures, including regulations, tax incentives, and budgetary support for key technologies; ③ Spreading the initiative throughout Asia. (3) Forest and forestry revitalization plan: ① Raising self-sufficiency in timber to 50%, thereby helping to revitalize local economies; ② Promoting sustainable forestry practices.

① White House, February 2011. *A Strategy for American Innovation: Securing Our Economic Growth and Prosperity*. www.whitehouse.gov/innovation/strategy

② European Commission, 2011. *Europe 2020: EU's Growth Strategy*, See http://ec.europa.eu/eu2020/index_en.htm.

③ METI, 2011. *New Growth Strategy*. www.meti.go.jp/english/policy/economy/growth/index.html

Emerging economies have maintained and accelerated support for manufacturing during the global economic downturn. Brazil's development bank, BNDES, financed 40% of the investment in infrastructure and manufacturing domestically in 2009,[①] 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 the training of engineers. The country's foreign investment has also increased from USD 9.1 billion in 2005 to USD 63.9 billion in 2009, mostly in the key inputs of the manufacturing processes – energy, metals and chemicals – as well as transportation and communications.[②] National and regional governments have also supported the development of special economic zones and industrial parks in China, Korea and beyond.

The World Bank has shifted its position away from the non-interventionist Washington Consensus, 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'.[③] Infrastructure, private investment and job creation, human resource development, trade, financial inclusion, growth with resilience, food security, domestic resource mobilization and knowledge-sharing – key pillars of strong and sustainable economic growth – will all require reform and transformation.

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 rapid growth of the Asian market.[④] According to the GMCI, the US, Japan and Germany, the former manufacturing superpowers, are now lagging behind these three.

2 A low carbon industrialization strategy for China

Over the next ten years, China will make significant improvements in energy and

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① Luciano Coutinho, 2010. *Challenges for Industrial Policy, Innovation and Competitiveness in Brazil.* BNDES. Presented at the Woodrow Wilson International Centre www.wilsoncenter.org/events/docs/BNDES%20in%20Woodrow% 20Wilson% 20BR-US%20BCouncil%2015%20July%202010.pdf

② John Bruner, 2010. *China widens its reach.* Forbes. April 21, 2010

③ Justin Yifu Lin and Célestin Monga, 2010. *Growth Identification and Facilitation: The Role of the State in the Dynamics of Structural Change*, The World Bank, Washington DC. Available: www-wds.worldbank.org/servlet/ WDSContentServer/WDSP/IB/2010/05/18/000158349_20100518154747/Rendered/PDF/WPS5313.pdf

④ Deloitte Touche Tohmatsu and US Council on Competitiveness, 2010. *Global Manufacturing Competitiveness Index*, p. 13-16.

carbon intensity, but the country can also lay the groundwork for a critical industrial transition between 2020 and 2030 through four measures: supporting emerging industries, accelerating innovation, developing infrastructure and reforming institutions.

Low carbon industrialization has three major pillars: restructuring industry to give a greater share to lower carbon, high-value industries and to change the energy mix; technical innovation, including the upgrading of heavy industries; and institutional development.

2.1 Optimizing China's industrial structure

Structural change will be very important for the "12th Five-Year Plan" and for the future of China's economic growth. As is clear from Figure 4, industry currently consumes a much higher proportion of energy than other countries. China needs to accelerate the development of tertiary industry and cultivate low carbon and strategic emerging industries.

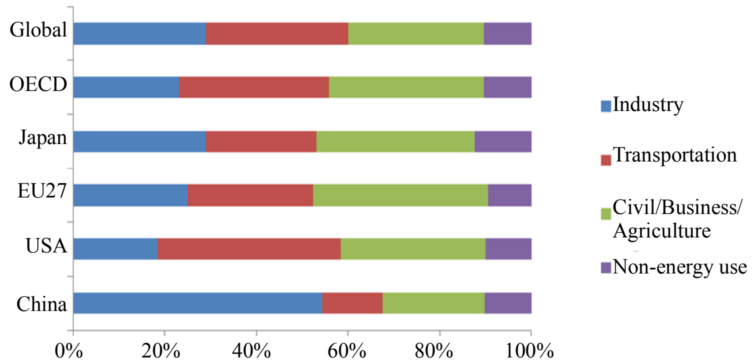

Figure 4 Industry's share of final energy consumption in selected countries

Source: Institute of Energy Economics Japan and Japan Energy and Economic Statistics Brochure 2010.

Guiding the merging and reorganization of enterprises. In the "12th Five-Year Plan" period, China plans to promote competitive enterprises in the following industries: automobiles, iron and steel, cement, machinery manufacturing, aluminium electrolysis, rare earth elements, electronics and information, and pharmaceuticals. Win-win corporate partnerships will be encouraged, as well as trans-regional merging and reorganization, and a higher industrial concentration. Furthermore, China aims to encourage heavy industries to consolidate and to co-locate in industrialization zones, while outdated production facilities will be closed down. Regulations on performance standards and the efficient use of energy and materials are improving but effective monitoring by regulatory agencies and tougher penalties for non-compliance are needed.

Increasing added value and progression up the value chain. Although China has already become a sizable industrial nation, it is far from being a world leader in many industrial areas. Product added value rates remain low in many sectors, and economic output per unit of energy consumption and greenhouse gas emissions has much room for improvement. In 2007, the added value rate in China's manufacturing sector was 26.5%, far below the average level of 35% in developed countries, especially the US where it is 45.9%. China is set to adopt a range of measures aimed at encouraging enterprises to increase R&D investment, bring new products to market and move to the high-value end of industrial chains. This will help to promote the international competitiveness of products and raise their added value.

Cultivating strategic emerging industries. The strategic emerging industries are planned to become the backbone of the national economy, constituting 8% of GDP by 2015 and 15% by 2020 – with much potential for this to expand by 2030. These industries not only feature high capital and technology intensiveness and higher added value compared with traditional industries, but will also help to transform and upgrade the traditional heavy industries, playing a key role in reducing energy and carbon intensity.

Optimizing the structure of Chinese industry. In 2010, the ratio of the primary, secondary and tertiary industries in China was 10:47:43, with the proportion of tertiary industry in its national economy being 30% lower than the average in developed countries. Policy frameworks can encourage the service industries to become a major driver for economic growth in future, and because the tertiary sector tends to require less material inputs than heavy industry, such a shift would help lower China's energy and carbon intensity. The adjustment of the energy structure is a special case – here, the key is to raise the share of non-fossil fuels in primary energy consumption (see Box 2).

Box 2 Reforming the structure of the energy sector

In the coming decade, the adjustment of energy structure will also be crucial to the achievement of low carbon industrialization. To lower carbon emission intensity further, the adjustment of energy structure must involve two measures: the adjustment of the proportions of fossil to non-fossil energy, and the adjustment of the structure of fossil energy.

Raising the proportion of non-fossil energy. In 2009, the proportion of non-fossil energy to total energy consumption in China was 78%. To lower carbon emission intensity, the proportion of fossil energy consumption in industry must be reduced. The Chinese government proposes to raise the proportion of non-fossil energy to primary energy consumption to 15% by 2020.

Optimizing the pattern of fossil energy consumption. In 2009, the proportions of coal, oil and gas to total energy consumption were 70.4%, 17.9% and 3.9% respectively. In industry, the proportion of coal resources to energy consumption is also very high. Furthermore, to lower the proportion of the consumption of coal resources with low calorific value and high carbon content, China must undertake R&D and demonstration of coal-based synthetic natural gas, coal-based liquid fuel, and coal-based poly-generation; step up exploration and development of oil and gas resources, particularly promoting the rapid growth of natural gas production; and boost the development and utilization of unconventional oil and gas resources such as coal bed methane (CBM) and shale gas.

2.2 Promoting technological advancement

Innovation is at the core of low carbon industrialization, and essential for accelerating energy conservation, not least because the potential for emissions reduction from existing technologies is decreasing. New technologies and systems are required if China is going to tackle increasing energy and resource consumption, and innovation is also the key to industry's progress towards maximum value addition in sectors such as renewable energy and electric vehicle production.

The development of energy technologies rarely follows a linear logic or evolves within the boundaries of individual economic sectors, and many breakthrough innovations occur precisely when different fields interact. For example, innovation in solar photovoltaic technologies has benefited from developments in consumer and industrial electronics, and advances in concentrating solar power derived from aerospace and satellite technologies. It is therefore essential to create an innovation system that encourages interaction between sectors, as well as between foreign and domestic firms. It would also be a mistake to focus only on the specific priorities of a particular technology as the nature of future breakthroughs is often difficult to predict.

Innovation in the supporting infrastructure for low carbon technology deployment will also play a vital role. For example, in terms of 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, since a more flexible model for electricity would allow for greater penetration of renewables and better demand management, spreading demand so that less generating capacity is needed at peak times.

Even though global R&D investment is mostly undertaken in the private sector and is increasingly global in nature,[①] 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. However, in recent years, partly as a result of the stimulus packages, energy expenditure has increased in a number of countries while over the same period private-sector R&D in energy decreased.[②] The other trend to note is a strong bias towards certain technologies. Nuclear power (both fission and fusion) has received over

① Government and non-governmental organizations spent around $350 billion on R&D globally in 2006 (40% of the total). Private sector spent the rest 60% ($525 billion) (Batelle, 2008 cited in OCC, 2008).

② The discussion in this section is drawn from the analysis in Thomlinson et al., E3G and Chatham House (2008), Innovation report.

half of all state R&D budgets from the G7 countries over the last two decades, more than five times their combined energy efficiency budgets.①

In 2005, China became the third largest R&D spender worldwide (in purchasing power parity terms), after the United States and Japan. Firms in emerging economies are also increasingly investing 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 United States and 11 in the EU).② Emerging-economy firms have also acquired developed-country firms in order to gain access to their intellectual property and markets.

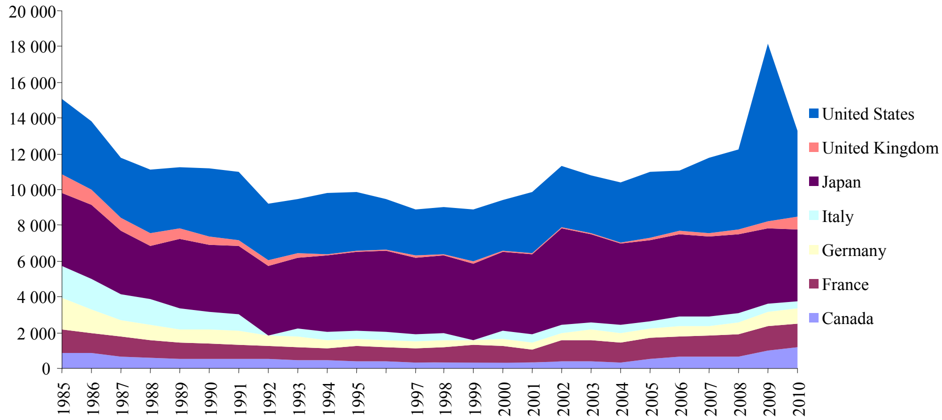

Figure 5 Public energy-related R&D spending in G-7 countries, 1985—2010 (USD m, 2010)

Source: IEA database of R&D, 2011.③

The challenge of bridging the gap between the R&D phase and full-scale commercialization can represent 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 finance them independently. This is particularly the case with large-scale or unproven technologies, such as carbon capture and storage (CCS) and bio-refineries. Public funding, public–private partnerships and joint ventures are an effective way of raising the necessary capital and pooling expertise essential to getting a new project off the ground.

① Glachant et al., December 2008. *Invention and transfer of climate change mitigation at global scale: a study drawing on patent data*.

② von Zedtwitz, 2005 cited in OECD, 2008

③ IEA, 2010. *International Energy Agency database of research and development*, accessed September 2011, http://www.iea.org/Textbase/stats/rd.asp. The 2010 value for France was unavailable so is assumed to be equal to the 2009 value.

2.2.1 Addressing resource and technology challenges

The scaling up of low carbon technology comes with a range of environmental, material and security risks. The predicted availability and price of a material will be an important consideration in the development of a particular design of a technology and will therefore help to frame the development path of a particular sector. These risks include:

(1) Access to materials or fuels needed for the manufacture or use of the new energy source;

(2) Use of resources – particularly if there is an impact on water or land use;

(3) Use of equipment, materials or fuels for military means – the dual-use capabilities.

For the foreseeable future low carbon technologies will depend on critical inputs from heavy industry – from the steel, concrete and plastics required for wind turbines to insulation materials and the batteries in electric cars. The EU wind industry alone consumes 700,000 tonnes of steel.① The 20GW of new wind capacity in China in 2010 is equivalent to about 2% of Chinese steel production in the same year.② High-voltage transmission networks will be another major area of steel demand. One million electric vehicles would require perhaps one-fifth of the current global production of lithium carbonate.③

Rare earth elements (REE) are a group of 17 elements (atomic numbers 57–71 along with Scandium and Yttrium) whose unique properties currently make them indispensable in a wide variety of advanced technologies. For example, some advanced wind turbines use permanent magnets instead of traditional gears, but about 2 tonnes of neodymium are required for each windmill. Demand for REE used in batteries is expected to grow at 10%–16% between 2008 and 2012, and those used in the manufacturing of batteries at 15%–20% per year.④

Today, access to REE for clean energy production is already creating trade tensions between China and the US. This is a result of China's recently imposed trade restriction on the export of Neodymium (Nd), Europium (Eu), Cerium (Ce) and Lanthanum (La) to 35,000 tonnes per year, and complete stop on exports of Thulium (Tm), Terbium (Tb), Dysprosium (Dy), Yttrium (Y) and Lutetium (Lu), as China states that it needs these REM resources for its own economic development in the coming years.⑤ However, REE are not the only

① World Steel Association.www.worldsteel.org/pictures/programfiles/Wind%20energy%20case%20study.pdf

② Chatham House calculations, 2011, based on current technology

③ Chatham House calculations based on 20kg Lithium Carbonate per vehicle – amount varies considerably by technology choice

④ NEF, 2009. *Unearthing the Rare Earth Market for Clean Energy Investors*, New Energy Finance, January 2009

⑤ Smith, 2010. Written Testimony, Mark A. Smith, Chief Executive Officer, Molycorp Minerals, LLC House Science and Technology Committee, Subcommittee on Investigations and Oversight "Rare Earth Minerals and 21st Century Industry", March 16, 2010.

elements needed for new energy technologies. Table 2 shows a range of other materials that will be needed in significantly greater volumes for key technologies in the low carbon economy.

Table 2 Raw materials used in new energy technologies

Raw material (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 2009.①

2.2.2 Access to new technologies

For smaller businesses, or for new entrants, access to new technology and software is critical in enhancing the chance of securing financial support, whether venture capital or equity investments. Companies may use patents to deter the entry of competitors, and shape the industry into an oligopoly able to charge prices above marginal costs and thus potentially support research.② However, the likelihood that the patent system will encourage research, that there will be cross-licences to disseminate technology and that such cross-licences will encourage innovation and implementation are all dependent on the competitive conditions of the industry.

① Mi2, 2009. *Material Scarcity, Materials Innovation Institute*, November 2009.
② See, for example, J. Barton, *Antitrust treatment of oligopolies with mutually blocking patent portfolios*, Antitrust Law Journal 69:851-882 (2001).

2.2.3 Price stability

Higher oil prices make non-fossil-fuel alternatives comparatively cheaper and as such can help determine the rate of their deployment. However, somewhat perversely, the wider the deployment of low carbon technologies and practices, the smaller the demand for fossil fuels, which in turn will reduce their price, making low carbon fuels less economically attractive. Even so, if assumptions are made that the finite nature of fossil fuels (in particular oil) and the global growth in demand will ultimately lead to higher energy prices, the gap between the current costs of fossil fuels and the alternatives could narrow rapidly.

Projections of the overall cost of the transition to a low carbon economy are therefore highly sensitive to assumptions about future energy and resource prices. McKinsey's 2009 report on a global carbon abatement cost curve explains that:

if we assume an average price of USD 120 per barrel rather than the USD 60 a barrel price assumed by the IEA in the BAU forecast we use, and that other energy prices increase proportionally, this reduces the total cost of abatement in 2030 by approximately €19 per tCO_2e, equivalent to cutting the total cost of abatement in 2030 by approximately €700 billion annually. As a very rough rule of thumb increasing oil prices by USD 10 (€6.7) per barrel cuts average abatement costs by €3 per tCO_2e within the USD 60–120 per barrel range.[①]

In another report by McKinsey, undertaken for the Republic of Ireland, the same variation in oil prices had a profound impact on the economic viability and carbon abatement costs of renewable energy technology. In this case onshore wind had a carbon abatement cost of €10/tCO_2 in the USD 60 scenario but a saving of €82/tCO_2 in the USD 120 scenario.[②]

In any case, even within a short time period the estimated cost of new technologies can vary significantly. In some areas, learning curves, economies of scale and new efficiency in production are driving down the cost of energy production. For example, a study by Lawrence Berkeley National Laboratory on solar PV found that average installation costs had decreased 30% over the past decade, falling from USD 10.80 per watt in 1998 to USD 7.7/W by 2009. However, the report noted that US costs are still significantly higher than those of other countries such as Germany and Japan, where average installed costs stand at USD 4.7/W and USD 5.9/W respectively. However, in other cases costs are not decreasing and may even be increasing. The CEO of the largest US nuclear utility Exelon has recently stated that 'economics of low carbon options have changed dramatically' in just two years,

① McKinsey, 2009. *Version 2 of the Global Greenhouse Gas Abatement Cost Curve*.

② SEI, 2009. *Irelands Low Carbon Opportunity, Sustainable Energy Ireland*, Assessment carried out by McKinsey, July 2009.

with the company's new-nuclear cost estimates having more than doubled to about USD 100/t CO_2, ten times the cost estimated by McKinsey.[①]

In most cases these low carbon and resource-efficient options bring significant additional societal benefits such as improved local environments, price stability and local and national job creation. However, the most important additional benefit relates to security of resource supply and increasingly price security. Diversifying away from fossil fuels or reducing their use will aid a country or region's energy independence, and therefore reduce the risk of supply interruption.

2.3 Institutional strengthening and reform

The next wave of improvement on energy and carbon intensity in China will require a stronger focus on institutional barriers. Institutional performance is also the key to implementing core policies, from energy efficiency targets to green taxation systems. China should make comprehensive use of tools such as market entry rules, energy and carbon pricing, fiscal measures, taxes and financial policies to improve the incentive system and framework for technical innovation. Although the state has traditionally supported new and emerging industries in China, a proliferation of multiple, independent policy plans has often undermined attempts to develop these industries into market leaders.

Today, the supporting infrastructure for technological innovation is inadequate. Research institutions are scattered across many universities with limited networks, and common platforms for the development and commercialization of standardized technologies have been slow to develop. In addition, firms in the emerging pillar in China typically have weaker R&D capabilities than their competitors in developed countries. This is especially true of smaller firms in China, which often have very limited R&D capacities.

New bridges are required between advanced academic institutions and entrepreneurial businesses to help turn new advances into low carbon growth. Scientific research in China currently depends on higher education and scientific research institutions. These focus on research and development breakthroughs rather than scaling up deployment of new products or fostering new industries. At the same time, many enterprises – some restricted by inappropriate infrastructure or insufficient funds –some inexperienced and with no long-term development plan – continue to rely on well-established technologies and are not enthusiastic about cooperating with universities to help bring new innovations to market. To bridge this commercialisation gap, China could draw on the experience of the UK's Carbon Trust and the

① John Rowe, 2010. *Fixing the Carbon Problem Without Breaking the Economy*. Exelon, 12 May 2010

Sustainable Development Technology Canada – two competing models for bringing low carbon technologies to the mass market. The Carbon Trust claims to have helped drive around GBP 1 billion of additional investment into the development and deployment of low-carbon technologies, markets, products and services between 2001 and 2009.[①]

There is also a lack of technical standards, testing and accreditation in many of the emerging sectors in China. The experience of the renewables industry highlights the problems that this can generate: initially firms rushed into the industry, causing strong competition. However, policy incentives and the lack of an entrance threshold led to the industry becoming 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 core technology and innovation capacity, these companies have tended to compete on price at the expense of product quality and consistency. Owing to the explosive growth of the industry, many products have only had a very short cycle from R&D to mass production and before sufficient testing regimes had been implemented, so potential problems may not have been fully exposed or effectively resolved.

3 Heavy industry is key in the short to medium term

The energy consumption of the heavy industry sectors in China is set out in Figure 6. These sectors have an enormous contribution to make in terms of short-term energy and emissions reductions over the next ten years and beyond.

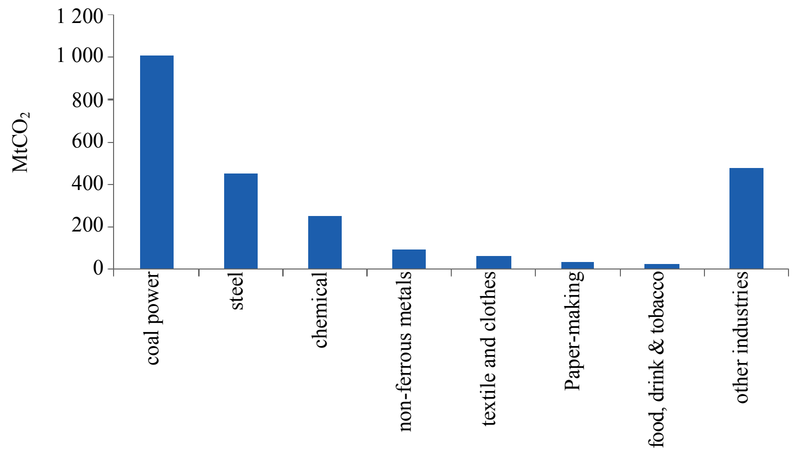

Figure 6　Energy consumption of heavy industries in China in 2010

Source: LCIS Task Force analysis.

① OECD, 2010. *Better Policies to Support Eco-innovation*. See case studies on Carbon Trust and SDTC

In terms of economic restructuring, the proportion of industrial added value coming from these energy-intensive industrial sectors will decrease by about 5% in 2020 compared with 2005, avoiding 4–5 Gtce energy consumption and 9-11 $GtCO_2$.

For rapid progress, barriers such as perceived technical risk, financial risk, and lack of investment and information will need to be overcome. Most importantly, clear, credible and long-term policy frameworks are required to push forward on energy- intensity improvements. For more advanced technologies, further research and development are required. Some of the major projects for heavy industry in the "12th Five-Year Plan" are listed in Box 3.

Box 3 Projects in the "12th Five-Year Plan"

1) *Energy conservation and transition*

Continuing cogeneration, motor equipment energy optimization, surplus heat/pressure utilization, boiler (kiln) improvement, oil saving/replacement, building and traffic energy savings, and green lighting.

2) *Popularizing energy conserving products*

Directing financial subsidies to energy-saving and high-efficiency products in electrical appliances, automobiles, motor equipment and lighting.

3) *Commercialization of energy-conserving technology*

Supporting the demonstration of key energy conservation technologies, products relating to the utilization of surplus heat and pressure, and high-efficiency generators; promoting the large-scale production and application of products with crucial energy conservation technologies.

4) *Contracted energy management for ESCOs*

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

Source: The "12th Five-Year Plan" .

3.1 Conserving energy

In the next decade, the energy-intensive industrial sectors can avoid a total of 456 Mtce of energy by 2020 if they adopt 79 key technologies① identified by this Task Force, equivalent to 1.22 $GtCO_2$ (see Figure 7).

① 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.

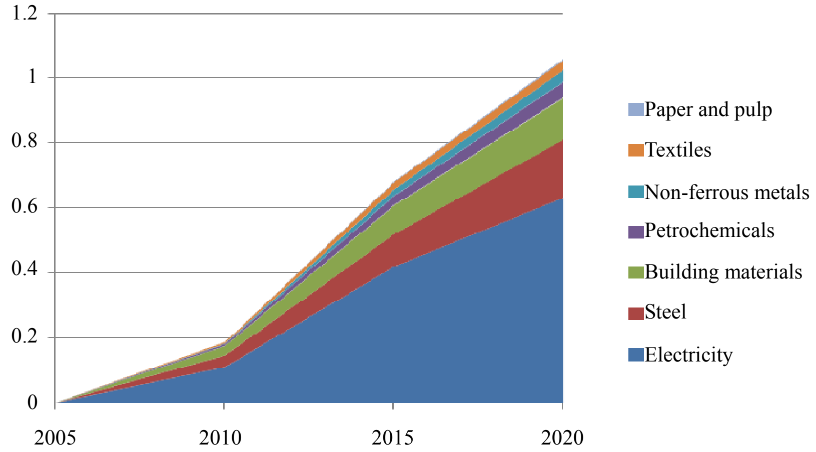

Figure 7 The potential impact of 79 kinds of industrial energy conservation technologies on China's CO_2 emissions (2006—2020 in $GtCO_2$)

Source: LCIS Task Force analysis.

However, this would just be scratching the surface of what is possible. If all the available energy-efficiency technologies (both existing and emerging) were to be widely and immediately deployed, 6.5–7.5 Gtce of energy demand could be avoided by 2020, equivalent to 17–19 $GtCO_2$. The most important technologies for energy efficiency in the steel, non-ferrous metals, petrochemicals and buildings materials sectors are set out in Box 4.

It is critical that investment for the development and promotion of industrial energy conservation technologies is delivered as soon as possible. The required investment in the 79 priority technologies alone would cost industry nearly RMB 1 trillion in the period 2011—2020. If all of the energy technologies that can be used in energy-intensive industrial sectors are promoted and applied in a timely fashion, investment could reach RMB 1.6–2.0 trillion over the next decade. However, these investment costs do not reflect the many savings that would be achieved through the application of such technologies. As China gradually moves towards a market price for energy, the payback periods for investments will also speed up.

Table 3 sets out the progress that Chinese industry has made in closing the gap with the average level of energy efficiency in developed countries ("international advanced level" – IAL) in each sector. For example, coal power required nearly 19% more fuel for every unit of power produced in 2005 than in OECD countries. By 2009 this had been reduced to 9%. For steel, the gap had closed from 17% to 6%. The changes are effected through the upgrading or closure of older plants (although a significant number of smaller plants are not recorded in the figures) as well as through more efficient new capacity.

Box 4 Key technologies for energy efficiency in heavy industry

Steel:

① Develop coke dry quenching equipment compatible with coke ovens.

② Equip all newly built blast furnaces with top pressure power generation equipment.

③ Employ advanced technologies and equipment such as feeding furnaces with carefully selected ores, using enriched coal spray, hot metal pre-treatment, large blast furnaces, converters and electric arc furnaces, external refining, continuous casting, tandem rolling and Thermo Mechanical Control Process.

④ Recycling and utilization of gases from coke ovens, blast furnaces, converters, combined cycle power generation with gas and steam, top pressure power generation of blast furnaces, evaporative cooling, smoke gas, dusts and solid wastes.

Non-ferrous metals:

① Utilize large and energy-efficient equipment in mines.

② Use oxygen-enriched flash and bath smelting technology in copper smelting, large prebaked cell in electrolytic aluminium, Queneau-Schuhmann-Lurgi process (QSL) and other direct smelting technology in smelting lead, and develop new zinc hydrometallurgy technology.

Petrochemicals:

① Employ technologies related to the optimized configuration of oil extraction equipment, energy-saving for heavy oil thermal recovery, optimized operation of water-flooding systems, carbon dioxide reinjection, energy saving for oil-gas tight line gathering and transportation, recycling of burned gases in the oilfield.

② Improve the mix of raw materials for ethylene production. Adopt advanced technology to improve ethylene cracking furnaces. Employ energy-saving technology in ammonia synthesis plants. Utilize new catalyst and energy-efficient equipment. Promote reclamation of stack-gas afterheat technology in natural-gas based ammonia synthesis. Speed up the conversion from crude oil to natural gas in petroleum-based ammonia synthesis. Adopt energy-efficient equipment and pressure swing absorption technology in small and middle-sized ammonia synthesis.

③ Replace traditional fixed-bed gasification technology with coal water slurry or advanced ash coal gasification technology. Gradually replace use of the metal-anode-diaphragm cell process to produce caustic soda by use of the ion-exchange membrane method.

Building materials:

① *Cement:* Develop new decomposition-outside-kiln technology. Actively promote energy-saving grinding equipment and kiln waste heat power generation technology. Upgrade middle-sized and large rotary kilns, grinding machines, dryers. Gradually eliminate shaft kilns, wet-process kilns, dry and hollow kilns and other outdated technologies. Replace mineral fuels with flammable wastes. Ensure comprehensive use of industrial solid wastes and tailings.

② *Glass*: develop advanced float and eliminate outdated vertical and horizontal drawing technology. Promote inclusive heat preservation technology for both furnaces and kilns as well as oxygen-rich and oxy-fuel combustion technology.

③ *Ceramics*: eliminate outdated kilns such as downdraft kilns, pusher kilns and beehive kilns, and promote roller kilns.

④ *Sanitary ware*: change fuel mix to adopt clean gas combustion and no-ring firing process. Promote new wall materials and high-quality environment-friendly sound- and heatproof materials, waterproof materials and sealing materials, increase the proportion of high-performance concretes to ensure longer building life.

Table 3 Major industrial products in China versus IAL of energy intensity

Total Energy Consumption (kgce/t unless otherwise stated)	China			International Advanced Level	Gap (2005)		Gap (2009)	
	2005	2008	2009		Energy consumption	Percentage gap	Energy consumption	Percentage gap
Thermal efficiency of electricity generation (gce/kWh)	370	345	339	312	58	18.6	27	8.7
Aluminium (kWh/t)	14,680	14,323	14,131	14100	580	4.1	31	0.2
Copper smelting	780	564	548	500	280	56.0	48	9.6
Steel* (kWh/t)	714	663	644	610	104	17.0	34	5.6
Cement	167	151	139	118	49	41.5	21	17.6
Oil refining	114	106	106	73	41	56.2	33	45.3
Ethylene	1,073	970	954	629	444	70.6	325	51.7
Ammonia	1,650	1,549	1,521	1000	650	65.0	521	52.1
Caustic soda	1,297	1,154	1,075	910	387	42.5	165	18.1
Soda ash	396	345	306	310	86	27.7	–4	–1.2
Paper and paperboard	1,380	1,158	—	640	740	115.6	518	80.9

* Steel figures refer to large and medium size enterprises only. For more information on the data presented in this table please see the full version of the LCIS TF report.

Source: LCIS Task Force analysis of industry sources.①

Significant potential savings exist even beyond the IAL level. This is because the average industrial plant in developed countries is older than in China and will often be much less efficient than the best available technologies. For example, according to UNIDO, producing one tonne of aluminium required 13.4MWh of electricity with the best available technology in 2007, whereas in a selection of industrialized countries it ranged from 14.8 to 15.8MWh/t at that time. The IEA estimates that China could still save an additional 0.9GJ/tonne of steel.②

All energy-intensive sectors are expected to make very significant cuts in energy intensity over the next ten years. Analysis by the Task Force indicates that paper and cement production have the potential to make the largest savings per unit of product, but all of these sectors have the potential to reduce carbon intensity by 2020 by at least 15% from 2005 levels (see Figure 8).

① Industry sources: 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.

② IEA, 2009. *Energy Technology Transition for Industry*, International Energy Agency 2009.

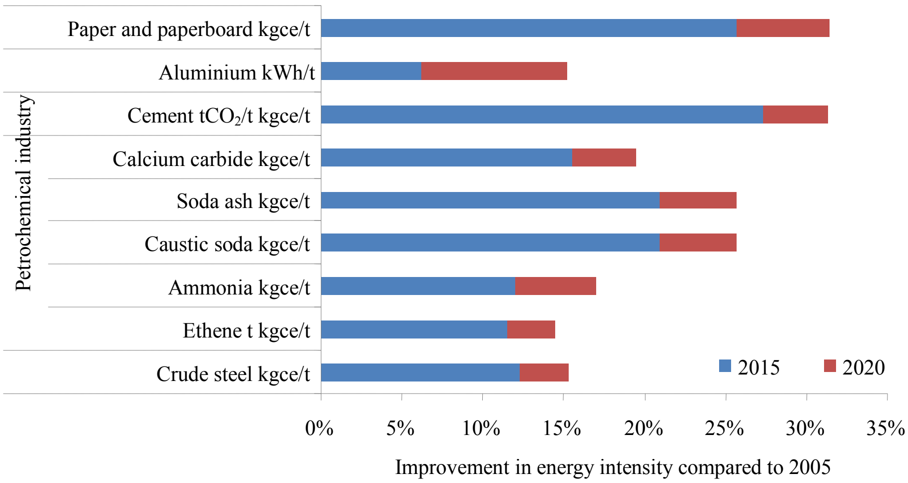

Figure 8 Potential for energy intensity improvement by 2020 in energy- intensive sectors (2005 baseline)

Source: LCIS Task Force analysis.

Despite these improvements in intensity, growth in demand for these products means that absolute energy consumption and demand will continue to increase for the next few years at least. Despite this, analysis by the Task Force suggests that by 2020 this situation may already have been reversed for some of the heavy industries (see Table 4). Overall, emissions from these seven heavy industries will climb dramatically by about 50% between 2005 and 2015, but just 6% between 2015 and 2020.

Table 4 Projections for heavy industries: production, energy consumption & carbon emissions

	Production (Mt)			Energy consumption (Mtce)			Carbon emissions ($MtCO_2$)		
	2005	2015	2020	2005	2015	2020	2005	2015	2020
Crude steel	353	710	800	262	462	501	769	1214	1277
Ethene	7.6	20.0	28.2	8.2	19.1	26.1	19.0	44.4	60.5
Ammonia	46.0	55.0	58.7	81.5	85.9	86.4	188.3	198.4	199.6
Caustic soda	12.4	28.0	37.6	16.8	29.9	37.7	38.7	69.1	87.1
Soda ash	14.1	27.0	35.9	7.5	11.7	14.5	17.3	27.1	33.4
Calcium carbide	8.9	18.0	22.2	18.7	31.9	37.4	43.2	73.6	86.3
Cement	1070.0	2100.0	2400.0	159.6	227.6	245.8	368.8	525.8	567.7
Aluminium	7.8	20.0	24.7	42.0	87.5	94.6	67.8	141.5	153.0
Paper	62.1	133.0	145.0	32.6	51.9	50.2	75.3	119.8	116.1

Source: LCIS Task Force analysis.

For example, in the case of steel a 15% improvement in energy intensity between 2010 and 2020 would still result in absolute increases in energy consumption over the period, owing to a doubling in steel demand (see Figure 9). However, total CO_2 emissions would only increase slightly under these assumptions.

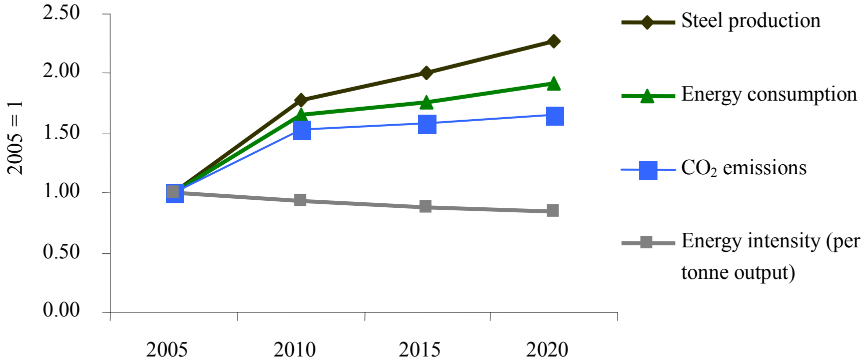

Figure 9 Steel sector – expected change in production, energy intensity, CO_2 emissions and energy consumption by 2020

Source: LCIS Task Force analysis.

The picture is similar for the cement industry. Here, carbon emissions are already close to peaking but will remain fairly flat over the next decade, climbing slightly by 2020 – in this case energy- intensity improvements largely offset the overall demand for cement, which is still increasing (see Figure 10).

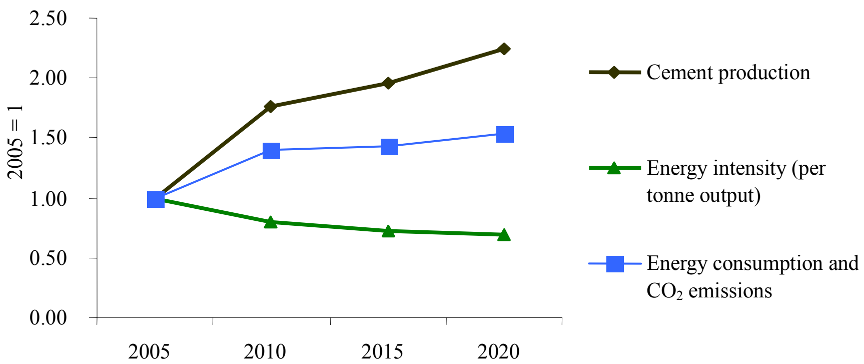

Figure 10 Cement: expected change in production, energy-intensity improvements and total energy consumption by 2020

Source: LCIS Task Force analysis.

Carbon emissions from the aluminum and papermaking industries are also expected to peak around 2020, but emissions from some petrochemical subsectors (e.g. ethane and calcium carbide) will still be climbing rapidly at this time.

3.2 The circular economy

The Chinese government has made progress towards achieving a circular economy – a key strategy for its national economy and social development, backed by the Circular Economy Promotion Law. This is also an important component of the LCIS.

According to China's cleaner production website, the concept can be defined as interlinked manufacturing and service businesses seeking the enhancement of economic and environmental performance through collaboration in managing environmental and resource issues. The focus is on the exchange of materials where one facility's waste, including energy, water, materials and information, is another facility's input.[①] In short, the idea is that significant additional efficiency gains can be achieved through cooperation between sectors and businesses on resource flows, energy and waste.

Today, China's energy-intensive industrial sectors consider improving their resource efficiency to be the primary target in the development of a circular economy. But as ever more waste accumulates, technologies for waste utilization and recycling will grow, so that energy saving, reutilization of waste and reclamation will deserve equal focus. The circular economy can help China's energy-intensive industrial sectors increase resource output efficiency, improve waste recycling efficiency, lower the consumption of energy, water and raw materials per unit, and reduce waste amounts and carbon dioxide emissions. According to China's circular economy yearbook 2010,[②] using waste steel in steelmaking requires 60% less energy than making primary steel from iron ore.

Most energy-intensive industrial sectors already have some foundation on which to develop a circular economy. For example, steel, non-ferrous metals, electrical power, the chemical industry, building materials and paper-making businesses have conducted pilot projects and have demonstrated the benefits of cooperation with other firms and efforts on recycling.

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① China's Cleaner Production website: www.chinacp.org.cn/eng/cppolicystrategy/circular_economy.html.

② Circular Economy Yearbook 2010, 2010. China Financial & Economic Publishing House.

Box 5　Key circular economy projects in the "12th Five-Year Plan"
① *Comprehensive utilization of resources*
Utilizing large bulk solid wastes such as, fly ash, coal refuse, industrial by-product gypsum, smelting wastes, chemical waste residue, tailings, construction wastes, as well as straw and waste wood. Several such bases will be established during the "12th Five-Year Plan".
② *Recycling system for waste products*
Demonstration areas in up to 80 cities will feature advanced waste product recycling systems, to achieve high rates of recycling of key products.
③ *Demonstration bases of "mineral industry in city"*
The circular economy in the mineral industry will be pursued in demonstration zones in 50 cities, deploying advanced technology and management and enhanced regulation of environmental standards. The demonstration areas will have a broad scope, including recycling of waste metals, waste electrical and electronic products, waste paper and plastics.
④ *Industrialization of re-manufacturing*
Several national re-manufacturing zones will be established, focusing on developing the size and quality of re-manufactured output from sectors such as automotive parts, construction machines, mining machines, machine tools and office supplies.
⑤ *Reclamation of kitchenware waste*
Several kitchenware waste reclamation facilities will be constructed in 100 cities, to improve the utilization and harmless disposal of kitchenware waste.
⑥ *Recycling transformation in industrial park*
Key industrial parks and industry cluster areas will make a major push on recycling.
⑦ *Promotion of resource-recycling technology*
Demonstration projects and service platforms consistent with the circular economy.
Source: The "12th Five-Year Plan".

The central and local governments in China have already introduced important measures to promote the circular economy, including planning and guidance, pilot projects, economic incentives and regulatory restrictions. The "12th Five-Year Plan" sets a target of 72% utilization for industrial waste by 2015, and an increase of 15% in the yield rate of resources. More supportive fiscal and financial policies will be introduced and laws, regulations and standards will be refined. China will establish lists of technologies and products to be included under the circular economy strategy. It will also set up a labelling system for re-manufactured products as well as a statistical and evaluation system. Energy- conservation technologies and techniques such as recycling, re-manufacturing and zero emission production, as well as cooperation between industries, will be developed and implemented.

At local government level, many provincial and municipal governments (such as in Gansu, Henan, Hebei, Zhejiang, Shenzhen and Dalian) have made local plans for the development of the circular economy, or plans focusing on special industrial sectors. Some local governments (such as Fujian) have already set up special funds dedicated to shifting to a circular economy.

Gansu province expects that its circular economy programme will deliver a 35% improvement in the energy intensity of nickel production, reducing it to 3.59tce/t by 2015. The province's recycling ratio for waste iron and steel, non-ferrous metals, paper, plastic and rubber will rise to 78%, 84%, 75%, 75% and 87% respectively. Altogether, 10Mtce of energy will be saved and more than 20 $MtCO_2$ will be avoided through these measures.[①]

3.2.1 Metal recycling

The proportion of secondary metals in China is far below that in developed countries. According to the China Non-Metallic Minerals Industry Association, China's secondary lead output in 2009 reached 1.23 mt or 33% of total lead output, compared with an average of 60% in OECD countries. Secondary copper output reached 2 mt, less than 40% of total copper output, compared with 60% in the US, 45% in Japan 45% and 80% in Germany. Most Chinese metal recycling enterprises are small and inefficient, failing to achieve economies of scale. Moreover they often lack advanced technical equipment.

Making full use of scrap metals is important because recycling can have a remarkable effect on energy conservation and emissions reduction. For example, by 2015, secondary copper utilization can save 5.6 Mtce and avoid 103.9 $MtCO_2$.

3.2.2 Combined heat and power generation

CHP is a highly efficient way of utilizing energy, simultaneously generating both electrical energy and thermal energy. By avoiding condensation losses, the standard coal consumption rate of CHP is lower than separate generation by 15–20 kg/GJ for heat, and by 30–50 g/kWh for power. It is estimated that, compared with separate generation of heat and power, 0.8 Mtce could be saved by installing 1GW CHP units.

3.2.3 Cogeneration

Cogeneration means transforming excess thermal energy during the production process to electrical energy. It has significant implications for lowering industrial energy consumption and emissions, especially in energy-intensive industries, and has been implemented in many industries, such as cement, iron and steel, glass, chemicals, and

① The overall plan of circular economy in Gansu.

non-ferrous metals. Nonetheless, further support is needed to scale up the use of cogeneration including an on-grid tariff and a pricing policy for waste heat.

3.3 Adjusting the energy supply structure

Compared with the global primary energy supply structure, China's primary energy supply structure is high carbon in nature, with coal constituting 70% of the total supply, while non-fossil energy sources constitute only a small part. This reliance on coal is a key cause of China's high level of carbon dioxide emissions per GDP. Shifting away from coal can make a great contribution to the transition of energy- intensive industrial sectors to a low carbon pattern, and to the reduction of carbon dioxide emission. In China's "12th Five-Year Plan", a target has been introduced requiring the proportion of non-fossil energy sources in the primary energy supply to increase from 8.3% in 2010 to 11.4% in 2015.

Box 6 Key energy projects in the "12th Five-Year Plan"
① *The exploration and transformation of coal*
Accelerating the construction of coal production bases in Northern Shaanxi, Huanglong, Shendong, Mengdong and Ningdong; developing coal bases in the northern, middle and eastern part of Shanxi, Yunnan and Guizhou; establishing coal bases in Xinjiang and setting up several large coal-fired power plants based on those bases.
② *Stabilization of oil output and increase in gas output*
Promoting the formation of five large-scale oil and gas production zones in 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 increasing the oil-refining capacity.
③ *Nuclear power*
Accelerating the development of nuclear power in coastal provinces, maintaining th development of nuclear power in middle areas, and setting up nuclear power stations with a total capacity of 40GW.
④ *Renewable energy*
Building large hydropower stations on the Jinsha river, Yalong river, Dadu river and other main rivers with a total capacity of 1.2TW. Setting up six large wind- power stations, whose newly installed turbines will have a total capacity of more than 70 GW. Building solar power stations with capacity of 5GW in key areas such as Tibet, Inner Mongolia, Gansu, Ningxia, Qinghai, Xinjiang and Yunnan.
⑤ *Network of oil and gas pipelines*
Constructing the pipelines in the second phase of the Sino-Kazakhstan oil projects, in Chinese areas involved in the Sino-Myanmar oil and gas project, in the second phase of the Central Asian natural gas project, as well as pipelines in the third and fourth project of the West to East Gas Pipeline Project. The total length of the pipelines under construction is 150,000 km. Also accelerating the construction of gas storage facilities.
⑥ *Power grid*
Accelerating the construction of large coal-fired power stations, hydropower stations and wind-power stations which can provide electricity to other regions, building up several cross-regional power transmission channels with advanced UHV technology. A total of 200,000 km of electrical power transmission channels with a capacity of 330 kV and above has already been constructed. Conducting pilot projects to build intelligent electric grid and intelligent substations. Expanding the application of intelligent electric meters and installing charging facilities for electric cars.
Source: The "12th Five-Year Plan".

By 2015, the proportion of coal energy in primary energy consumption will drop by 7 percentage points from the 2010 level, 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. However, overall growth will mean that coal demand continues to rise.

The power sector has already taken several important measures to adjust its structure and accelerate the transition to a low carbon economy but these will be accelerated in the next ten years. Five large power-generating companies have adjusted their power supply structure and made this transition the main priority of their strategic plans. In addition, China's two grid companies have developed their own green development strategies. One of the most important parts is to accelerate the construction of advanced cross-region electricity transmission channels, which can set up a transmission platform to support these structural adjustments.

There will be another rapid expansion in the Chinese power sector over the next decade – by 2020, the total installed capacity of generators will reach 1.7 TW. The installed capacity of the new generators will total 0.8 TW, providing huge capacity for the sector to adjust its power supply structure.

The 15% target implies 600 Mtce of avoided coal consumption. By 2020, the installed capacity of non-fossil energy will have increased by 500 GW compared with 2005 and the proportion of the installed capacity of coal fired plant will decrease from 73.6% in 2005 to 60%. Most of the remaining capacity will be highly efficient and, compared with current performance levels, will avoid 260 Mtce of energy consumption. By 2020 there will be 60GW of gas generation capacity. The greater relative efficiency of combined cycle gas plant over coal generation, and the lower emissions per unit of output, will avoid about 32 Mtce and 140 MtCO_2.

4 Emerging industries – catalysing low carbon transformation

After 32 years of reform and opening up, China is at a crossroads. Economic development is facing increasing pressure from resource restraints and environmental degradation. With the advantages of its cheap resources and labour force fading away, China's future development depends on enhancing endogenous development momentum and international competitiveness.

The "12th Five-Year Plan" identifies seven emerging strategic industries that will play a key role in China's economy: energy conservation and environment protection; new energy technologies, including renewables and nuclear; new energy vehicles, including electric vehicles; biotechnology; information technology; advanced materials and equipment manufacturing. This is a major strategic move for China, designed to promote sustainable growth and ensure that China will be at the forefront of science, technology and innovation in the future. This chapter sets out the pivotal role of the emerging pillar industries for China's low carbon industrialization strategy.

The development of low carbon industries is a priority for major economies attempting to kick-start their economies in the wake of the global financial and economic crises, in particular to create jobs and achieve low carbon green growth. The US, for example, has invested significantly in researching and promoting alternative energy and electric vehicles; the EU has emphasized 'green' innovation and investment as well as a rapid transformation to a low carbon economy; Japan has significantly enhanced the budget for new energy R&D and utilization. In addition, countries around the world have invested in the information and communications sector and strengthened support for biotechnology and nanotechnology.

China has a vast potential domestic market for the promotion and application of new technologies, as well as a broad industrial platform to support the commercialization of new technologies. If the current opportunities for innovation are seized, it is likely that the technology gap between China and developed countries can be narrowed, eliminated, or even reversed. China is catching up with OECD countries in terms of patenting activity in low carbon technology, a proxy for innovation activity, but it is still some way behind the leaders – the US, Germany and Japan (see Box 7).

Innovation is not just about R&D: it is an evolutionary process involving a complex mix of public- and private- sector actors and dynamic interactions between consumers and producers. Successful innovation requires a balance between "push" and "pull" factors, with varying levels of public–private finance and policy interventions at different stages from R&D to mass deployment. In OECD countries, private businesses account for the bulk of R&D in terms of both funding and performance. However, government remains crucial for creating the right conditions for accelerating the rate of innovation and diffusion and in many cases public investments in innovation have led to key breakthroughs. A crucial consideration for governments, therefore, should be creating the right balance of risk and reward in innovation markets to leverage private-sector activity.

Box 7 China and low carbon energy innovation

The geographical distribution of patenting and how it 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 the size of the potential markets in China.

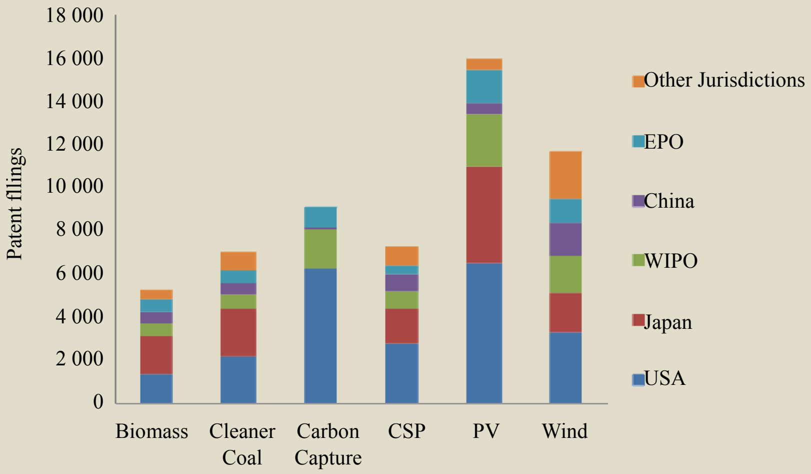

Figure 11 Patent filing locations for six energy technologies

The country of origin of the patenting organization shows 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 second tier.

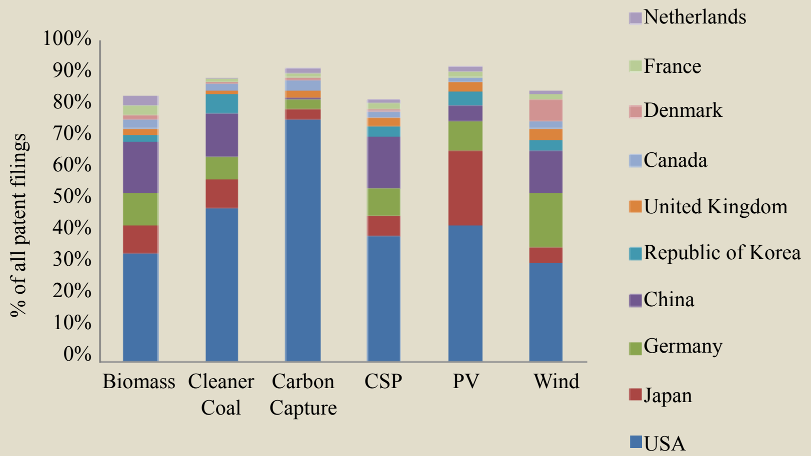

Figure 12 Patent assignee origins

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

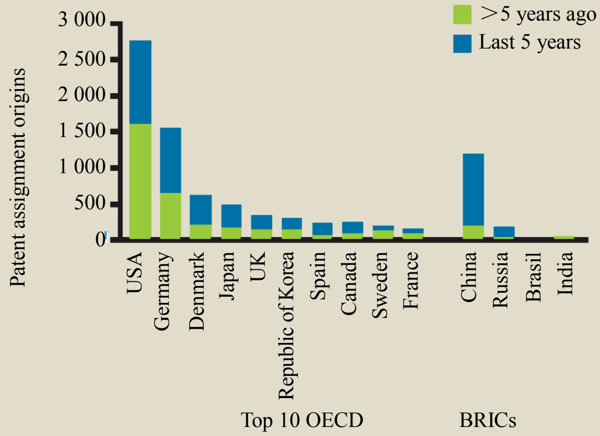

Figure 13 Patent assignee origins – wind power

Source: Chatham House, 2009.

The development of energy-saving technologies, advanced vehicles and biological industries can directly improve energy intensity, replace fossil fuels, and reduce pollutant and industrial carbon emissions through the provision of equipment and materials that enhance industrial systems. The new generation of technology developed through the emerging industries will also provide indirect support for the low carbon industrialization process. For example, wind and solar power are intermittent by nature and the large-scale deployment of such renewables could be facilitated by a smarter grid. By 2020 the emerging sectors together have the potential to avoid 4.6 $GtCO_2$ of emissions (see Table 5). However, their decisive contribution to low carbon transformation will emerge in the 2020s if the groundwork is laid during the “12^{th} Five-Year Plan”.

Table 5 Impact of emerging industries on CO_2 emissions

	CO_2 emissions avoided		Note
	2015	2020	
Energy-saving and environmental protection	818 Mt	1.9 Gt	Direct effect
New energy	1.2 Gt	1.8 Gt	Direct effect
New energy vehicles		300 Mt	Logistics and transportation
Biological industry	Can replace oil and gas as feedstocks and fuels		Direct effect
Information Communication industry	615 Mt of emissions will be reduced by 2020 and the ratio of direct to indirect emissions reduction is 1:5		The ratio of direct to indirect emissions reduction is 1:5
New materials High-end manufacturing industry	Will have an important impact on resource- saving, environmental treatment, material recycling and reutilization		Indirect effect

Source: LCIS Task Force.

4.1 Energy-saving and environmental technology

This rapidly expanding sector includes a broad range of technologies, products and services aimed at saving energy, preventing and treating pollution and protecting ecological systems. During the "11th Five-Year Plan" the sector grew by over 20% per year so that by 2009 it had an added value of RMB 1.9 trillion, more than half of which was in the area of resource efficiency and utilization, including recycling, waste and water treatment. Within the energy-saving sector, the service industry accounted for over RMB 50 billion (see Figure 14).

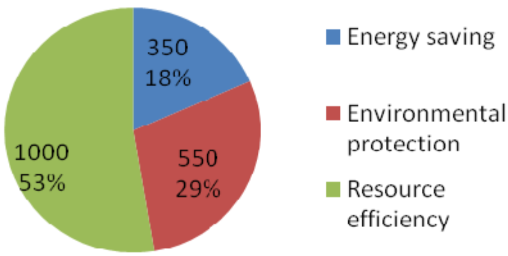

Figure 14 Breakdown of energy-saving and environmental protection sector in 2009 (RMB bn)

Source: LCIS Task Force analysis of industry sources.①

Part of the explanation for the explosive growth is that industrialization and urbanization have increased the scale of the environmental challenge: industrial waste, for example, has grown at an average of 13% annually over the past five years. Recycling of non-ferrous metal is booming but it still comprises just 24% of China's annual production of such metals.② In 2010, 75% of urban sewage was treated but there are still 61 cities without a sewage treatment plant, and virtually no sewage treatment facilities exist in rural areas. Landfill continues to be the dominant form of waste management in China, with incineration and composting making up less than 20% of the total, much lower than in Japan and South Korea.③

As described in 3, Chinese industry still lags behind its advanced foreign counterparts in terms of energy consumption per unit of output (see Table 3). The energy-saving and environmental protection sector will play a key role in closing this gap, helping to reduce per

① China Statistical Yearbook, China Energy Conservation Association, China Environmental Protection Industry Association, Chinese Renewable Energy Industries Association and China Environment Service Industry Association.

② Secondary Metal Branch of China Nonferrous Metals Industry Association.

③ China's National Development and Reform Commission.

unit energy consumption, promote resource reutilization and cut costs. If all the measures set out in Table 6 were achieved, 2.1 GtCO_2 could be avoided by 2020.

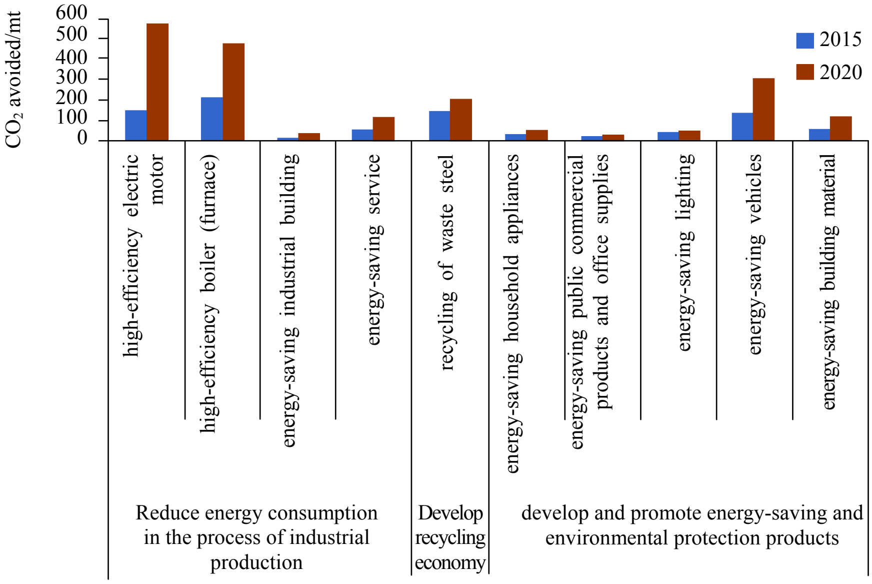

Figure 15 Impact of energy-saving and environmental technologies and services on CO_2 emissions

Source: LCIS Task Force analysis

As is clear from Figure 15, efficient motors, boilers and vehicles are three critical areas to address. The electricity consumption for industrial motor systems (including the electric motor, water pump, fan and compressor) is responsible for 80% of the total electricity consumption in China, but high-efficiency energy-saving models make up just 3% of all motors installed and have a current market share of only 30%.① The smart grid will play an important role too: demand-side management has an important role to play, but will require significant upgrading of information and control systems. Large efficiency gains are possible by aligning the specifications of transformers and machinery with electricity distribution (further details can be found in Table 8).

The design of industrial buildings should be given much greater attention in future. If 20% of existing industrial buildings received an energy-saving upgrade by 2020 and energy consumption dropped by an average of 15%, 345 MtCO_2 could be avoided. Moreover,

① Zhang Shaochun (Deputy Minister of Financial Department), "Accelerate the promotion of high-efficiency electric motor and boost the scaled application in China", March, 2011.

energy-efficient buildings require a range of materials such as thermal insulation for walls, reinforced fly-ash brick and draught-free, double-glazed windows. By 2020 an additional 113 MtCO_2 could be avoided through such measures.

This emerging sector also has a key role to play in developing China's circular economy. At the production end this includes new technologies and facilities for the separation, enrichment and use of minerals. It also means technologies and systems which allow the upgrading and reuse of existing machinery and materials. Increasing the share of metals, rubber and plastic made from recycled material will have a significant impact on greenhouse gas emissions. A tonne of secondary copper requires only 27% of the energy used to produce a tonne of primary copper. By 2020 is it expected that renewable aluminium, renewable copper and waste steel will reach 65%, 75% and 25% respectively of the total market for each metal. Reaching these levels will require investment in technologies and services along the supply chain.

Household appliances are responsible for about 13.5% of the total electricity demand in China, and this percentage is set to grow with increasing living standards. Energy-saving household appliances currently account for only 15%—30% of the market; if the average consumption of household appliances can decrease by 30% in 2010, 67 TWh will be avoided, equivalent to 50 MtCO_2. In addition, lighting is responsible for roughly 10%—12% of the total power demand. About 1.4 billion incandescent lamps are in use in China today. During the three years from 2008 to 2010, nearly 350 million energy saving lamps were accumulatively promoted with the help of financial subsidies. If 150 million lamps can be added each year, it will take 7-8 years to replace all the ordinary incandescent lamps. Taking the conservative estimate that each lamp saves 50 kWh per year, 70 GWh would be avoided by 2020, or 53.1 MtCO_2.

4.2 Lower carbon energy

Generation of electricity and heat was by far the largest producer of CO_2 emissions in 2008 and was responsible for 41% of global CO_2 emissions. This sector relies heavily on coal, the most carbon-intensive of fossil fuels.

Decarbonization in the power sector can be divided into three areas:

(1) Reducing consumer energy demand (e.g. encouraging the public not to use lighting unnecessarily);

(2) Increasing efficiency at the power station, in transmission (including smart grid technologies) and at end-use (efficient buildings, lighting and appliances);

(3) Switching from fossil fuels to renewables and nuclear, from higher carbon fossil

fuels to gas, and the use of CCS. Decarbonization can also be achieved through the use of combined heat and power.

The "new energy industry" emerging pillar focuses on the third dimension. China's non-fossil energy accounted for 8.1% of the total energy consumption in 2010. As noted in 3, the "12th Five-Year Plan" specifies that by 2015 this should have risen to 11.4%, keeping China on track to meet its target of 15% non-fossil energy by 2020.

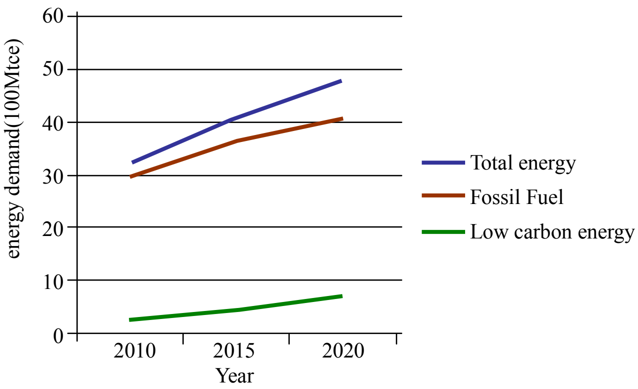

Figure 16 Projected energy consumption: proportion met by fossil and non-fossil energy, 2010–2020

Source: LCIS Task Force analysis.

By 2015, renewables and nuclear power can replace 467 Mtce, equivalent to 1.15 $GtCO_2$, reducing carbon intensity per unit GDP emission by 3%. By 2020, 720 Mtce, equivalent to 1.771 $GtCO_2$, can be avoided compared with business as usual, further reducing per unit GDP emissions by 3%—4% (see Table 6).

Table 6 Projection of non-fossil energy and impact on CO_2 emissions

	2010	2015	2020
Total energy consumption (Mtce)	3240	4100	4800
Proportion of non-fossil energy (%)	8.11	11.4	15
Hydropower installed capacity (GW)	213.4	280	430
Wind installed capacity (GW)	31.07	90	150
Nuclear installed capacity (GW)	10.82	40	80
Solar installed capacity (GW)	0.6	5	20
Alternative energy (Mtce)	263	467	720
CO_2 emissions avoided ($MtCO_2$)	646	1150	1771

Source: LCIS Task Force analysis.

China still has to import many high-value components of low carbon energy technology – for example, in wind power these include the control system and bearings, and its nuclear energy continues to use designs based on imported models. Improving domestic innovation capacity is a priority for the "12th Five-Year Plan" – putting China in a position to design and manufacture globally competitive high-tech components while pursuing breakthroughs in third-generation nuclear power, large-scale wind turbines, solar polycrystalline silicon manufacturing and other key technologies. By 2020, the focus of the industry will have shifted from low labour cost to high-value components and utilizing economies of scale.

There are also practical and regulatory obstacles to the scaling up of renewable energy. Box 8 describes the challenge of connecting wind power to the grid.

Box 8 Wind power: grid strengthening and technology deployment

The natural distribution of new energy resources is somewhat scattered, and the power generated from them fluctuates. The generated electricity has to be distributed over a large geographic area, in order to buffer power fluctuation on the grid. China's wind resources are mostly far away from the load centres (see Figure 17), and require large-scale power transmission. There are major bottlenecks resulting from the high concentration of wind power in a few areas, such as Jilin Province. At times, power generated from wind accounts for 25% of the total load, which is detrimental to the safe operation of the power grid until it can be upgraded. This acts as a constraint on the further development of wind power.

At the end of 2010 total wind-power capacity in China was 45 GW, but only 31 GW had been connected to the grid. The huge idle capacity of wind power is partially attributed to temporary factors, such as the comparatively slow pace of grid construction. However, the fundamental cause lies in the industrial structure, including a lack of coordination between new energy development and power grid construction, delayed transfer of the rising costs of power generation, and lack of mandatory requirements for and supervision of power grid companies.

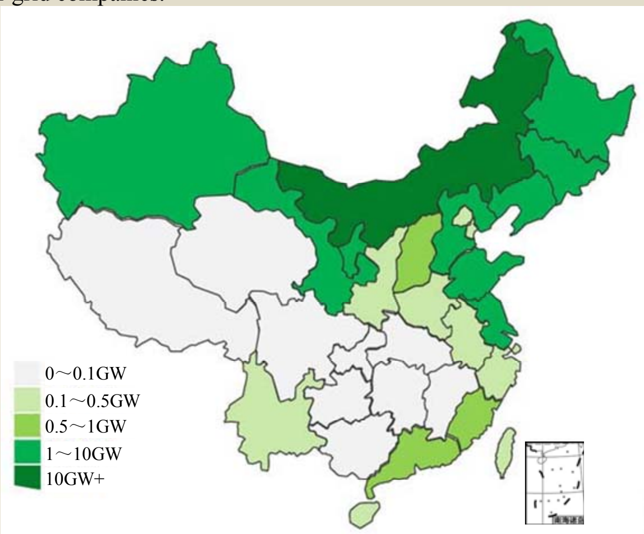

Figure 17 Aggregated installed capacity across various provinces in China in 2010

Source: Task Force analysis.

4.3 Vehicle efficiency and electric vehicles

Global automobile demand is set to grow rapidly, largely driven by increasing car ownership in developing countries as incomes rise. In the IEA's baseline scenario, the total stock increases from about 750 million in 2007 to 1600 by 2035 (see Figure 18). This represents a major area of potential growth in greenhouse gas emissions.

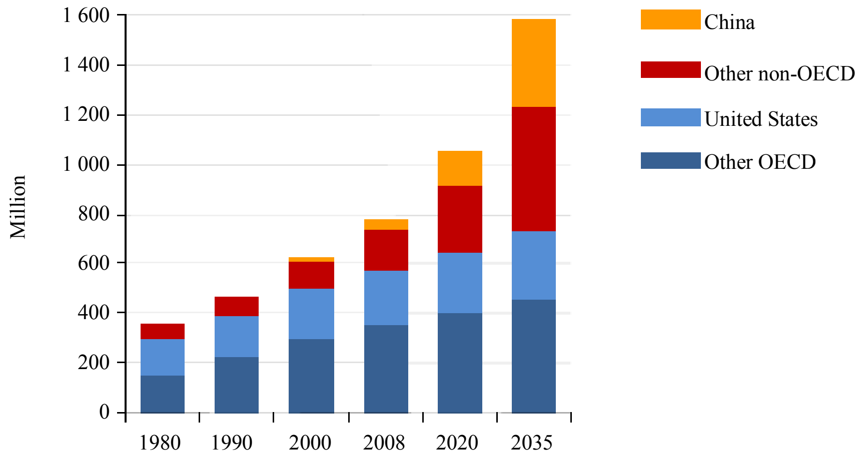

Figure 18 Passenger vehicles in the IEA's New Policies Scenario

Source: IEA 2010.

The number of vehicles owned by Chinese citizens continues to rise rapidly, as shown by Figure 19. In 2000, the total number of civil automobiles stood at 16 million; by 2009, the figure had reached 57 million, a threefold increase over eight years, with an annual growth rate of 15.2%. In the decades to come, the number of personal automobiles will continue to grow at a very high rate; the total is forecast to reach 153 million by 2020 and 241 million by 2030.

This poses major challenges to China's energy security. Automobiles were responsible for 29% of oil consumption in 2008, up from 25% in 2005.[①] If the current growth pattern, mileage pattern and fuel efficiency were to remain unchanged, by 2020 China's automobile oil consumption would reach 333 Mtoe, and by 2030 over 500 Mtoe.

① The ratio is a result of total consumption of petrol and diesel divided by the overall oil consumption.

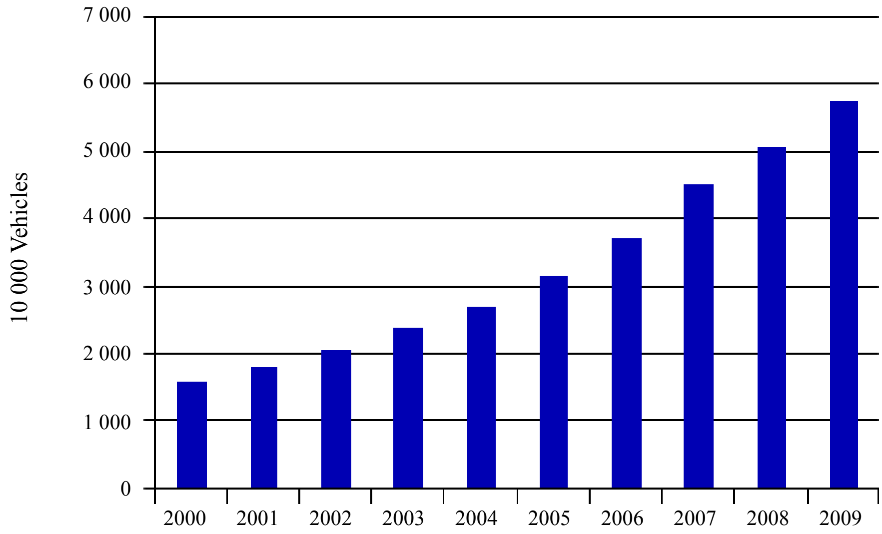

Figure 19 Number of automobiles on China's roads (2000—2009)

Source: China Energy Yearbook.

The three main options for reducing automobile emissions are to encourage a 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 20 shows international standards in gCO_2/km normalized to the "New European Driving Cycle" methodology. 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 third quarter of 2011.① 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.②

① ICCT, 2011. *Global Light-duty Vehicles: Fuel Economy and Greenhouse Gas Emissions Standards* www.theicct.org/info/documents/PVstds_update_apr2011.pdf

② Odysee, 2009. "Energy Efficiency Indicators in Europe" www.odyssee-indicators.org/reports/transport/transport09.pdf.

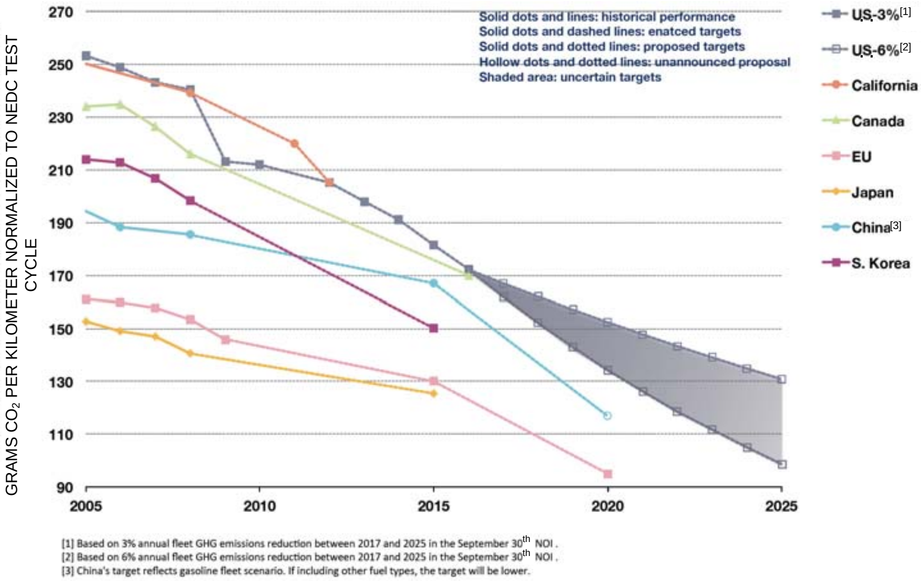

Figure 20 Evolution in vehicle emissions standards

Source: ICCT, 2011.

In the EU, an ambitious compromise deal was agreed in December 2008, despite industrial pressures caused by the financial crisis. This deal 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.① According to the FIA, using current projections of vehicle numbers, cutting global average automotive fuel consumption (litres of fuel /100 km) by 50% would avoid emissions by over 1 $GtCO_2$ a year by 2025 and over 2 $GtCO_2$ per year by 2050, and result in savings in annual oil import bills alone worth over USD 300 billion in 2025 and USD 600 billion in 2050 (based on an oil price of USD 100 per barrel).②

Further emissions savings can be made by substituting sustainable biofuels for petrol and diesel in internal combustion engines. However, biofuels are at the centre of an often heated international debate involving questions of energy security, climate change, food

① 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 for each gram exceeding the target.

② FIA, 2010. “50 by 2050”. www.fiafoundation.org/50by50/documents/50BY50_report.pdf prices, land use, biodiversity conservation and social development.① 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 analyses have suggested that estimates of biofuels-related carbon benefits generally fail to include emissions from land-use changes.② 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.③ 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 10% target for biofuels 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 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 that used in 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 emissions reductions. However the main technologies are not yet scaled up commercially and technical challenges remain. The impact on soil quality of growing second-generation biofuels is also under consideration. China is second only to the United States in terms of academic research and patenting applications in this area④ and biofuels company Novozymes is exploring the potential for commercialisation of second generation fuels in partnership with China Oil and Foodstuffs Corp., Ltd. (COFCO), China's largest oils and food importer and exporter, and China Petrochemical Corp (part of the major Chinese oil company Sinopec).⑤

In the last few years electric vehicles have increasingly come to be considered the most promising alternative to the internal combustion engine. Many developed countries and China have made commitments to deploy electric vehicles (see Table 7). The EV20 alliance

① Bernice Lee, 2009. "Managing the Interlocking Climate and Resource Challenges", International Affairs. November 2009

② Timothy Searchinger et al. 2009, "Use of US croplands for biofuels increases greenhouse gases through emissions from land-use change", Science 319: 5867, 29 Feb. 2008, pp. 1238–1240.

③ World Bank, World Development Report 2008: agriculture for development (New York, 2008).

④ Chemical Abstracts Service (2010). China Takes Lead in the Commercialization of Bioethanol. American Chemical Society www.cas.org/ASSETS/EC83F01563A74A51A1F651C3148A0F22/CASChemResearchReport6.23.10.pdf

⑤ China Daily, 2011. "Dancing to a different tune" (interview with the head of Novozymes). www.chinadaily.com.cn/cndy/2011-09/29/content_13814014.htm of companies announced in September 2010 that its members would add one million EVs to the roads by 2015, above the targets already announced by companies.

Table 7 Electric vehicle 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: 500,000 EVs deployed
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 deployed

Source: Foley et al., 2010.[①]

The key issues for scaling up electric vehicles is battery technology (rates of recharge and discharge, energy density and battery life); charging infrastructure; and the associated costs and financing options. Electric vehicles will only make a major dent in the internal combustion engine market when they compete more closely on price, and the upfront cost of an electric vehicle is currently high, with the battery being a major factor in this. While improvements in battery technology and a modest increase in manufacturing capacity are helping to bring down the costs, the battery remains problematic from the economic standpoint, both because of the upfront cost and because of its uncertain residual value when it is no longer useable.[②] In the short term, many governments are offering incentives that help reduce the cost of electric vehicles and companies are starting to offer a broader range of financing options to help spread the cost.

① Aoife Foley, Hannah Daly and Brian Ó Gallachóir, 2010. Quantifying the Energy & Carbon Emissions Implications of a 10% Electric Vehicles Target. www.kth.se/polopoly_fs/1.64178!Paper_B5_Foley.pdf

② The Climate Group. 2010. "Financing Electric Vehicles". http://www.theclimategroup.org/our-news/news/2010/10/28/financing-electric-vehicles/

Box 9 CO_2 emissions from electric vehicles in China
Electric vehicles in China would be charged on a power system still dominated by coal. This raises the question: would China be better off using efficient internal combustion engines in the medium term? Although it is a complicated picture, early deployment of EVs will probably result in a similar level of emissions as efficient internal combustion engine vehicles (ICEVs) and over the medium term they promise deeper reductions as the power sector becomes more efficient and switches to renewables and nuclear power. Today, the emissions from a pure electric vehicle are similar to the average ICEV sold in China. Based on projected emissions per unit electricity in 2020, an EV would result in about 130 gCO_2e/km, similar to the US proposed target for 2016 for ICVEs sold in that year.① But if electric vehicles are produced on a large scale, it may be fairer to compare them with the emissions performance of the new electricity capacity built to support them – and on this basis, Chinese EVs will be at parity with the relatively ambitious EU target for ICVE vehicles sold in 2020 – 95 gCO_2/km – as early as 2015. This is not to mention the potential benefit of using EVs as storage on the grid, reducing the need for carbon-intensive peak generating capacity.

4.4 Information and communications technology

Information and communications technology (ICT) is already an important driving force of the global economy, and will provide the tools and information necessary to improve environmental performance across and between other sectors in the economy. It also promises to open up whole new areas of resource and energy efficiency, for example by enabling the collection of data right along the supply chain.

The ICT industry can make an important contribution by limiting its own emissions. In China, ICT was responsible for about 2.5% of GHG emissions in 2007.② If the current trend of energy efficiency remains unchanged, by 2020 emissions from the ICT industry will reach 415 $MtCO_2$, accounting for 4% of total emissions.③ However, the major contribution of the ICT industry will be in enabling emissions reductions in other sectors. According to the Climate Group, these potential savings are about five times greater globally than the energy and emissions of the ICT industry itself. By 2020, ICT can reduce global emission by 7.8 $GtCO_2$, reducing emissions compared to business as usual by about 15%. The energy efficiency savings would amount to nearly 600 billion euros (USD 946.5 billion).

① This assumes that 10% additional emissions occur during upstream oil and processing and the same amount for transmission losses in the power grid. Importantly, this calculation is not based on a life cycle assessment of the vehicles. However, the life cycle impacts for both types of vehicles are typically relatively small compared to the operation-based emissions. See http://pubs.acs.org/doi/pdfplus/10.1021/es903729a Dominica Notter et al. 2010. Contribution of Li-Ion Batteries to the Environmental Impact of Electric Vehicles. Environmental Science & Technology. Vol. 44, No. 17, 2010

② Xie Mengzhe, *ICT's Potential contribution to China's achieving the development goal of low-carbon economy*, 2010

③ Ibid.

ICT will deliver energy savings and emissions reductions in a host of different ways. Some of the largest gains in the short term are summarized in the remainder of this section.

4.4.1 Smart logistics

By optimizing the logistics sector, ICT could reduce transportation-related emissions in the sector by 16% and its storage-related emissions by 27% worldwide. By 2020, the application of ICT in logistics could reduce the world's CO_2 emissions by 1.52 Gt, an equivalent of 280 billion euros (USD 441.7 billion). WWF and China Mobile found that smart technology in China's highway logistics could reduce the number of lorries travelling with empty loads from 30% to 15%. The emission reduction opportunities of smart logistics are estimated at up to 78 $MtCO_2$, 128 $MtCO_2$ and 207 $MtCO_2$ respectively in 2010, 2020 and 2030.[①]

4.4.2 Smart buildings

The construction industry ranks second to manufacturing worldwide in terms of energy consumption. Smart building technology is expected to reduce emissions by 1.68 $GtCO_2$ by 2020, equivalent to about USD 340.8 billion. China's buildings consume 4,000–5,000 kWh of electricity every year, 22%～24% of the total electricity generation, and electricity consumption per building area is 26–27 kWh/m^2, or 2–3 times that of developed countries. Because China is a relatively late entrant in this sector, companies in developed countries are the leaders of most core technologies and the market for smart construction products is also dominated by foreign enterprises. China's current focus on smart buildings is in R&D of advanced ICT, along with the rapid development of its domestic smart building industry.

4.4.3 Smart grid

In China, the smart grid concept includes everything from high-voltage direct current (HVDC) power lines to the use of storage technologies (including batteries in electric vehicles) and the integration of decentralized renewable energy technologies with the grid. The aim is to establish a next-generation power grid characterized by safety, reliability, economy, high efficiency and environmental protection. Analysis by the Task Force suggests that if China can largely complete the reform of the traditional grid to a smart grid by 2020, an amount of energy consumption equivalent to 220 Mtce can be saved compared with business as usual. This would be equal to emissions reductions of nearly 500 $MtCO_2$, 4.9 Mt

① WWF and China, 2010. Low Carbon Telecommunication Solutions China: Current Reductions and Future Potential. www.wwfchina.org/english/downloads/ClimateChange/China_Mobile_English%20summary.pdf.

sulfur dioxide and 2.2 Mt nitrous oxides (NO_x) can be avoided (see Table 8).

Table 8 Potential for avoiding energy consumption and emissions due to the smart grid

Specific links	Energy (Mtce)	Carbon dioxide (Mt)	Sulfur dioxide	NO_x
Line loss reduction	2.1	4.5	0.1	0.02
Fuel consumption for electricity generation reduction	61	129.3	1.3	0.6
Electricity consumption reduction	120	254.4	2.6	1.2
New energy and renewable energy	40	84.8	0.9	0.4
Electric vehicles	—	21	—	—
Total	223.1	494.0	4.9	2.2

Source: LCIS Task Force analysis

At present, China's smart grid is in the early exploration and piloting phase. Because the smart grid is heavily dependent on ICT, its future development is closely linked to advancement in this area. Key technologies include communications and sensor technology; accurate parameter-measurement technology for understanding the real-time operation of the grid; automatic control technologies; and finally, decision-support technology.

4.4.4 Smart work

"Smart work" means describes working with the assistance of advanced communications tools such as the internet to avoid rush-hour traffic jams, inflexible workplaces and numerous other business travel issues connected with traditional work patterns, creating economic benefits for enterprises and environmental benefits for the general public. According to projections, if 5% of commuters can start tele-working by 2020, 15% of business travel can be replaced by e-conferencing and as a result global emissions will be reduced by 100 $MtCO_2$.

4.5 Biotechnology

China is the leading developing country in the areas of life sciences and biotechnology and its industry and skills base continues to strengthen. In addition, the country has extremely rich biological resources. This is one sector in which developed countries have yet to develop a strong hold over the high end of the market. China's bio-industry has a relatively small gap to close in terms of technology, talents and the scientific research base.

Based on conservative projections, by 2020 China's bio-medicine market, broadly defined, will be worth RMB 4 trillion, bio-manufacturing RMB 1 trillion, bio-agriculture RMB 500 billion, bio-energy RMB 3000 billion and bio-environmental-protection RMB 100 billion; overall, the bio-industry market could be worth about RMB 6 trillion.

According to WWF, by 2030 the global industrial bio-manufacturing technology could find savings of 1–2.5 $GtCO_2$ annually.[①] In the medium term the sector has the potential to find transformative alternatives to the use of fossil fuels to produce heavy chemicals and plastics. In other words, it makes great strategic sense in terms of encouraging sustainable development, developing China's industrial economy, reducing reliance on oil resources and cutting carbon dioxide emissions to develop bio-manufacturing, increase the percentage of green, low carbon and renewable bio-chemical production, and reorganize material flows in the petrochemical industry.

4.6 Advanced materials and high-end equipment manufacturing

The "advanced materials" sector develops and supplies materials with superior performance and special functions as well as traditional materials with improved functionality. This includes materials with a range of different physical attributes, functions and applications. Innovative materials are essential for the development of the other emerging sectors. Solar power, for example, requires advances in polycrystalline silicon, and battery technology is the key to electric vehicles. Lightweight and strong new structural materials, including high-performance compound fibre materials and light metal materials (such as aluminium, magnesium, titanium and their alloys) can conserve energy and reduce emissions in a range of sectors such as aerospace, automobiles, communications, transportation, shipping, construction and other industries.

New materials are also needed to improve the quality of building materials, which largely determines their efficiency. Every year, about 2 billion m^2 of housing is constructed in China, while 70% of heat is currently lost from buildings through windows and exterior walls. If the current scale and level of energy consumption in construction remain unaltered, the annual energy consumption will be equivalent to 1.2 TWh of electricity and 410 Mtce by 2020, almost three times the current level.

① WWF, 2010. *Industrial Biotechnology More than green fuel In a dirty economy?* www.bio-economy.net/reports/files/wwf_biotech.pdf.

5 Recommendations

The key policies required to implement a low carbon industrialization strategy in China are set out in Table 9, separated into potential actions for the 12th and 13th Five-Year Plan periods.

Table 9 Policy priorities for LCIS during 12th and 13th Five-Year Plan periods

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

Five areas of policy have been identified by the Task Force as critical to the delivery of China's LCIS.

5.1 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 10. These are based on detailed analysis by the Task Force, taking into account the experience of China's industry during the "11th Five-Year Plan" 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 10 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 fibers kgce/t	743	18.4	23.3
Paper-making			
Paper and paperboard kgce/t	525	25.7	31.4

5.2 Scaling up support for seven emerging industries

The "12th Five-Year Plan" has identified seven emerging industries that could contribute 15% of China's GDP in 2020 and will play a key role in achieving a low carbon economy: The products and services of these sectors will contribute to reductions in energy intensity in the heavy industries.

Scaling up of these emerging industries, rightly considered a strategic priority, will require detailed sector-by-sector planning. These emerging sectors are: energy conservation and environment protection; new energy technologies; new energy vehicles; biotechnology; information technology; advanced materials; and equipment manufacturing.

A special fund should be set up by the central finance authority for the development of the emerging industries, integrating the various special funds for industrial development and R&D in China and bolstered by additional resources. The central government should set up a pilot fund targeted at the supporting infrastructure (such as the smart grid) needed for large-scale deployment of low carbon technology in key locations and other key projects for the emerging industries. Local financial authorities should also set up industrial development funds consistent with their priorities for these sectors.

The private sector will play a growing role in the expansion of the emerging sectors, and encouraging small and medium-sized enterprises (SMEs) and foreign firms to enter these sectors will be ever more important. It is critical to remove barriers to entry that are based on the size or geographical origins of companies, to encourage companies with technology prowess and strong environmental performance.

Tax incentives should be boosted to encourage private investment in the development of the emerging industries and to guide consumption. This will help companies to overcome high human capital and R&D expenses as well as to aid commercialization at the early stages of product development. Discounted loans, risk compensation and other policies should be used by government to encourage financial institutions to develop tailored solutions for the emerging industries.

China should encourage the use of innovative finance for low carbon projects, reducing the barriers to investment for small and medium-sized businesses in particular. Trust funds, private equity, venture capital, social capital and international carbon finance all have an important role to play in low carbon and emission- reduction projects. With the emergence of an emissions trading system, carbon financial products such as swaps, options and futures should also be developed.

5.3 A major push on low carbon innovation

Achieving both short-term technology improvements and medium-term strategic objectives requires the reinforcement of an innovation culture in China. Thinking beyond the 2020 target, it is clear that there is still be much to be done before China becomes a true low carbon economy; the focus will need to shift from carbon- intensity improvements to absolute reductions of greenhouse gases. The ongoing process of industrialization means that total emissions will have increased substantially by 2020. This will need to be addressed in the 2030s and the 2040s and must be the focus of long-term innovation.

China should raise its R&D budget so that low carbon technology takes a growing share of the overall R&D budget and climbs significantly in absolute terms. Large- scale projects that conserve energy, reduce emissions and demonstrate the potential of the low carbon transformation are also needed to bring innovative low carbon technologies to the mass market.

The time is right for a world-class national energy laboratory to be established in China, with the ability to support innovation from basic research all the way to demonstration and commercialization. This could play a similar role to the national laboratories for energy technology and renewable energy in the United States. With regards commercialisation, China can draw on the experience of the UK's Carbon Trust and Sustainable Development Technology Canada. The institute should be open to companies, universities and other research organizations.

Sectoral platforms are needed so that industry can work with government to develop joint solutions, for example on technology standards. Cross-sectoral hubs should also be established to facilitate exchanges between the different sectors – for example between the power sector, electric vehicle manufacturers and information technology providers. Scaling up the deployment of low carbon technologies will depend on bringing together technologies and systems from multiple sectors.

China should seek to strengthen international cooperation on technology and innovation. Given the scale of the challenge and the complexity of some technology systems, no single country or company can be a world leader in low carbon solutions without effective international linkages.

5.4 Effective regulation and technology standards

A "Top Runner" program should be introduced along the lines of the policy in Japan, covering a wide range of industrial, domestic and commercial technologies. Under such schemes, today's best available technology becomes the minimum standard for all products manufactured and imported by a given year in the future, at which point the process begins again – so that standards are continuously raised. To complement this approach the existing scheme of mandatory efficiency labelling should be expanded to cover many more products. A carbon footprinting methodology should also be established and promoted so that the life-cycle greenhouse gas emissions associated with products are visible to consumers. Table 11 shows the key regulatory measures that could be introduced during the "12th Five-Year Plan".

Table 11 Key regulatory measures and technology standards

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

Action is needed to ensure that when industrial assets are developed or upgraded they meet strict energy and emissions standards; from now on, regulators should refuse to examine projects and prevent their implementation if they have not followed a formal assessment procedure. Similarly, large-scale public and residential buildings should be subject to detailed assessment of their energy efficiency – and if they fail they should not be approved for development.

New or reformed laws and regulations are needed in a range of key areas including energy, natural resources and environmental protection. As a priority, China should introduce an energy law and a law on “Responding to Climate Change”, consistent with China’s situation, with the aim of encouraging utilization of clean energy and low carbon energy. Revisions to the existing Laws on coal, electricity, energy conservation and renewable energy are also needed to harmonize and simplify the legislative framework covering the relevant industries.

5.5 Energy pricing reform and green taxation

The system of energy pricing in China should be reformed to reflect market supply and demand, resource constraints and environmental impacts. Energy prices should be set by the market through competition. Where natural monopolies exist, clear rules should be set by regulatory authorities based on transparent cost and pricing information.

The external costs of energy development, conversion and utilization should be fully reflected in the prices of energy products; for example, the principle of making all costs visible applies to nuclear power (from the costs of nuclear accidents to decommissioning and waste management) as well as the coal industry and renewables sector.

China should aim in the medium term for an end to demand-side subsidies in the energy sector, with disadvantaged groups protected instead through the fiscal system, infrastructure development or other measures. In the near future, however, the priority should be to make invisible subsidies transparent and to replace the current system of cross-subsidization with a basic energy consumption subsidy for poor people in both rural and urban areas, supported by public finance.

China's tax system should be reformed so that environmental and resource pressures are taken into account, investment is channelled to green technologies and green infrastructure, and consumers are encouraged to buy green products. Green taxes should cover areas such as discharges of air and water pollutants and wastewater and solid waste management. Policy priorities for green taxation are set out in Table 12.

Table 12 Green fiscal policies

Support for energy conservation	Support for clean 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
Subsidy 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

The government should impose a carbon tax during the "12th Five-Year Plan" period to encourage investment in low carbon technology innovation and its large-scale deployment. The carbon tax should start from a relatively low tax rate (e.g. RMB 10 per tonne of CO_2) allowing time for China's industry to adjust, but then increase in step with economic development.

It is important that the tax level is predictable in terms of its implementation schedule and levels. Future tax levels should therefore be set by a transparent formula taking into account the domestic situation but also the need for coordinated international efforts to tackle climate change. The proposed levels for the carbon tax as assessed by the Task Force are set out in Table 13. These have been determined through a combination of modelling analysis and consultation with sector experts and the Ministry of Finance.

Table 13 Preliminary design of CO_2 tax rate

Tax rate	2012	2020
Carbon tax (RMB per tonne of CO_2)	10	40
Raw coal carbon tax (RMB per tonne)	19.4	77.6
Crude oil (RMB per tonne)	30.3	121.2
Gasoline carbon tax (RMB per tonne)	29.5	118
Diesel carbon tax (RMB per tonne)	31.3	125.2
Natural gas carbon tax (RMB per 1000 cubic metre)	22	88