

THE °CLIMATE GROUP

# CHINA'S CLEAN REVOLUTION II:

OPPORTUNITIES FOR A LOW CARBON FUTURE  
AUGUST 2009

If the 20th century was dominated by the West, the 21st will undoubtedly be the century of the East. Already in the last decade China and the countries of the Asia Pacific region have made a huge impact on our global economic growth, trade and employment. And China has led the way. Startling modern cities, a new breed of entrepreneurs and the magnificent 2008 Olympic Games are all testament to this leadership. During my ten years in office, China's economic growth and its mounting influence on world affairs were inescapable.

The other big trend of the early 21st century has been our growing understanding of the risk that climate change poses to us, with impacts that if left unchecked will seriously undermine our efforts to end poverty and sustain growth, maybe forever. Alongside this, there has been an incipient, but definitely noticeable, shift towards a lower carbon green economy. All around the world, businesses are investing in clean energy, low emissions vehicles and efficient new buildings and appliances.

This report, 'China's Clean Revolution II: Opportunities for a low carbon future', brings these two trends together, showing how China is fast becoming the global leader in this new range of low carbon products and services and highlights its huge potential for further growth.

It is essential that China realizes this potential. With world energy demand expected to grow by nearly half in the next twenty years, and its own use likely to double, the path that China chooses to meet this demand will have a crucial bearing on our ability to cut greenhouse gas emissions. And its capacity to provide a market for clean technologies and manufacture them for use elsewhere will determine the ability of the rest of the world to do so too.

China is now the world's largest emitter; it is also one of the countries – with its many poor and vulnerable communities – that will suffer most from climate change. Water scarcity is already an issue; coastal flooding would devastate some of its most important cities. The challenge for China, like the rest of the world, is to keep its economy growing while slowing and reversing the growth of its emissions.

This challenge is demanding but both achievable and exciting. We know that fully 70% of the emissions reductions we need by 2020 can come from technologies that are already in use. We also know that using more renewable energy and more efficient buildings, vehicles and appliances is good for growth and jobs. China's economic stimulus package recognizes this with close to 40% of the spending targeted at these sectors. The current 11th Five-Year Plan has ambitious goals for energy efficiency, renewable energy and forest protection. The ones in the 12th Plan are likely to be even more ambitious.

This report makes it clear that Chinese businesses are rising to the challenge, backed by government interventions and incentives to invest. Chinese companies are now among the world's leaders in wind turbine and solar panel manufacture, large producers of biofuels and are leading the development of electric vehicles. New steel mills and cement plants are now among the most energy efficient in the world and new buildings some of the most innovative. The phrases low carbon business opportunity, clean energy investment and green technology are on everyone's lips. But immense challenges lie ahead.

To beat climate change, we all can and must do more. As well as extending the technologies we already have, we need to speed up the development of important new ones, like carbon capture and storage, large scale solar power and smart grids that will all be essential after 2020. A new global climate agreement will set a route map for this to happen and for our journey to a prosperous low carbon 21st century. As one of the world's major economic powers, China will have to be at the forefront of this journey. This report shows that it can be.

**Rt Hon Tony Blair**

As the issue of climate change and the gap between the availability of conventional fossil fuel, such as coal, petroleum and natural gas, and our energy demands grows, the international community is having an increasingly heated discussion on the patterns of resource and energy use. Governments around the world are also re-examining their development strategies, and promoting low-carbon technology systems, through the development of renewable and new energy and energy efficiency optimization. The main objective is to address climate change through technological and institutional innovation.

In recent years, more and more countries have introduced incentive policies to promote the development of low-carbon technologies, around which a new wave of competition has been unfolding in many major developed countries. Some multinational corporations are tapping new business opportunities in a low-carbon future.

Climate change is an environmental issue. But more fundamentally, it is an issue of development. Only in the context of sustainable development can it be properly addressed. Sustainable development requires coordinating economic growth, social development, and environmental protection. Neither halting development to combat climate change, nor ignoring the issue of climate change in the pursuit of economic growth is advisable. Fundamental measures to meet the challenge of climate change are to establish new production and consumption patterns aligned with sustainable development, to optimize the energy mix, and to promote industrial upgrading.

After entering the 21st century, China is operating in a new development stage represented by the building of a Xiaokang (well-off) society and the acceleration of its socialist modernization. As outlined by the Sixteenth National Congress of CPC, it is China's goal to establish a Xiaokang society by 2020, through optimizing its economic structure and improving efficiency. China shall strive to quadruple its GDP against that in 2000, and significantly enhance its comprehensive national strength and international competitiveness. Meanwhile, it will continuously enhance its sustainable development, improve its ecological environment and the efficiency of resource use, and promote harmony between man and nature.

The new century has also witnessed some profound changes in the international situation: multi-polarization and economic globalization are finding their ways forward amid twists and turns; science and technology have been making continuous progress, and fierce competition is seen in terms of overall national strength. Both developed countries and many international organizations have increased their efforts in the development and use of alternative energy, trying to find their advantageous positions in a new round of international competition while reducing greenhouse gas emissions.

Faced with new development challenges and a new international situation, China is urged to make active adjustment to the connotation of its sustainable development strategy and tackle all of the potential problems with a historical and global perspective. China should plan ahead, develop its mid- and long-term development strategies in line with its own and international environmental requirements, and accelerate the implementation of its independent innovation strategies. All of these will help China to resolve contradictions faced by its development, to address global environmental problems, and to contribute in the building of a harmonious world.

Along with the penetration of efforts on energy-saving and emissions reduction in addressing climate change, China has made remarkable progress: China's installed wind power capacity is doubling annually; China has produced nearly 40% of the world's solar PV products; China has the world's largest raw material resource for bio-fuel; and China's auto industry is working to lead the world's new energy automotive industry. A number of large state-owned enterprises have proudly been entitled with 'World's No.1'; some private companies have found their footings in the international market; and energy service companies are playing an increasingly important role in China's energy market. However, as a developing country, China is still faced with many challenges, such as technological and financial shortages. In the context of globalization, Chinese enterprises should take on a broader, long-term vision and a pioneering approach, explore the road to green development in line with China's ambitions, and make a greater contribution to China's sustainable economic and social development.

In this report *China's Clean Revolution II: Opportunities for a Low Carbon Future*, there are specific analyses of China's climate change-related policies, commercial activities in the low-carbon tide, business opportunities under the dual motivation of policy and market, and the obstacles and challenges we are facing. I hope this report will be accessed and received by a wide audience, including policy-makers, entrepreneurs, scientists and the general public, whose work helps China save energy, reduce emissions and combat climate change, and will promote the development of low carbon technology and the construction of an eco-civilization in China.

**Liu Yanhua**  
Vice Minister, Ministry of Science and Technology of China

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In August 2008, The Climate Group produced a report entitled 'China's Clean Revolution',<sup>1</sup> which chronicled the astonishing growth of low carbon industries and policies in China, and highlighted the country's potential to become one of the largest forces in low carbon development. The interest in that report was so strong, and China's subsequent progress has been so rapid that, just one year on, an update is warranted. This report highlights the recent advances achieved and challenges encountered in China's clean revolution, and spotlights specific progress and opportunities in four key sectors: low carbon vehicles, energy efficiency, renewable energy, and efficient urban design and buildings.

## CHINA'S INCREASINGLY CENTRAL ROLE IN SOLVING THE CLIMATE CHANGE CHALLENGE

In recent years the scientific evidence on climate change has become increasingly clear: it is now almost universally accepted that, in order to minimize the risk of irreversible damage to our planet and our livelihoods, we need to strive to keep the average global temperature increase below 2°C. It is also widely recognized that, to achieve this, we will need to peak global emissions before 2020 and then reduce them by 50-85% below 2000 levels, setting interim targets along the way.

We also know which technologies we need to use – across transport, energy, buildings and industry – to achieve these targets. The challenge lies in developing, deploying and funding those technologies at the massive scale and rapid pace needed. While the already industrialized countries will have to lead the way in these efforts, achieving our global goals will require the participation of all countries and sectors.

China is now almost certainly the largest national emitter of carbon dioxide (CO<sub>2</sub>) – although its per capita emissions are still a fraction of the USA's and EU's, and below the global average. Less widely acknowledged is the leading role that China is already playing in producing the technologies needed to solve the climate change challenge. For example, China is the world's largest producer and consumer of solar water heaters, accounting for 50% of the world's total production and 65% of all installations. Mainland China supplies 30% of the world's demand for photovoltaic (PV) sets (Greater China, including Taiwan, 40%), and it has developed the first mass-produced plug-in electric hybrid car.

# 65%

65% OF ALL SOLAR WATER HEATER INSTALLATIONS ARE IN CHINA. THEY ALSO MANUFACTURE 50% OF THE WORLD'S UNITS.

This is just the start. There is much that Chinese and other world leaders can still do to ensure that clean technologies are ramped up at the scale, cost and innovation levels needed to contribute to substantial emissions reductions within and beyond China's borders. Chinese government policy, driven by a strategic vision of China's role in a low carbon world, has already been a key determinant of the country's clean revolution – and the government has put strong emphasis on clean development in the 4 trillion Yuan (US\$ 580 billion) stimulus package launched in response to the global economic downturn. It can afford to be bold in setting ambitious targets in forthcoming Five Year Plans and other policies.

In addition, a global deal on climate change would greatly increase China's impact in reducing world CO<sub>2</sub> emissions. For one thing, Chinese companies are in a position to supply and bring down the cost of the technologies needed by other countries to cut their own emissions, and a global deal involving all major players will help expand this market. Second, technology agreements as part of a global deal would provide some of the key external knowledge and systems needed to unlock the full potential of China's low carbon industries. There is also a major low carbon business opportunity within China, and encouraging participation by foreign companies in key areas could help spread risk, help overcome the technology, skills and financing gaps that some industries still face, and accelerate their development. For these foreign businesses there is also a huge potential in finance, consulting engineering, technology development and equipment manufacture, amongst others.

What then is the progress and potential in China's major low carbon industries?

## LOW CARBON TRANSPORT: THE STEEP ROAD AHEAD

Beyond its traditional reliance on bicycles and public transport, China has succeeded in scaling up a range of low carbon transport technologies. There are now more than 50 million electric bicycles and motorcycles in China, while energy efficient compact cars account for 60% of the country's auto market. In 2009, encouraged by the government, Chinese producers have delivered key advances in commercializing electric vehicle (EV) technology: Chery produced its first pure EV, while BYD unveiled the first all-electric car to reach a range of 400 km per charge. In key areas such as energy storage technology, China is already a world leader.

Chinese transport reached another milestone in January 2009, when car sales in China exceeded those in the US for the first time. China is now both the world's largest auto market and the third largest producer – but most vehicles are still powered by gasoline and diesel. Rapid demand growth creates an urgent imperative to accelerate the development of EVs, fuel-cell vehicles and other forms of low carbon transport: if current trends continue, the cars on China's roads will triple to 150 million by 2020 and will produce 20% of global CO<sub>2</sub> emissions by 2030.

To meet this challenge, government and industry will need a major push on several fronts at once, including strengthening research and development (R&D), putting clearer rules in place for licensing and insuring EVs, ramping up EV charging facilities and natural gas stations, and boosting consumer awareness of the advantages of low carbon transport – particularly important given that rising wealth is leading Chinese consumers to buy bigger cars.

**ENERGY EFFICIENCY IN INDUSTRY: RAPID ADVANCES**

As the 2008 report noted, the energy intensity of the Chinese economy has fallen by over 60% since 1980, and the government has set a goal of reducing it by a further 20% between 2005 and 2010. Energy efficiency measures in major industries such as metals, chemicals and cement are expected to save 240m tons of coal equivalent (tce) by 2010. For example, China is a world leader in harnessing the wasted heat from cement kilns and has begun exporting this technology. In 2009 the government announced additional measures as part of a plan for the revitalization of ten key industries: outmoded, high-energy production technologies are to be eliminated, and better resource use and recycling promoted.

# 240M

BY 2010 THE GOVERNMENT'S TOP TEN ENERGY CONSERVATION PROJECTS MAY SAVE AS MUCH AS 240 MILLION TONS OF COAL EQUIVALENT (TCE).

Although fossil fuels, notably coal, still provide the bulk of China's power, an aggressive push is underway to replace inefficient power stations with efficient super-critical technology. China is already one of the world's largest users of supercritical and ultra-supercritical generation technology, with 150 generation units already in operation.

Government policies including fiscal incentives and credit support are helping to shape an energy-saving market that could already be worth 800 billion Yuan (US\$ 117 billion) and which is expected to grow substantially over the next decade. China is already home to the highest number of clean development mechanism (CDM) projects in the world. Yet it is estimated that China will need to invest 1.8 trillion Yuan (US\$ 263 billion) a year to meet its energy conservation and emissions reduction goals; given the high cost of deploying clean technologies, innovative business and financing models will be needed to help meet this investment bar.

**RENEWABLE ENERGY: WORLD LEADER**

Complementing its efficiency gains in traditional energy sources, China is driving rapid growth in renewable energy. For example, growth in installed wind turbines is faster in China than in any other country, with wind power generation capacity topping 12 million kW in 2008 – a figure that is doubling each year. China is also the world's largest producer and consumer of solar water heaters, accounting for 65% of all installations – and 95% of core technology patents on solar water heaters were developed by Chinese companies. Penetration of photovoltaic (PV) solar power has also shown rapid growth, as have geothermal energy and biofuels.

The global economic downturn has hurt China's exports of renewable energy technologies and products and created new impetus to expand their domestic coverage. For example, the government introduced subsidies for building installed PV (BIPV) in early 2009. Such supportive national policies, together with continued technological innovation, have the potential to reduce costs of renewable energy significantly, greatly increasing its penetration across China and reducing dependence on highly polluting coal and imported fossil fuels.

**URBAN DESIGN AND SUSTAINABLE CONSTRUCTION: CITIES OF THE FUTURE**

China's Energy Conservation Regulation, Evaluation Standard for Green Buildings and a range of other laws, promote low-cost solutions to reduce the carbon requirements for buildings and the built environment. The government has set ambitious energy conservation targets for new buildings, promoting low carbon building materials and renewable energy, especially solar. Many successful low carbon buildings, for residential, commercial and public use, have been completed, with several entire 'eco-cities' in advanced stages of planning. The government has also announced a large-scale promotion project for energy efficient lighting, with the aim of distributing 100 million subsidized lights in 2009.

Although China's hitherto booming property market is currently in a slump, growth is expected to resume, with total floor space, currently at 40 billion m<sup>2</sup>, expected to reach 70 billion m<sup>2</sup> by 2020. The slowdown creates an opportunity for increased emphasis on low carbon urban design and building standards, including by extending regulations, improving public awareness, reducing costs, and attracting private sector capital.

**ACHIEVING CHINA'S LOW CARBON POTENTIAL**

The 2008 report found that 'China and its new generation of low carbon entrepreneurs are already seeing significant economic benefits as a result of their push into the low carbon economy'. Just one year later, these entrepreneurs have moved well into the mainstream of China's economic development. Although there are major challenges ahead, China has demonstrated that it has the capacity and determination needed to achieve a rapid, large-scale transformation to low carbon ways of building, producing, and consuming. Achieving such a transformation will take continued leadership from China's government and the support of a global deal on climate change. The benefits, in terms of avoided climate change as well as economic development and energy security, will be tremendous.

In 2008, The Climate Group produced a report called 'China's Clean Revolution'.<sup>1</sup> The report came as a surprise to many who were unaware of the progress China is making towards a low carbon economy, in terms of low carbon policies and innovation. This report builds on the earlier one, reflecting the rapidly changing Chinese economy, providing greater detail and focusing on four areas with significant emissions reduction potential: low carbon vehicles, energy efficiency, efficient urban design and buildings, and renewable energy. It is designed to give greater insight into the drivers, growth and obstacles to key components of China's low carbon development.

In doing this, 'China's Clean Revolution II' draws on a wide range of sources, including government reports, independent academic analysis, news reports, interviews and informal conversations. While every effort has been made to present a balanced account with information corroborated where possible, some evidence – in particular the most recent information – is inevitably circumstantial. Any errors are the sole responsibility of The Climate Group.

**OPPORTUNITY FOR GROWTH**

After 30 years of unparalleled economic change, China is confronted by global financial recession and the challenge of dealing with climate change. The sheer scale of growth in China will require energy resources that outstrip available conventional sources. Meanwhile, climate change threatens Chinese lives and livelihoods. But climate change also brings China the potential to develop and market green technology solutions.\* China has already made more progress than many would have thought, providing the world with both a challenge to match its efforts and the opportunity to invest and benefit from its green success.

China's trajectory towards becoming an important global hub for low carbon investment, innovation and growth in coming decades has already begun. Its progress in the industrialization of low-carbon technologies (to reduce global CO<sub>2</sub> and the other greenhouse gas emissions that are the cause of climate change) will help to reduce the growth of its own emissions, and also provide options that will help other countries reduce their emissions. At the same time, these technologies and practices will contribute to China's economic growth, as part of China's current model for development, which seeks to find opportunities for economic growth and recovery through new, 'greener' domestic development. In this, China will utilize the potential of its big domestic market for low carbon products and services, to be able to reduce the costs of these products and services on the international market.

Chinese decision-makers are adjusting their national development strategy to provide a greater focus on low carbon opportunities, while playing a greater role in the global move towards a low carbon economy. One goal is to improve the image of China in the international negotiations on climate change taking place under the UNFCCC, while also benefiting China from the sale of emissions reductions under the Clean Development Mechanism. In many cases, low carbon technologies are also more cost effective, providing an economic incentive for their adoption.

The government of China is keenly aware that it is not sustainable to base its development exclusively on intensive use of fossil fuels, in the face of dwindling on and offshore reserves of coal, petroleum and natural gas. This is a time of transition for China, which is still heavily dependent on such sources, especially coal. So while its reliance on carbon intensive sources of energy will continue for the foreseeable future, the country is both looking to use these supplies more efficiently and diversifying into alternative renewable resources.

Although it is both essential and laudable that countries like China take the lead in shifting to a low carbon economy, true progress in addressing global climate change can only be achieved if the US, China and other major economies work together. At the core of such cooperation must be a mutual acknowledgment of the political and economic realities faced by different countries. To that end, how the US and China, for example, position themselves in the international negotiations will depend largely on how the US interprets the progress in China, as well as the opportunities and challenges of such a large developing country with so many resources and such a large population. This will affect the decisions made at Copenhagen at the end of 2009, and through that, on global sustainability.

\*McKinsey's Cost Curve for Greenhouse Gas Reduction study in 2007 shows about 75% of greenhouse gas abatement could be done using either non-technological measures, or currently available and already mature technologies. In addition, in its full life cycle, about 25% of abatement potential requires no cost, or even negative cost. A great many low carbon technologies have proven to be technologically viable and economically reasonable.

**POLITICAL WILL**

There is growing domestic policy support for a low carbon economy to support business and consumer decisions. The central government has shown its resolve through a number of watershed laws and programs, including China's National Climate Change Program, China's Scientific and Technological Actions on Climate Change and the white paper, 'China's Policies and Actions on Climate Change'. Meanwhile, the Energy Law, Energy Conservation Law and Renewable Energy Law, together with supporting regulations and standards, seek to give effect to the government's policy on low carbon development.

The government recognizes the importance of guidance and restrictions and has the capacity to enforce these. There is already an overall structure in place comprising regulations, administrative measures, guidelines and directives to turn China's larger objectives into more specific, manageable, and reachable targets. There is also a high level of intensity in its development of policies and regulations. Energy conservation policies and regulations are one example: The country made the '2010-20% -10%' goal on energy conservation and emissions reduction a part of its 11th Five-Year Plan in 2005. Since that time, more than 20 policies, laws, measures, standards and guidelines have been introduced. This would have been unthinkable in the past. One of the main reasons for the swifter establishment of these policies and measures, and their rapid implementation, is the joint effort by its policy makers, including the National Development and Reform Commission (NDRC), the Ministry of Science and Technology (MOST), and the Ministry of Finance (MOF).

Recognizing the great potential of these technologies, the government has placed equal emphasis on conserving energy, emissions reduction, renewable forms of energy development and low emission vehicles, including pure electric vehicles in its 4 trillion Yuan (US\$ 586 billion) economic stimulus package.

**INNOVATION IN TECHNOLOGIES AND FINANCING MODELS**

Many Chinese enterprises have joined the search for low carbon technologies, through research and development (R&D) and the installation and promotion of green technologies. This development is often supported by the growing set of stringent laws and regulations in China, by its growing technological ability and by the continued exploration of finance mechanisms and business models.

Ongoing innovation holds the key to finding solutions to climate change and enabling a shift to a low-carbon economy. In the autumn of 1986 following a long and heated debate, Plan 863 (the National High Technology Research and Development Program) was officially adopted, opening a new era for technological innovation to support China's national development. As a result of this Plan, many companies both large and small have been undertaking R&D and the deployment of low carbon technologies.

For example, the Huaneng Group, China's largest power enterprise, is investing heavily in clean coal technology R&D. It is also examining sources of renewable energy such as wind and solar power. Huaneng has been the forerunner of many technologies in China: the first to have a supercritical generation unit; the first to have an ultra-supercritical unit; the first to have a carbon capture and storage (CCS) demonstration project; and the first to export power generation technology to the US.

**THE ROLE OF SMES IN RENEWABLE TECHNOLOGIES**

In spite of their lack of capital, technology and human resources, small and medium-sized enterprises (SMEs) in the private sector have become a significant part of the domestic market, and in some cases have participated in the global market. Notable in this respect are: Goldwind Science & Technology, Suntech Power, BYD Auto, Chery Automobile and the Tianguan Group, to name just a few. BYD, for example, has made the remarkable transformation from being a maker of cell-phone batteries into a car manufacturer, benefitting from its R&D and production capabilities that were developed in the battery industry. Because it was difficult for SMEs to enter traditional, capital-intensive industries like thermal power generation, emerging markets in renewable energy have provided great opportunities, especially in wind and solar power, biofuels, low emissions including electric vehicles and through energy management contracts (EMC). In terms of EMCs, Energy Service Companies (ESCOs) are contracted to provide energy management and design and project development solutions to save energy through increased efficiency and decreased power and energy costs.

These markets are relatively new, frequently immature and pose various challenges. But the flexibility of SMEs enables them to be more proactive, adaptive, responsive and sensitive to market trends and so take advantage of emergent market opportunities.

Intellectual capital is growing. Rapidly improving conditions in higher education and the increasing attractiveness to young people worldwide means that the numbers of engineers in China are increasing. This growing resource of talent will contribute to China's innovative technological role. Also, during the current world financial crisis, Chinese companies are becoming more active in mergers and acquisitions around the world. At the same time, they are finding international partners and obtaining advanced technologies.

With these developments, China can, in the long run, become a major center of production and innovation, and transform itself from an importer into both an importer and exporter of technology.

#### OBSTACLES TO CHINA'S LOW CARBON FUTURE

**TECHNOLOGY GAPS:** Although investing widely in independent R&D, China still finds itself downstream of industrial flows. One example is wind power. In spite of being the fastest growing renewable energy in China, bottlenecks remain. China is able to manufacture wind turbines that are below 1.5 MW, but still cannot produce larger turbines or key components such as bearings, gearboxes and control systems.

China lacks expertise in 'hard' technologies like design, production and manufacturing as well as in 'soft' skills such as regulation, management, standards and monitoring. For example, connecting wind and solar PV power to a grid has been delayed in China for some time, inhibiting scaled growth of wind and solar power. The absence of a smart grid is one of the main reasons for this difficulty, partly because of the lack of experience in developing smart power equipment and appliances, but also because of the absence of a smart market and of smart regulations.

**EXTERNAL FINANCING DEFICIT:** Research by McKinsey and Company indicates that financing China's green economy could require capital of 40 trillion Yuan (US\$ 5.8 trillion) by 2030<sup>2</sup>. This would require an annual investment of 1.8 trillion Yuan (US\$ 263 billion). But where will this money come from?

In increasing its spending and investment, the Chinese government has found many new sources of finance, which include green credit by banks, EMCs, the clean development mechanism (CDM) and cooperation with global financial institutions like the World Bank's International Finance Corporation (IFC), the KfW Bankengruppe and the Asian Development Bank (ADB). China has even started to develop domestic environmental exchanges that put climate change at their core.

Yet, these efforts have so far produced only limited results. IFC's China Utility-Based Energy Efficiency Finance Program (CHUEE) is one example. It has been very successful for a program of its kind, providing 97 loans to China by the end of 2008, worth 3.3 billion Yuan (US\$ 483 million), to cut 9.7 million tons of carbon dioxide emissions. Truly an amazing achievement – but just one step on the road to raising the 40-45 trillion Yuan (US\$ 5.9 – 6.6 trillion) needed.

Spurred by international markets and government policies, Chinese businesses have expanded successfully into low carbon sectors such as property, renewable energy, energy conservation, and clean vehicles. The scale of the opportunity is clearly huge, but a number of obstacles remain, including technology development, skills and capital investment. Overcoming these will require further support from government and building partnerships with foreign companies, governments and multilateral bodies. A successful climate change agreement in Copenhagen would provide a strong foundation for this kind of collaboration.

**CHAPTER 1:  
LOW CARBON  
VEHICLES**



Globally, the transport sector is the largest source of CO<sub>2</sub> emissions, and there is a consensus that industrialization of low carbon vehicles is a key strategic option to reduce emissions. This imperative is just as strong in China – now the world’s largest auto market.

- China recognizes that its auto industry – which supports 36 other industries and millions of jobs – must invest in low carbon transport solutions to survive and prosper.
- China is committed to the development of electric vehicles (EVs) and other low carbon vehicles, and the domestic auto industry has already launched several models.
- The number of electric bicycles and motorcycles in China now exceeds 50 million, providing a good starting point for the industrialization of EVs, while China is already a world leader in key areas such as energy storage technology.

However, several challenges must be addressed if wide-scale production of low carbon vehicles is to be achieved.

- R&D input in Chinese auto makers still lags behind the international average.
- Consumer awareness is weak.
- Important issues such as EV safety and battery disposal must be addressed.
- Standardization – or the lack of it – is still a major obstacle to the development of the sector.

Beyond its traditional reliance on bicycles and public transport, China has succeeded in scaling up a range of low carbon transport technologies. There are now more than 50 million electric bicycles and motorcycles in China, while energy efficient compact cars account for 60% of the country's auto market. In 2009, encouraged by the government, Chinese producers have delivered key advances in commercializing electric vehicle (EV) technology.

However, most vehicles on China's roads are still powered by gasoline and diesel. Rapid demand growth creates an urgent imperative to accelerate the development of EVs, fuel-cell vehicles and other forms of low carbon transport: if current trends continue, the cars on China's roads will triple to 150 million by 2020 and will produce 20% of global CO<sub>2</sub> emissions by 2030.

This chapter discusses the rapid growth of China's auto industry, the steps being taken by the government to promote the uptake of low carbon vehicles, early successes in developing and manufacturing these vehicles, and challenges that will need to be addressed if they are to be rolled out at scale.

#### IN THE FAST LANE: THE GROWTH OF CHINA'S AUTO INDUSTRY

After 30 years of reforms, China has become the world's largest auto market and the third biggest auto producer.<sup>3</sup> In January 2009, Chinese auto sales exceeded those in the US for the first time, at 790,000 versus 668,000.<sup>4</sup> In China, 80% of the people buying a car are doing so for the first time.<sup>5</sup> In February 2009, Chinese production and sales reached 807,900 and 827,600 units respectively, representing year-on-year growth of 23.08% and 24.72%. The number of passenger cars smaller than 1.6L shows a growth rate of 18.78% and accounts for a 7.7% growth in the market share.<sup>6</sup> In 2009, production and sales in China's auto market are both forecast to exceed 10 million. By 2030, China is projected to have 287 million automobiles on the road, or about 30% of the world's total; China will also surpass the US to become the largest auto market in terms of value.<sup>7</sup>

The auto industry is a significant element of China's industrial economy, supporting industries up and down the value chain and contributing significantly to the country's GDP.<sup>8</sup> Directly or indirectly, the auto industry affects 11% of the entire working population. In 2007, 2.91 million people in China were working in the auto industry, and 30 million were employed in related industries, accounting for 2.31% of GDP. One report from the State Council's Development Research Center says that the auto industry's demand from upstream industries is equal to more than twice its own share of the market, resulting in a three-fold impact on the economy.<sup>9</sup>

In this context, the negative impact of the global economic downturn on worldwide vehicle sales has been of serious concern in China. In its response to the downturn, the Chinese government is actively promoting the development of low carbon vehicles.

#### THE IMPERATIVE FOR LOW CARBON VEHICLES

The total number of automobiles on China's roads is now 50 million, which gives a per capita figure that is one-third of the world average. These vehicles account for 60% of the country's petroleum consumption.<sup>10</sup> If we go by the current growth rate and fuel consumption pattern, by 2020 the number of cars on China's roads will exceed 150 million and will burn up more than 250 million tons of petroleum per year.<sup>11</sup>

It does not take much effort to imagine what the pressure on natural resources and the environment would be if the majority of this fleet were still to be powered by gasoline and diesel – by 2030, China would have to import 6.2 billion barrels of oil in total and its cars would contribute 20% of global CO<sub>2</sub> emissions.<sup>12</sup>

Energy efficiency and emissions reduction are essential for the auto industry's long term survival and success. There is little room to improve traditional fuel production, and better road-planning and traffic management will not make enough of a difference. So, to further reduce emissions, China will need to shift to low-emission or zero-emission fuel and energy sources. Hybrid and pure electric cars, as well as fuel-cell vehicles, will be crucial.

Against this backdrop, the Chinese government has made the development of low carbon vehicles an important priority. In 2009, the government introduced the Adjustment and Revitalization Plan for the Automotive Industry, with the aim of promoting the independent, innovative development of energy-efficient, low-emission and compact vehicles. In addition to a direct 5 billion Yuan (US\$ 732 million) subsidy, the Plan cut sales tax from 10% to 5% on vehicles with engines below 1.6L, abolished road maintenance fees, dropped a fuel tax under discussion for more than 14 years, and launched a demonstration project aimed at putting 1,000 EVs on the road in each of ten selected Chinese cities before the end of 2009. The government has allocated 20 billion Yuan (US\$ 2.9 billion) over the next three years specifically to promote the development of low carbon vehicles, with a focus on battery-charging stations and grid construction. It has also announced an array of further measures due this year to promote energy-efficient and low-emission vehicles (Chart 1).

#### CHART 1 – MEASURES IN 2009

JANUARY	AUTOMOTIVE INDUSTRY ADJUSTMENT AND REVITALIZATION PLAN
	JANUARY 2009 – DECEMBER 2009 CUTTING PURCHASE TAX FROM 10% TO 5% FOR VEHICLES WITH ENGINES UNDER 1.6L
MARCH	MARCH 2009 – DECEMBER 2009 5 BILLION YUAN – LUMP SUM GOVERNMENT SUBSIDY FOR FARMERS WHO TRADE IN THEIR OLD TRICYCLE CARS AND LOW-SPEED TRUCKS FOR LIGHT-CARGO TRUCKS OR MINI BUSES WITH ENGINES BELOW 1.6L
JUNE	POLICIES ENCOURAGING PURCHASE OF NEW ENERGY VEHICLES REVISE GOVERNMENT PROCUREMENT VEHICLE RULES
OCTOBER	ESTABLISH FUEL ECONOMY STANDARDS AND RELATIVE TAXES
DECEMBER	ESTABLISH INFRASTRUCTURE PLANS FOR NEW ENERGY VEHICLES

With strong encouragement from the government stretching back more than a decade, China's auto industry has become a leader in electric vehicles (EVs), for example being the first to develop a mass-produced plug-in electric hybrid car. China's auto industry thus has a key role to play in helping reduce the carbon emissions of the world's auto fleet – a crucial contribution, given that transport accounts for 57% of the world's petroleum consumption<sup>13</sup> and that, on average, each conventional vehicle emits 5,000 kg of CO<sub>2</sub> per year.

From 2008 to 2015, the global hybrid electric vehicle (HEV) market could grow at an annual rate of 12%, representing an important opportunity for China's industry.

By 2030, if EVs and other low carbon vehicles account for 20-30% of China's auto sales, the domestic market for low carbon vehicles could be worth between 700 billion and 1.5 trillion Yuan (US\$ 102 billion and 220 billion). In this scenario, China's domestic battery market alone could be worth 150 to 400 billion Yuan (US\$ 22 to 58 billion),<sup>14</sup> while the infrastructure needed for charging those batteries could cost another 5 to 10 billion Yuan (US\$ 732 million to 1.5 billion), by 2020.<sup>15</sup>

#### CHINA'S LOW CARBON VEHICLE SUCCESS STORIES

The growth of China's car industry is connected with its development of low carbon vehicles. In September 2008, US investor Warren Buffett's US\$230 million investment in BYD, gave the Chinese automaker the cash and credibility it needed to pursue its ambition of making a 'green' car. (See Box: BYD – from cellphones to batteries to cars). In January 2009, BYD's e6 and F6DM made an appearance at the North American International Auto Show in Chicago. The BYD e6 is the first car in the all-electric category to reach a range of 400 km per charge. It seats five.

In February 2009, Chery's first pure EV, the S18, rolled off the assembly line. It reaches a top speed of 120 km/hour and has a range of 120-150 km per charge.<sup>16</sup> In March, the Zotye 2008EV passed one of the public security bureau's toughest tests to become China's first roadworthy EV.

Although independent brands are still weak and immature compared with their international counterparts, especially in the case of conventional models, China stands at the starting line alongside its western competitors in the area of EVs.

According to a Ministry of Science and Technology (MOST) plan, 10% of China's new vehicles will have to be energy-efficient or low carbon models by 2012. This could lead to 1 million low carbon vehicles on China's roads within this timeframe, which would save 780 million liters of petrol, reduce CO<sub>2</sub> emissions by 2.3 million tons and NO<sub>x</sub> emissions by 78 million tons. It would also mean 50 to 100 billion Yuan (US\$ 7.3 to 14.6 billion) in sales (if the average price of a car is around 50,000 to 100,000 Yuan or US\$ 7,300 to 14,000).<sup>17</sup>

Technological advances in China's auto industry make these targets achievable. China's auto manufacturers can now produce a variety of new models using compressed natural gas (CNG), improved petroleum/diesel, as well as electric power. China has world-leading battery production capabilities, notably the BYD's ET-Power battery – essential to the successful and cost-effective development of EVs.

#### BYD – FROM CELL PHONES TO BATTERIES TO CARS

Even in the worsening global economic environment, sales by Build Your Dream (BYD) grew strongly in January 2009 to 24,107 vehicles, an 80% year-on-year increase and a 40% month-on-month increase.<sup>18</sup> BYD has always been a front-runner in the EV race. By the end of 2008, its first mass-produced plug-in electric hybrid car, the F3DM, had rolled off the assembly line, at least a year ahead of similar efforts in the US and Japan. This and its e6 models have secured the future of BYD and China in the global auto industry.

Wang Chuanfu, founder and chairman of BYD, recently announced a 2009 sales target of 400,000 units. In addition, Wang said that BYD would start sending EVs to the North American market in 2011. Previously, he had said his ambition was to become China's No. 1 EV manufacturer by 2015, and the world's top by 2025: "We have every confidence in surpassing GM and Toyota and other global auto makers in electric-vehicle technology."

BYD is already the world's second largest mobile battery producer, with an edge and core competence in battery technology. The newest battery, ET-Power, represents a breakthrough in volume, safety and cost. A lithium iron phosphate battery-powered vehicle like the F3e costs 500,000 Yuan (US\$ 73,000), but with the ET-Power this can be brought down to 160,000 Yuan (US\$ 23,000).

It only took ten years for BYD to grow from 2.5 million Yuan (US\$ 366,000) in capital to 30 billion Yuan (US\$ 4.4 billion). By almost doubling its size every year, BYD has become the world's leading integrated mobile phone parts provider as well as a significant player in China's auto market. A single model, the F3, has had excellent sales – over 100,000 vehicles to date.

#### CHALLENGES ON THE ROAD AHEAD

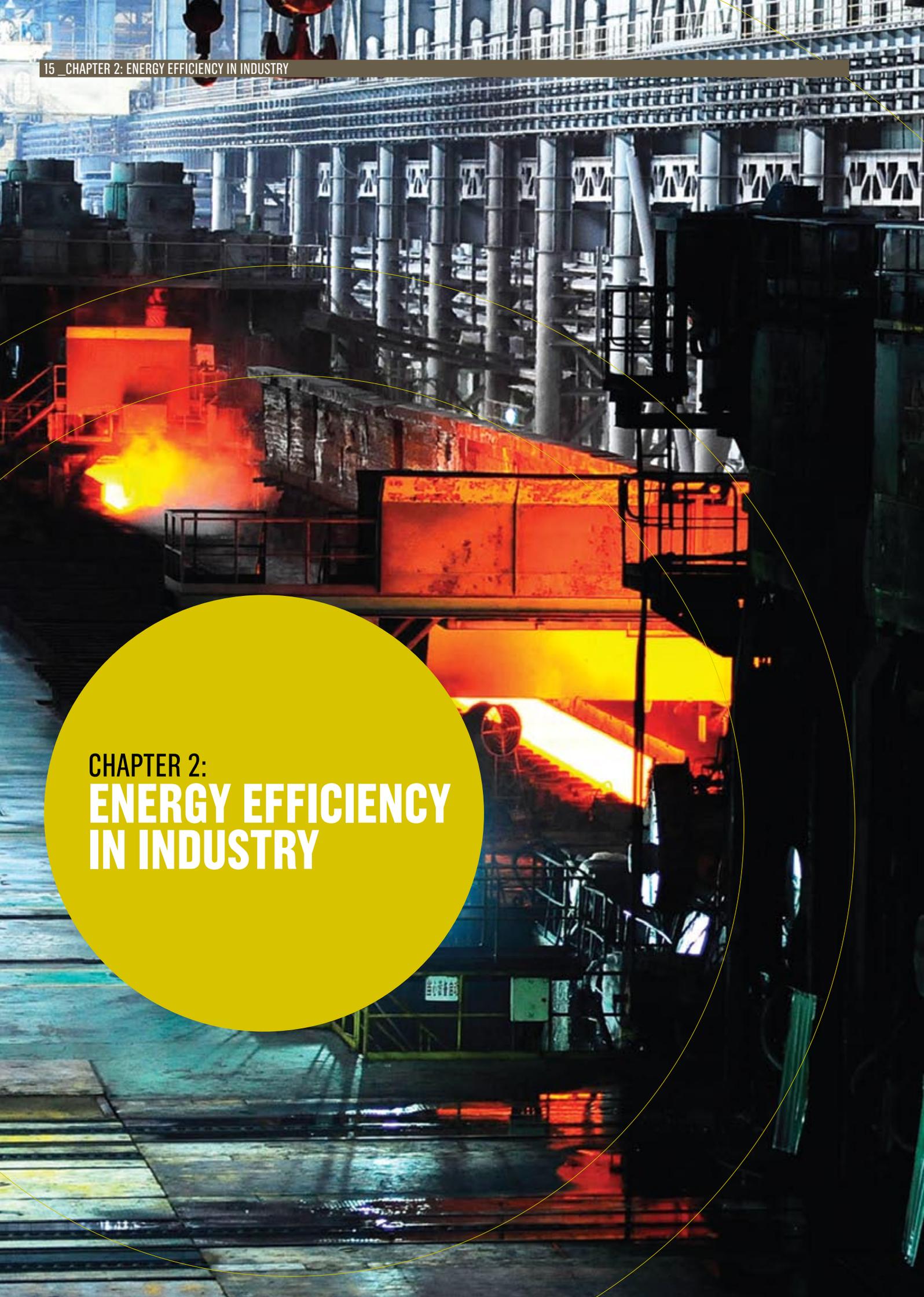
China's young auto industry faces considerable challenges ahead. There are growing pressures to upgrade products and processes, shrinking overseas demand, trade protectionism issues, technology gaps, low added value and the fluctuation in the price of raw materials to deal with.

Despite the remarkable achievements, it could take decades for new technology to mature, especially one that involves a totally new power source. There is a lack of charging facilities for EVs and natural gas stations even in major cities. This discourages potential purchasers of low carbon vehicles, but the very high cost of installing this infrastructure means that finding investors is difficult, particularly in the current economic downturn.

All aspects of its renewable car industry raise important issues to be addressed, requiring substantial R&D for development and to deal with other issues, such as safety, maintenance and battery disposal. Chinese auto makers' R&D levels still lag far behind the international average and to meet international standards, China's renewable cars will have to improve many of their components.

Although there are many policies in place, China's auto industry still needs more certain standards and rules. For example, EV manufacturers continue to encounter various problems with insurance companies and local transportation bureaus, simply to get EVs on the road.

Consumer behavior is another challenge, as the buying power of Chinese households grows. The government's goal is that engines below 1.5L should have a 40% share of the market and engines below 1L a 15% share, but Chinese consumers are moving in the opposite direction. In 2004, compact cars with an engine of less than 1.3L had 18.6% share of the market. Then the figure began to slide: 12.6% in 2005, 8.6% in 2006 and 8.3% in 2007. Moreover, the average engine size went up by 11%, from 2007's 1.68L to 2008's 1.86L.<sup>19</sup> Behavioral issues raise challenges. At the end of 2008, 129 million vehicles, or 76% of vehicles in China, were privately owned, an increase of 6.4% over the 2007.<sup>20</sup> Changing the habits of so many will not be easy.

A photograph of a steel mill interior, showing a complex network of pipes, walkways, and structural beams. In the center-left, a bright orange and yellow glow emanates from a furnace or ladle, indicating molten metal. The scene is dimly lit, with the primary light source being the intense heat of the industrial process. A large, semi-transparent yellow circle is overlaid on the lower-left portion of the image, containing the chapter title.

**CHAPTER 2:  
ENERGY EFFICIENCY  
IN INDUSTRY**

China's burgeoning industries consume substantial amounts of energy and are responsible for a major part of the country's CO<sub>2</sub> emissions. The government has set a goal of reducing the energy intensity of industry by 20% between 2005 and 2010, and has introduced an array of policies and regulations to support this goal.

Energy efficiency measures in major industries such as metals, chemicals and cement, supported by a variety of new technologies, are expected to save 240 million tons of coal equivalent (tce) by 2010, and have generated significant long-term energy-savings for enterprises.

This energy efficiency drive requires substantial investment and has already created a large energy-savings market, which could already be worth 800 billion Yuan (US\$ 117 billion). Innovative business and finance models will be needed to provide investment, technology and expertise.

To sustain a fast pace of energy efficiency improvement, China will need to raise awareness of the potential economic benefits, particularly amongst business owners who see such projects as a cost and not an investment. This will have to be supported by creative financing mechanisms and investment in technology development to bring costs down.

As the 2008 report noted, the energy intensity of the Chinese economy has fallen by over 60% since 1980, and the government has set a goal of reducing it by a further 20% between 2005 and 2010. Energy efficiency measures in major industries such as metals, chemicals and cement are expected to save 240 million tons of coal equivalent (tce) by 2010. For example, China is a world leader in harnessing the wasted heat from cement kilns and has begun exporting this technology. In 2009 the government announced additional measures as part of a plan for the revitalization of ten key industries: outmoded, high-energy production technologies are to be eliminated, and better resource use and recycling promoted.

Although fossil fuels, notably coal, still provide the bulk of China's power, an aggressive push is underway to replace inefficient power stations with efficient super-critical technology. China is already one of the world's largest users of supercritical and ultra-supercritical generation technology, with 150 generation units already in operation.

Given China's major and growing role as a center for world manufacturing, achieving greater energy efficiency in industry is an imperative not just for the competitiveness and energy security of the domestic economy, but also in global efforts to reduce CO<sub>2</sub> emissions. Government policies including fiscal incentives and credit support are helping to shape a substantial energy-saving market, but innovative business and financing models – and the knowledge and resources of foreign companies – will be needed if China's full energy efficiency potential is to be met.

This chapter highlights the Chinese government's strong drive for energy efficiency in industry, and sets out the major investment needs, business opportunities, and financing options to achieve energy savings. It then surveys China's major energy consuming industries – iron and steel, non-ferrous metals, chemicals and petrochemicals, and cement – and highlights the key technologies enabling energy savings in each of them. Finally, it assesses the challenges that must be overcome if China's industrial energy efficiency potential is to be met.

#### GOVERNMENT POLICIES AGGRESSIVELY DRIVE ENERGY EFFICIENCY

In support of its aggressive '2010-20%' energy efficiency goal, the government issued a range of strict regulations of industry, strengthened institutional and R&D capability, and launched an energy-savings plan for China's top 1,000 energy-consuming enterprises. The government's ten key energy conservation projects are expected to save 240 million tce by 2010 (Table 1).

# 240M

BY 2010 THE GOVERNMENT'S TOP TEN ENERGY CONSERVATION PROJECTS MAY SAVE AS MUCH AS 240 MILLION TONS OF COAL EQUIVALENT (TCE).

TABLE 1 – KEY ENERGY CONSERVATION PROJECTS<sup>21</sup>

KEY ENERGY CONSERVATION PROJECTS	GOAL (IN MILLIONS OF TCE)	EMISSIONS REDUCTION	MARKET ASSESSMENT IN BILLIONS OF YUAN (US\$)
COAL-FIRED INDUSTRIAL BOILER (KILN) TRANSFORMATION	41.60	2.20M TONS OF SO <sub>2</sub>	167 (24)
REGIONAL CHP	–	–	50M KWH*
USE OF RESIDUAL HEAT AND PRESSURE	30.00	–	45 (6.58)
CONSERVATION OF, AND ALTERNATIVES TO, OIL	80.00	–	400 (59)
MOTOR SYSTEM ENERGY CONSERVATION	20BN KWH	–	20 (2.9)
ENERGY SYSTEM OPTIMIZATION	8.14–8.39	19.98–20.37M TONS OF CO <sub>2</sub>	21.84–23.79 (3.20–3.48)
BUILDING ENERGY-SAVING	100	–	3336 (488)
GREEN LIGHTING	14.00	7.30M TONS OF CO <sub>2</sub>	2.2
*NO MONETARY DATA AVAILABLE			

By 2009, China had already made an effort to eliminate outmoded production and pursue foreign investment to upgrade its industrial structure and its processing business. Many entry standards were aligned, including those in the calcium carbide, coking, ferroalloy, copper smelting, aluminum, fiberglass, lead and zinc and chlor-alkali fields, as well mandatory energy indices for 22 types of high-energy-consumption products.

In February 2009, the state drew up plans for the revitalization of ten key industries – iron and steel (including strict control of production and the elimination of outmoded products), automobiles, shipping, petrochemicals (including promotion of integrated utilization of resources and recycling), textiles (including elimination of outmoded production and high-energy and high-polluting technologies), light industry, non-ferrous metals (including the establishment of a recycling system, with integrated use of resources), equipment manufacturing (including improving industrial structure and development models), electronic information services and logistics. In all of these, industrial restructuring, energy-saving and environmental protection were considered vital.

Further steps by the Chinese government to promote energy efficiency include a differential electricity pricing policy, financial and tax incentives, preferential loans, and labeling and certification measures.

**DIFFERENTIAL ELECTRICITY PRICING POLICY:** In 2004 and 2006 the government categorized several industries as eliminated, restricted, permitted or encouraged, sending clear signals to the market (Table 2). Since the implementation of these differential electricity pricing standards, around 2,000 high-energy-consuming enterprises have been shut down or have changed production – of these 70% fell into the 'eliminated' category.<sup>22</sup> Further, in 2007, electricity rebates and concessions were abolished for industries such as electrolytic aluminum, ferroalloy and chlor-alkali, and regional preferential electricity pricing measures were halted for industries that consume high energy.

TABLE 2 – DIFFERENTIAL ELECTRICITY PRICING STANDARDS FOR HIGH-ENERGY-CONSUMING ENTERPRISES<sup>23</sup> YUAN/KWH (US\$/KWH)

INDUSTRY		CURRENT PRICING STANDARD	SINCE 1 OCT 2006	SINCE 1 JAN 2007	SINCE 1 JAN 2008
ELECTROLYTIC ALUMINUM, FERROALLOY, IRON AND STEEL, CALCIUM CARBIDE, CAUSTIC SODA, CEMENT, YELLOW PHOSPHORUS, ZINC SMELTING	ELIMINATED	0.05 (0.007)	0.1 (0.002)	0.15 (0.02)	0.2 (0.03)
	RESTRICTED	0.02 (0.003)	0.03 (0.004)	0.04 (0.006)	0.05 (0.007)

**FINANCIAL INCENTIVES AND TAX CONCESSIONS:** To save energy and reduce emissions, the government provides subsidies to support technology upgrades for companies according to the amount of energy they save. The standard in the eastern region is 200 Yuan (US\$ 29) per tce, and 250 Yuan (US\$ 37) per tce for central and western regions. In addition, tax incentives apply when certain technologies are used and products manufactured; to encourage the import of advanced energy-saving technology and equipment; and to control the export of high-energy-consuming products and pollution levels. Tax rebates on some exports have been cancelled or cut to 5%. The first key energy-saving technologies catalog, published in 2008, encouraged 50 energy-saving technologies in the non-ferrous metal, building materials, power, iron and steel and other industries.

**PREFERENTIAL LOANS:** In 2007, to facilitate national energy-saving and emissions reduction strategies and to reduce credit risk, the China Banking Regulatory Commission (CBRC) introduced a series of green credit policies stipulating the types of financial institutions that can provide special energy-saving loans. These also motivate banks to provide credit and provide increasing levels of support for energy-saving and emissions reduction projects. New projects are discouraged in the restricted or eliminated categories, high-energy-consumption enterprises, polluting projects that lack ineffective reform, and projects with outmoded production techniques. CBRC statistics show that the five major state-owned banks issued 106.3 billion Yuan (US\$ 16 billion) in loans in 2007 to support key energy-saving and emissions reduction projects, of which almost 3.9 billion Yuan (US\$ 570 million) went for technological innovation and 20.9 billion Yuan (US\$ 3.1 billion) for technological upgrades, while 3.9 billion Yuan (US\$ 570 million) in corporate loans was recovered from enterprises that could not meet national policy standards.<sup>24</sup>

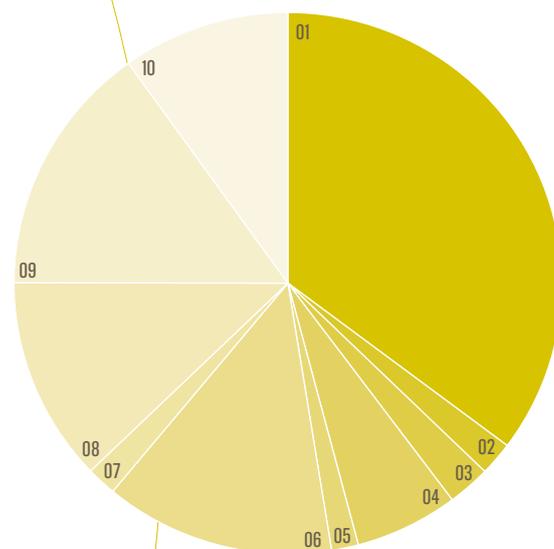
**LABELING AND PRODUCT CERTIFICATION:** Energy-efficient labeling requirements, introduced in 2005, oblige manufacturers and importers to display the energy efficiency of household appliances. Manufacturers and distributors can apply for energy-efficient product certification. By March 2009, more than 1,000 companies and 60,000 products had been registered in a government inventory of energy-efficient products.<sup>25</sup> According to statistics from China's National Institute of Standardization, these programs have resulted in more than 90 billion kWh of electricity saved, or some 30 million tce, over the past four years – and have caused many energy-inefficient and energy-consuming products to be discontinued. Thanks to the energy efficiency labeling system, the efficiency of indoor air-conditioners has improved 6% on average, while the proportion of high-energy consuming products in this category fell from 60% in 2005 to 20% in 2008. Energy performance of household refrigerators improved 4% on average, with the proportion of energy-saving products rising from 60% in 2005 to 90% in 2008.<sup>26</sup>

## INVESTMENT NEEDS AND BUSINESS OPPORTUNITIES IN ENERGY EFFICIENCY

Improved energy efficiency is in itself a major economic opportunity for Chinese business, offering the prospect of significantly lower future energy costs. Developing and installing the technology needed to achieve China's energy-savings goals will, however, require substantial investment – 50 billion Yuan (US\$ 7.3 billion) a year in EMCs alone over the next few years, according to the China Energy Conservation Association. Energy efficiency technologies and projects therefore represent a major market and business opportunity in their own right. For example, research by Morgan Stanley suggests that China's energy-saving market could already be worth 800 billion Yuan (US\$ 117 billion).<sup>27</sup>

Who will fund the required investment? Perhaps 5-10% will come from the government. The remainder will have to come from corporate financing in the form of commercial loans, international carbon market trades (including CDM projects) and EMCs. Innovative business and financing models will help industrial enterprises to invest in their own energy conservation.

EMCs and regional energy-saving programs are considered viable options. After years of development, EMCs in China have begun to take shape. Chart 2 reflects estimated figures for most of China's EMC projects for industrial energy conservation.

CHART 2 – EMC PROJECTS IN CHINA<sup>28</sup> MILLION YUAN (MILLION US\$)

01 _INDUSTRIAL BOILER ENERGY – SAVING RENOVATION & CHP	615.30 (89.96)
02 _HEAT SUPPLY SYSTEM ENERGY – SAVING RENOVATION	34.99 (5.12)
03 _POWER DISTRIBUTION SYSTEM ENERGY – SAVING RENOVATION	44.04 (6.44)
04 _MOTOR DRIVE SYSTEM ENERGY – SAVING RENOVATION	106.91 (15.63)
05 _GREEN LIGHTING	27.84 (4.07)
06 _INDUSTRY KILNS ENERGY – SAVING RENOVATION	238.22 (34.83)
07 _FORGING HAMMER ENERGY – SAVING RENOVATION	30.98 (4.53)
08 _RECOVERY AND REUSE OF RESIDUAL ENERGY	213.01 (31.14)
09 _BUILDING ENERGY – SAVING RETROFIT	262.85 (38.43)
10 _OTHERS	173.51 (25.37)

Further key financing and business opportunities include the following.

**CARBON MARKETS:** China stands out as the country with the highest number of registered Clean Development Mechanism (CDM) projects and the highest number of issued Certified Emission Reductions (CERs) in the world. Fifty-five of China's 417 registered CDM projects (by 17 February 2009)<sup>29</sup> involved energy-conservation and energy efficiency projects, mainly cooperative projects in the iron and steel, cement and chemicals industries. Although there are a number of recognized shortcomings with the current functioning of the CDM, China's CDM projects have proved profitable and numerous CDM agents have emerged in the market. As 2012 approaches and with the impact of the financial crisis, the international carbon market has slowed, but international carbon trading will continue in the long run, though there is clearly a need to improve the CDM to promote larger scale emission reductions and ensure that all participants benefit from its intent.

Following this trend, China set up three environmental exchanges for future carbon trading in August and September of 2008 – the Shanghai Environment and Energy Exchange (SEEE), the Tianjin Climate Exchange (TCX) and China Beijing Environment Exchange (CBEE). These will be able to advance the domestic market for energy-saving-quota transactions, in anticipation of a mature carbon market.

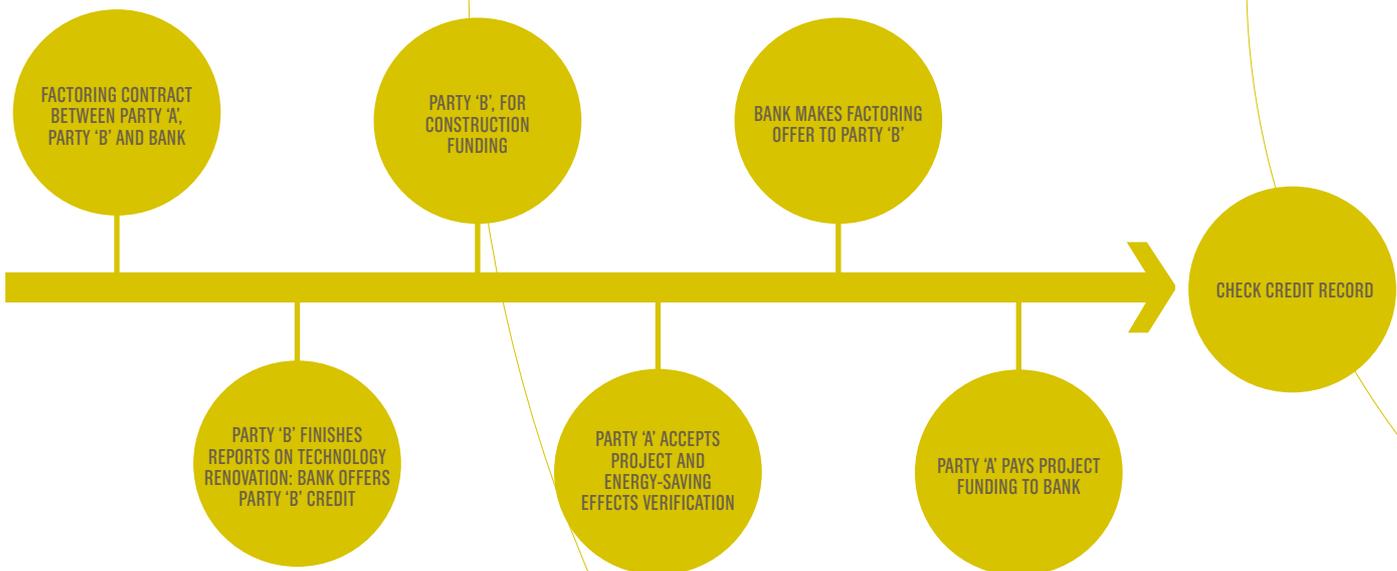
**URBAN ENERGY-SAVING SOLUTIONS:** Regional energy services are relatively immature and a communication bridge is needed to connect government and enterprise. Urban energy-saving solutions and emissions reduction could provide the focus for such cooperation and this is being promoted by enterprises that are capable of integrating various resources. For example, the ENN Group (XinAo) has been successful in coming up with regional clean-energy and energy efficiency solutions. ENN Gas provides comprehensive energy conservation services for local governments and enterprises, where it integrates all aspects of domestic and foreign resources. Their success may be attributed to having a gas distribution network in 60 cities nationwide with long-term operations that have helped its image as a vendor.

A dedicated research institute and R&D center provides the needed technological support. The Group was named one of the top ten enterprises in China's low-carbon industry in 2008. With financial partners such as the Bank of China, the Group helps to relieve funding pressures on leading domestic and international enterprises.

**FACTORING:** In the face of limited state financial help coupled with huge funding gaps to serve the energy-saving market, the People's Bank of China is actively studying the application of factoring to finance energy-saving and emissions reduction (Chart 3). By factoring, the right to collect on claims under contracts is taken over by a bank for a fee, allowing a company to overcome the delay in being paid, the loss of interest involved and the risk of bad debts. The factoring contract gives the bank the right to take action to collect on the contractual claims. The People's Bank of China, as the country's central bank, has a pilot project involving factoring for other banks for energy-saving technology upgrade enterprises and service providers. This is seen as a way to channel some direct investment project funds into a bad debt reserve. Some financial institutions' bad debts arising from energy conservation projects will be partly covered by the state.

One central bank study<sup>30</sup> indicates that this process allows enterprises to complete energy conservation projects free from the approval process and financial pressures. As a result, service providers can expand their business while financial institutions can benefit from the enormous market opportunities in energy conservation.

CHART 3 – PROCESS OF FACTORING IN ENERGY-SAVING PROJECTS



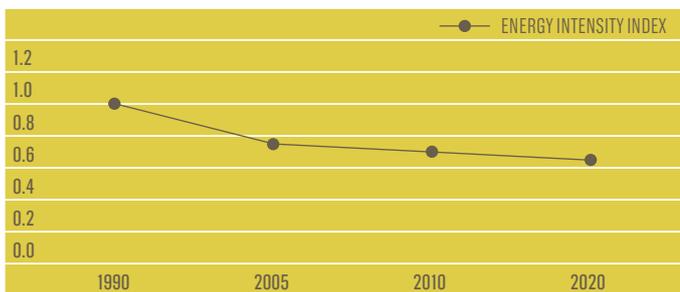
**RISK-SHARING TO PROMOTE CREDIT FOR SMES.** The Bank of Beijing and Shanghai Pudong Development Bank decided to follow the Industrial Bank in joining the International Finance Corporation's (IFC) China Utility-Based Energy Efficiency (CHUEE) financing program, to provide funding for energy efficiency projects of SMEs. By 31 December 2008 the program had approved 97 loans worth 3.3 billion Yuan (US\$ 483 million) with an anticipated annual CO<sub>2</sub> emissions reduction of 9.7 million tons. This program has helped to buttress the enthusiasm and capacity of China's financial institutions to finance energy efficiency projects through the IFC's 'Loss-sharing Agreement', which shares the losses incurred in short-term or long-term loans. Based on this risk-sharing mechanism, the CHUEE plans to promote loans of more than US\$ 600 million by the end of 2010. Investment in energy efficiency, renewable energy and clean production will amount to US\$ 100 million.<sup>31</sup>

What, then, are the advances to date, future prospects, and technology drivers for energy efficiency in China's major energy consuming industries?

#### IRON AND STEEL: TECHNOLOGY ADVANCES DRIVE MAJOR GAINS

China's iron and steel industry consumes nearly 480 million tce and accounts for 17% of the energy consumed nationwide, second only to the power industry.<sup>32</sup> The industry has continually sought to conserve energy and consistently reduced energy consumption per ton of steel produced, represented in an energy intensity index that has fallen by more than 30% over the last two decades (Chart 4).

CHART 4 – ENERGY INTENSITY INDEX FOR IRON AND STEEL INDUSTRY<sup>33</sup>



The iron and steel industry is poised to harness key technology advances and make considerable further progress in energy efficiency. According to estimates by McKinsey:<sup>34</sup>

- The industry will continue to promote the use of advanced technologies that are being used in developed countries, including the blast furnace Top Gas Recovery Turbine (TRT), pulverized coal injection (PCI), oxygen-rich PCI, dry coke quenching (CDQ) plant and process automation. They will also make better use of blast-furnace gas, and replace basic oxygen furnaces (BOFs) with electric arc furnaces (EAFs) to reuse scrap steel. These technologies are expected to be in full use in China within 20 years. Expected abatement potential amounts to about 330 million tons.

- Of all these methods, the increased use of EAF contributes most to energy efficiency improvement, with its 200 million tons of abatement potential. It is expected that by 2030 China's annual iron and steel production will reach 755 million tons, with EAF production amounting to 240 million tons, or 30% of the total. At the same time, the scrap supply will go from 70 million tons in 2005 to 290 million tons in 2030. The better use of blast furnace gas will also contribute 40 million tons of carbon dioxide abatement. In 2030, because of the closure of small-scale steel mills, the utilization rate of blast furnace gas is expected to grow by 95%.

The following technologies are critical:

**DRY BLAST-FURNACE TOP-GAS RECOVERY TURBINE (DRY TRT):** Major Chinese iron and steel producers currently use TRT equipment. In terms of the 11th Five-Year Plan, the TRT permeation rate will reach 100% (60% for Dry TRT). Sixty-seventy percent of blast furnaces of more than 1,000m<sup>3</sup> will use this technology, at a cost of about 1.2 billion Yuan (US\$ 175 million). Energy-savings are expected to reach 4 billion kWh annually – the equivalent of a power plant with 600 MW installed capacity.<sup>35</sup> The financial savings will also be considerable.

**CONVERTER-GAS RECOVERY AND REUSE:** Several companies in China have introduced LT Recycling Technology. There are now 19 enterprises with large-scale converters and 42 with medium-sized ones. In 2010, half of all enterprises are expected to be using this technology, with an energy saving of five million tce<sup>36</sup> and considerable financial savings.

**COMBINED CYCLE POWER PLANT (CCPP):** According to McKinsey's analysis,<sup>37</sup> reusing low-heat-value blast-furnace gas through a CCPP allows emissions reduction of 45 million tons at a cost of about 90 Euros (US\$ 129) per ton. The main obstacle to its use is the large initial capital investment and the need for adequate planning to ensure stable gas supplies for large plants. The major suppliers of this equipment are currently enterprises from abroad and only a small number of enterprises in China currently use CCPP technology. National objectives outlined in the 11th Five-Year Plan are for an expansion of this technology to 20-30% of cases. This will cost about 10 billion Yuan (US\$ 1.5 billion) and will generate 2 billion kWh of electricity annually.<sup>38</sup>

**CENTRALIZED NETWORKS TO MANAGE ENERGY:** An energy management center can enable comprehensive monitoring of various energy vectors along the entire steelmaking process. For example, Baoshan Iron & Steel's Energy Center saves 50 million Yuan (US\$ 7.3 million) annually. It consists of about 30,000 signal points, which connect all plant substations, drainage facilities, water supply and drainage pump stations, gas compressor stations, mixed gas stations and energy distribution facilities through a computer network, enabling decentralized control, centralized management and optimized allocation of the energy system. The increased use of information technology gives such centers tremendous potential: over the next 5-8 years the building of energy management centers in ten large or medium-sized enterprises will need 1-1.2 billion Yuan (US\$ 146-175 billion). If as an example we take a large steel plant with annual production capacity of 8 million tons, with annual energy consumption of about 6.5 million tce, 1% of that will be saved with direct cost savings of about 50 million Yuan (US\$ 7.3 million).<sup>39</sup>

#### **COKE MAKING, COAL WINNOWING AND MOISTURE CONTROL PROCESS:**

The abatement potential of this technology is as high as 50 million tons, at a cost of about 80 Euros (US\$ 115) per ton<sup>40</sup> but is only being used to a limited extent in China because of the lack of reliable equipment and sophisticated monitoring requirements. Only one coke plant at Jinan Iron & Steel is using this technology to use the heat of flue gas in its coke ovens. Baoshan Iron & Steel, Taiyuan Iron & Steel and Panzihua Iron & Steel are establishing moisture control processes based on low-pressure steam. With technological improvements, this technology could be very beneficial.

#### **NON-FERROUS METALS: BOLD TECHNOLOGICAL INNOVATION**

Energy conservation needs to be emphasized in the non-ferrous metals industry because of the relatively long process involved: mining, ore dressing, smelting and processing, all of which involve high energy consumption. In 2005 the annual consumption by China's non-ferrous metals industry was about 83.4 million tce. This accounted for 3.8% of total domestic energy consumption. Most of the energy is consumed in mining, smelting and processing and, because of the high yields, aluminum electrolysis uses the most.<sup>41</sup>

The energy consumption of China's non-ferrous metals enterprises is currently at or approaching an advanced international level. Since the 10th Five-Year Plan the non-ferrous metals industry has formed an advanced technology group to develop its own intellectual property rights for a range of innovations; aluminum electrolysis technology, for example, was developing fast and some aluminum technologies have now even been exported.<sup>42</sup>

The key technologies include the following:

#### **LARGE ALUMINUM ELECTROLYSIS TECHNOLOGY (ALL ELECTRICITY CURRENTS):**

This technology was part of a major industrial technology program established by the NDRC in November 2006. After a technical appraisal, the China Nonferrous Metals Industry Association put it in the advanced international class and some ten enterprises in China and abroad have expressed interest. The 11th Five-Year Plan anticipated this technology being heavily promoted and by 2010 bringing 0.8-1.5 billion kWh in energy-savings, reducing the consumption of heavy oil by enterprise-owned power plants by 50,000-150,000 tons.<sup>43</sup>

As an example, the Henan Zhongfu Industrial Co. Ltd. achieved direct cost savings of 20 million Yuan (US\$ 2.9 million) annually from energy and increased productivity. To adopt this new technology, the company's 250,000-ton, 320 kA aluminum electrolysis series required no equipment upgrade or changes in the original model's corporate control. The technology and equipment have also greatly simplified the process and improved security. Spending on the technology upgrade ran to about 5-8 million Yuan (US\$ 0.7-1.2 million) for a three-month construction period. Annual energy-savings are above 10 million kWh and the direct cost savings are 20 million Yuan (US\$ 2.9 million) annually, with a payback period of only three months.

**SMELTER OFF-GAS WASTE HEAT RECOVERY:** This technology can be used for all large and medium-sized smelters in the non-ferrous metals industry, as well as for iron and steel, cement and related industries. It is now in operation at the Yunnan Copper Co. Ltd. and elsewhere, and is showing positive economic benefits. The 11th Five-Year Plan anticipates this technology being promoted in more than 85% of the large and medium-sized enterprises by 2010, costing about 200-300 million Yuan (US\$ 29-44 million). The annual energy-savings based on medium capacity estimates amount to 444,100 tce.<sup>44</sup>

**OXYGEN BOTTOM-BLOWN SMELTING:** This technology is already at an advanced level comparable to international best practice and has won top prizes from The Nonferrous Metals Society of China, supported by Ministry of Sciences and Technologies of China. Five lead-smelting companies have adopted the technology, as have three in brass smelting, while another 10 to 15 overall are expected to adopt it. During the period of the 11th Five-Year Plan, the promotion of its use has been anticipated to run to about 300 million Yuan (US\$ 44 million), while total energy savings should amount to 195,000 tce.<sup>45</sup>

#### **CHEMICALS AND PETRO-CHEMICALS: ROOM FOR IMPROVEMENT**

The chemical and petro-chemical industry comprises a diverse set of industrial sectors, though almost all require large energy consumption and the use of fossil fuels directly in the production process. The efficiency of this industry in China is about 15% lower than in developed countries,<sup>46</sup> mainly because of the low-quality energy structure based on the use of charcoal, out-of-date equipment and unscientific methods in terms of company size, product mix, raw materials and energy use. Obviously there is room for improvement and the industry's energy-saving potential is tremendous: in management, 15-20%; in structure, 80-85%.

The key technologies available to achieve this improvement include the following:

**AIR PRE-HEATING IN CRACKING FURNACE:** The use of this technology stands at about 20%, but is expected to climb to 90% during the period of the 11th Five-Year Plan with annual savings of 80,000 tons of oil equivalent.<sup>47</sup> The technology has been adopted at CNPC's ethylene plant and piloted by Sinopec.

**NOVEL ALKALINE PRODUCTION FROM SHIFT CONVERTER GAS:** This technology started in China and moved abroad, with 10 Chinese enterprises showing significant energy-saving results from its use. The technology is suitable for any enterprise producing an alkali from shift converter gas and the China Soda Industry Association has begun promoting it. The current penetration rate is around 15% and it has been expected that this would grow to 50% during the 11th Five-Year Plan, with 6,833 tce in energy-savings.<sup>48</sup>

**SYNTHETIC AMMONIA ENERGY SAVING TECHNOLOGY:** This involves a comprehensive integration of nitrogen fertilizer industry applications which can be used as a complete package or in different combinations. If half the enterprises nationwide were to implement this, 8 billion kWh/year of electricity would be saved in China.<sup>49</sup>

#### CEMENT: INDUSTRY CONSOLIDATION DRIVES ENERGY EFFICIENCY

The building materials industry accounts for more than 15% of China's total energy consumption, or 20% of total industrial energy consumption. A major feature of China's cement industry is fragmentation. The top 10 producers account for a mere 13.68% of total output.<sup>50</sup> According to Advice on Speeding the Structural Adjustment of the Cement Industry (2006) issued jointly by eight ministries, China is to work toward industrial consolidation because those companies with new production technologies and higher energy-saving levels will be at a clear advantage:

- During the 11th Five-Year Plan, the proportion of novel pre-calcination cement production capacity was to be raised to 70% in 2010 from under 12% in 2000 and out-of-date production capacity of 250 million tons is to be eliminated.
- Average scale of production is to go from 200,000 tons (in 2005) to about 400,000 tons.
- By 2010, the output of the top 10 enterprises is to reach more than 30 million tons; the production concentration is to be raised to 30%, and the concentration of the top 50 enterprises to above 50%.

According to research reports,<sup>51</sup> emissions reduction in the cement industry will mainly depend on the replacement of outmoded kilns with pre-decomposition kilns and the application of various automation technologies, such as advanced process control (APC) and pure low temperature wasteheat power generation. According to the 11th Five-Year Plan, this has the potential to save 3 million tce, through an investment of 8 billion Yuan (US\$ 1.2 billion).

#### CROSS-INDUSTRY ENERGY-SAVING SOLUTIONS

Many cross-industry energy-saving solutions have vast abatement potential, including the sophisticated use of inverter control and of intelligent control for central air-conditioning, which are supported by national policy.

**INVERTER SPEED CONTROL.** At present, China's high-voltage inverter industry is growing at 30% annually,<sup>52</sup> but because of its small scale a mature market has not yet formed. The market potential is substantial and has developed in recent years with competition between manufacturers shifting to the high-voltage inverter field. Converters, especially high-voltage inverters, are an important component of power transmission and can be used for high-voltage and high-wattage transformers where the energy savings will be more noticeable. A motor system energy conservation project begun by the NDRC is one of the 11th Five-Year Plan's key energy-saving projects.

**CENTRAL AIR-CONDITIONING INTELLIGENT-CONTROL:** This promising technology has reached maturity.<sup>53</sup> It passed the new product identification process of Guizhou Province and of the State Economic and Trade Commission and was listed as a part of the Global Environment Facility's (GEF) energy conservation programs in China, as well as in the National Science and Technology's Torch Program in 2006. In terms of the 11th Five-Year Plan, the technology should be extended industrially at a rate of 10%, with total spending of 6.24 billion Yuan (US\$ 913 million) and account for annual electricity savings of 8.5 billion kWh. Used in more than 300 central air-conditioning systems in over 20 provinces and cities, the technology has shown that a 20% energy-saving rate is achievable.

#### CHALLENGES ON THE PATH TO ENERGY EFFICIENCY IN INDUSTRY

While it is widely recognized in the policy and academic community that energy efficiency investment can bring substantial returns on investment and short payback periods, this awareness has not fully permeated the business community, particularly in the SME sector. Many business owners still view these investments as a diversion of funds from their core business and as a cost rather than an investment. A lack of in-house expertise in the design and implementation of efficient energy management plans means that senior managers are often not aware of the scope for improvement. Given its significant potential impact on both energy use and the business productivity, the government and other agencies – supported by external programs – need to focus attention raising awareness of these benefits and the best practice means for achieving them.

This needs to be linked to the development of new, creative financial vehicles as there is currently huge gap between the demand for and supply of financing for energy efficiency. It is estimated that implement the available options, China will need additional investment of up to 40 trillion Yuan (US\$ 5.8 trillion) is needed by 2030. While the government could provide some of this in the form of seed capital, other sources – as yet not in place – will be required. This means an expanded role for the domestic private sector, as well as capital provided by international banks, institutional investors and multilateral development agencies. However, beyond the funds themselves, means for channeling resources to companies, in a way that does not simply increase company debt but that is linked in some way to the efficiency and productivity gains achieved are required. Combining such vehicles with an enhanced role for ESCOs and EMCs could be one part of the solution.

The relatively low participation of the private sector is also explained by the fact that the energy conservation market is still largely driven by regulatory requirements rather than by market forces. Although China is making practical efforts to develop more innovative business models, as well as financing mechanisms to incentivize the energy efficiency market, the reality is industrial energy conservation in China is largely dependent on policy requirements. The market's role is still weak and will need to be strengthened if energy conservation and management is to develop into a profitable business.

Finally more effort is needed in the area of technology innovation and development to help reduce cost. Despite the savings that can be achieved, the upfront investments are still often seen to be too high and are often greater than elsewhere in the world. A vibrant market for energy-saving technologies with domestic firms responding to the needs of Chinese firms, would not only bring costs down but potentially create a new export market.

**CHAPTER 3:  
RENEWABLE ENERGY**

首批国产六百

Renewable energy offers the most promising business opportunities of all China's low carbon developments, with solar photovoltaic (PV) energy, wind energy, geothermal energy and biofuels being among the most important.

This chapter discusses the progress, prospects and challenges of each of these technologies in turn.

## **SOLAR PHOTOVOLTAIC: GLOBAL LEADERSHIP, DOMESTIC OPPORTUNITIES.**

Supported by government policies, mainland China's PV production has boomed in recent years, and already supplies 30% of global demand (Greater China, including Taiwan, 40%). Chinese solar companies are reaching international standards, leading the world in thin-film battery technology and diversifying into the complete industrial chain.

However, the global recession has impacted negatively on the Chinese PV industry, which exports 98% of its output.

There is potential for large-scale expansion of PV in China's domestic market, supported by government subsidies to reduce price barriers, thus overcoming the problem of 'consumption abroad, pollution at home.'

Solar energy technologies include both PV and solar water heating technologies. While China's progress in solar heating was discussed in depth in the 2008 report, this report focuses on developments in PV, which involves the use of materials that react to sunlight to create an electrical current.

#### RAPID GROWTH – BUT GLOBAL DOWNTURN HURTING CHINA'S PV INDUSTRY

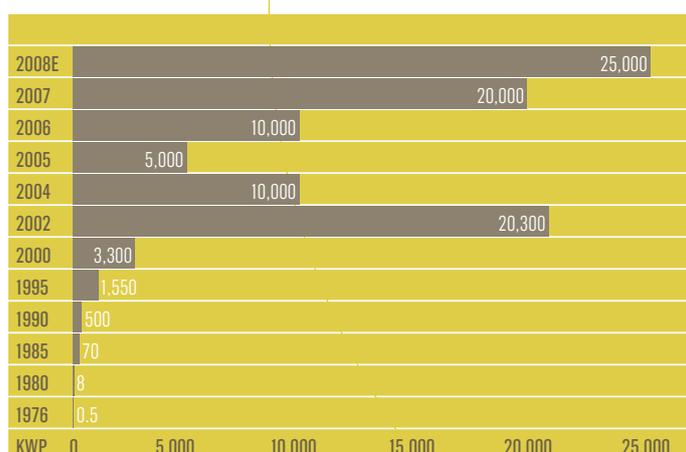
Direct incentives for solar power by the German, Japanese, Spanish and other governments have encouraged the sale of Chinese PV cells. Mainland China has 30% of the world market<sup>54</sup> (Greater China, 40%). The recent economic boom created the rapid rise of the PV cell industry, where profits have stimulated R&D and the growing capacity for polycrystalline silicon refinement, an important material which is in very short supply around the world.

In the context of the current global economic downturn, however, the recent rapid growth of the industry risks creating significant surplus production capacity. South Korea's Displaybank has predicted that by 2010 China's supply of PV cells will reach about 15 GW, greatly exceeding demand (estimated at about 11 GW) and lead to drastic price cuts.<sup>55</sup> The current price of poly-silicon materials is about \$100 per ton, or 80% less than the highest previous price of almost \$500 per ton. But this situation could create opportunities for domestic enterprises and lower the costs of photovoltaic electricity.

Most Chinese photovoltaic enterprises are in the mass production category, where the technology is not advanced. Here there is fierce competition, with unsteady profits. With an export rate of 98%, China's PV industry is limited – effectively driving 'consumption abroad, pollution at home.'

Shrinking demand in international markets because of the financial crisis and depreciation of the Euro has reduced production and profits. Both Suntech (STP-US) and Zevi (LDK-US) have lowered their earnings projections,<sup>56</sup> necessitating a reexamination of the industry and of its market structure in China. However, PV power generation is still at an early stage of development in China, with great potential for expansion in both off-grid applications and PV power stations to supply the grid (Chart 5).

CHART 5 – ANNUAL INSTALLATION OF SOLAR PV IN CHINA<sup>57</sup>



#### TECHNOLOGY AND BUSINESS DEVELOPMENTS IN PV

In 2007, there were more than 500 PV enterprises and R&D units in China.<sup>58</sup> In the area of silicon-ingot/silicon-rod manufacturing, major domestic producers now have mature technology. In battery manufacturing, the majority of Chinese PV companies are at an internationally advanced level.

Batteries are the core of the industrial solar-energy chain and mainly come in three forms: single crystal silicon, poly-silicon, and thin-film (amorphous silicon). Advances in thin-film technology and improvements in the conversion rate over the next two years will gradually reveal the cost-control advantage of thin-film batteries, which use less crystalline silicon. It is estimated that even at the 5 MW production level, the cost of amorphous silicon, thin-film battery components can be held below \$2 per watt, or even lower in an automated production line with a capacity of 40-60 MW or higher.<sup>59</sup> Considering that the price on the international market averages \$3.50 per watt, profit margins are substantial.<sup>60</sup> Major manufacturers are turning to thin-film production technology, a trend that is growing in 2009. This will help thin-film technology to mature quickly. With increased investment and production by major companies because of the price advantage a rapid rise in the market share of thin-film can be expected.

For glass-curtain wall facades, thin-film batteries will be used because they transmit a high degree of light, but crystalline silicon batteries are preferred for the roofs of new construction projects and non-transparent surfaces. The promotion of building installed photovoltaics (BIPV) by government policies will benefit both categories and help encourage the industry.

As poly-silicon material supplies begin to exceed demand, expanded production capacity will be less profitable and a downward movement along the industrial chain will be inevitable. Sales of PV power-generating systems would have a higher profit margin than raw materials, components or batteries; and enterprises with the complete industrial chain will be more resilient and able to adapt to market fluctuations.

This has led to a 'vertical integration' strategy by companies such as Yingli Solar, Changzhou Tianhe, Zhongsheng PV and Shandong Huangming, by shifting from raw-material production to diversified production and R&D. For example, ET Solar, China's first solutions provider and the world's third for PV solar-energy integration, was not affected much by the sharply falling prices of raw materials, batteries and components at the end of summer 2008. This was because of its core competence and '3rd-generation PV power station' technology that led to a contract with Europe worth 2.5 billion Yuan (US\$ 366 million) for involvement in a 50 MW solar energy plant built by the WattnerGroup.

Vertical integration reduces risks, which helps attract international capital. For example Intel Capital has injected US\$ 20 million in capital into Shenzhen Trony, a manufacturer of thin-film PV products and systems, which will improve its production capacity from 35 MW to 105 MW. The company produces strong-light and low-light amorphous silicon thin-film batteries, BIPV power-generating systems, solar street lighting solutions, solar aerators and solar power plant technologies. Its focus now is on large-scale, thin-film PV for the external walls of building. The price of thin-film PV is expected to fall dramatically, and Trony's main product – amorphous silicon thin film PV only needs 0.12-0.15 tons of crystalline silicon per MW, while crystalline silicon solar batteries need 13-15 tons.<sup>61</sup> The advantage of Intel Capital's involvement is its technological support.

**POLICY SUPPORT FOR EXPANDING DOMESTIC DEMAND**

While there are hopes to bring the price down, PV power generation is currently as high as 4 Yuan (US\$ 0.58) per kWh, placing limitations on the market. Large-scale domestic market expansion and rapidly reduced costs are needed. Some companies in China complain that policies favor renewable sources of energy other than PV.

In March 2009, the Ministry of Finance and Ministry of Housing and Urban-Rural Development promulgated their Opinions on Accelerating BIPV Applications and Interim Measures for the Administration of BIPV Subsidy. These promote the use of PV applications in the domestic building market as an important contribution to energy efficiency as well as to promote the PV industry in China, expand domestic demand and promote economic growth. The 2009 subsidy is set at 20 Yuan (US\$ 2.93)/Wp\*, which is equal to 50-60% of production costs. The subsidy for any project can reach 1 million Yuan (US\$ 150,000) and projects must have PV production capacity of not less than 50 kWp to qualify. Once the government is convinced by the results of such demonstration projects, the scale and amount of governmental subsidies will probably be increased substantially. Growth will then encourage market standardization.

Although a directly supportive policy has yet to be announced, these two documents recognize the importance of expanding domestic demand for BIPV for saving energy, reducing emissions and meeting other economic goals. The documents refer to the 'Solar-roof Plan' and financial subsidies, which show the government's intention to integrate building construction and PV power, supporting the PV market.

Meanwhile, the government encourages applications that generate off-grid electricity. The 'sending electricity to the villages' project, from 2002 to 2005, drove the domestic PV industry, promoted training, built capacity and gave rise to a large number of domestic enterprises. The project solved the problem of electrical shortages on a daily basis for about 1.3 million people through building 268 small hydropower stations and 721 PV or hybrid wind/PV power plants. This remains the largest PV-power-generation or wind-solar-generation project in rural areas worldwide.

In the project, the government covered the high costs of construction, but a sustainable market will only be established with the development of new financing and business models. For example, the Indian SELCO business model involved cooperation with micro-credit facilities to provide loans for the installation of solar energy systems, and also researched applications and adapted them to the needs of rural and small business. The SunEdison business model in the US is another example. Here flexible financing was provided to cover the high initial cost, through long-term contracts with users and the support of a favorable local tax policy.<sup>62</sup>

Up to now, high costs have prevented grid-connected, PV electricity-generation from scaled commercialization, but the Chinese government has approved three solar PV power station projects as demonstration models, with large government subsidies – a 10 MW one in Dunhuang, Gansu; a 1 MW one on Congming Island, off Shanghai; and a 255 kW one in Erdos, Inner Mongolia.

A joint bid of 0.69 Yuan (US\$ 0.1)/kWh from SDIC Electric Power and Yingli for the Dunhuang project was seen as highly unprofitable by the market. But winning the tender would signal that the company had the capacity to take on similar projects, bringing profits over the long-term that will be increased when the 12th Five-year Plan accelerates the industry's growth. These large government subsidies for demonstration projects help attract investors, leading to a drop in price and increased profit margins as the market adjusts.

**CHALLENGES IN THE WAY OF FUTURE GROWTH**

China's PV industrial chain is now complete, but the proportion of key equipment that is produced locally along that chain has a long way to go.

- **HIGHER END:** Polycrystalline-silicon-purification equipment, like hydrogen compressors and reducing furnaces, polycrystalline silicon ingot furnaces and multi-slicers, which are at the upper end of the crystalline-silicon-solar-battery manufacturing process are just beginning to be produced locally.
- **MIDWAY:** The battery-slice-production-line equipment, such as screen printers and plasma-enhanced chemical vapor deposition (PECVD), a process that is used to deposit thin films from a gas state to a solid state on a substrate, are mainly imported, but some auxiliary materials in the assembly process are locally produced, along with the fully automatic production lines.
- **SYSTEMS INTEGRATION:** Despite progress with grid connected PV power generation, it remains inconsistent, interfering with the quality of the power grid. But this is also true in Germany. China's power grid companies are establishing a solar-power-generation research center to try to solve the problem, learning from wind power generation.

China is late in coming to commercial crystalline-cell applications and product certification is mainly done by UL and TUV. Although China has some certifying agencies, most of them are not internationally recognized so many products have to be sent to foreign countries for certification, which costs time and money.

Each production link for PV products involves standards of some sort. Although most enterprises do have their own standards, national standards do not nearly meet present-day development needs for enterprises. For one thing, they fail to cover all PV products. For another, some standards are a mere copy of international ones. So Chinese national standards for PV products do not even constitute a complete system, let alone set internationally advanced standards. So, while large, it will not be easy for China to become powerful in the PV industry.

For China to confront the dangers of high energy consumption at the cost of high-pollution, the necessary steps should be taken to enhance the PV conversion rate and reduce pollution through proper recycling of silicon tetrachloride in the production of high-purity silicon.

\* Wp is a unit specially used for electricity generated from solar PV. W stands for watt and p stands for solar PV.

## **WIND POWER: POLICY SUPPORT DRIVES RAPID GROWTH IN INSTALLED CAPACITY.**

Between 2007 and 2008, China's wind power capacity doubled to more than 12 million kW, making China the largest wind power generator in Asia and fourth in the world. It is likely to double again in 2009, accounting for one third of the world's new capacity.

Government policies have supported the rapid growth of the wind power industry. For example, 70% of the equipment needed for wind power plants must be made domestically, giving the local industry a competitive advantage and forcing foreign companies to set up in China. There are tax breaks for producers and consumers of wind power.

Several challenges must be overcome if wind power in China is to meet its full potential. For example, China still lacks the ability to build large capacity turbines favored by the market and still depends heavily on imported technology; some Chinese products have only 20-30% of the efficiency of foreign ones. There are still no wind turbine testing and certification agencies for domestic production, although there are plans to establish a quality assurance and control system.

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**CHINA'S WIND POWER CAPACITY DOUBLING EACH YEAR**

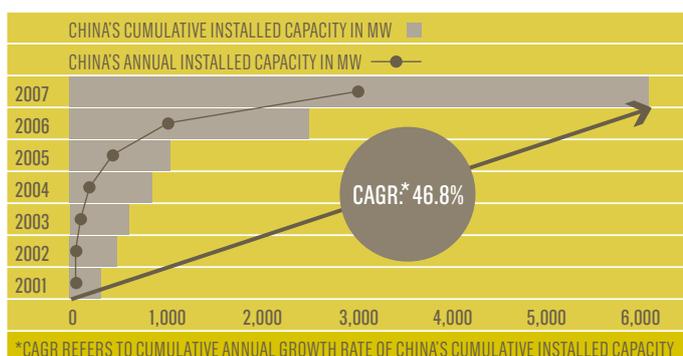
In 2008, China's wind power capacity increased by 6.3 million kW to 12.21 million kW, surpassing India, and becoming the major wind power supplier in Asia, and fourth in the world after the US, Germany and Spain.<sup>63</sup> The jump from almost nothing to breaking the 10 million kW barrier was achieved in eight years, beating all expectations, with the share of domestic suppliers increasing from 5.3% in 2003 to 55.4%<sup>64</sup> (Chart 6). Thanks to the maturity of the technology, solid financial backing, broad participation of power companies and competitiveness of cost and scale, wind energy will rapidly increase its share of total energy output.

# 30M

ACCORDING TO THE GLOBAL WIND ENERGY COUNCIL, A CAPACITY OF 30 MILLION KW IS POSSIBLE IN CHINA IN 2010.

It is estimated that during 2009 its wind power capacity is likely to more than double, so that China's capacity will make up a third of the world's new capacity. China's Mid- and Long-term Development Plan for Renewable Energy set the goal of reaching 30 million kW by 2020. According to the Global Wind Energy Council, a capacity of 30 million kW is possible in China in 2010. This would put China ten years ahead of its own schedule<sup>65</sup> and surpass the capacity of Germany and of Spain.

**CHART 6 – CHINA'S CUMULATIVE AND ANNUAL WIND POWER INSTALLATION CAPACITY<sup>66</sup>**



At current rates, China could have more than 100 million kW of installed capacity in ten years, despite challenges that have arisen in the past few years. Thanks to innovations in technology, scaled expansion and changes in supply and demand patterns, the kW unit cost will drop. The World Wind Energy Association expects global per kW turbine unit costs to drop from the current US\$ 950 to US\$ 650 in 2010 and to US\$ 500<sup>67</sup> by 2020. As state subsidies for wind power fall away, China's wind power plants will need to lower their costs.

**COMPREHENSIVE GOVERNMENT SUPPORT**

Of all its renewable energy policies, China's policies on wind power are the most comprehensive. The rapid growth in its wind power industry results from a macro-level plan to support wind power development, through industrial, fiscal and taxation policies. These policies will increase the proportion of energy derived from wind, drive down costs and help to increase the proportion of equipment that is produced locally. These policies could also provide the basis for policy development in respect of China's other renewable energies.

**FRANCHISING MECHANISM:** In 2001 the NDRC began a franchising mechanism to facilitate cooperation between government and business. This involves a tender process to determine both developers' and on-grid prices. After selecting the scale and construction required, government sells the right to operate and manage the plant to the company that bids the lowest price for the electricity produced. The project developer with the lowest bid is then given the right to sell its electricity at the price contracted with the government to a company that operates the grid, selling electricity to end users. The difference between that price and the electricity generated from fossil fuels is distributed between the grid company and its users, in terms of government policy. The first five projects set up under this financing mechanism total 700 MW of installed capacity,<sup>68</sup> equivalent to the wind power capacity of the previous 20 years. In the bidding process, a holistic approach helped to strengthen the industry by taking various factors into account (such as financial capacity, financial planning, technical planning, the extent to which equipment is local and current on-grid prices, etc).

**DOMESTIC CONTENT REQUIREMENT:** The Notice on Requirements for Administration of Wind Power Construction, together with a new wind power bidding policy implemented in 2006, means that international companies are required to set up factories in China to access this market. Construction work will not be approved unless at least 70% of the wind power equipment is manufactured in China. These mandatory domestic requirements have been effective, though there are concerns that the difficulties faced by foreign firms in establishing themselves in the country are deterring investment.

**DIRECT SUBSIDIES:** On August 20 2008 the MOF issued its Interim Measures for the Administration of Special Funds for the Industrialization of Wind Power Generating Equipment to support the industrialization of China's wind power equipment through subsidies. For enterprises that meet the necessary conditions, a 600 Yuan (US\$ 88)/kW subsidy is provided for the company's first 50 wind-turbine-power units above 1.5 MW. Wind turbine manufacturers and key component manufacturers each won half of these subsidies; and focus is placed on the weaker links in key processes in component manufacturing.

Grants are also provided for research into developing new products. Direct cash subsidies have been more successful than others in supporting industry upgrades, according to Qin Haiyan, the secretary-general of the China Wind Association. They are more successful than tax rebates or other methods and provide real benefits to the manufacturers of components and systems. In this way the government has helped to build a solid base for long-term growth,<sup>69</sup> rather than pursuing rapid growth.

**FACILITATING CONNECTION TO GRID:** Chinese policies support wind power access to the grid (Table 3).

**TABLE 3 – POLICIES SUPPORTING THE POWER GRID**

POLICY	CORRESPONDING MEASURES
RENEWABLE ENERGY LAW	REQUIRES GRID COMPANIES TO BUY ELECTRICITY FROM RENEWABLE SOURCES OF ENERGY
PROVISIONS FOR THE ADMINISTRATION OF ELECTRICITY GENERATION USING RENEWABLE ENERGY	CLARIFIES THE PRINCIPLE THAT GRID COMPANIES ARE RESPONSIBLE FOR INVESTMENT IN CONNECTING LARGE-SCALE WIND FARMS TO THE GRID
INTERIM MEASURES FOR RENEWABLE-ENERGY-GENERATED ELECTRICITY PRICING AND COST SHARING, INTERIM RENEWABLE-ENERGY-GENERATED ELECTRICITY TARIFF MEASURES FOR THE DISTRIBUTION OF ADDITIONAL REVENUES	DETERMINES THE PRICE-SHARING MECHANISM FOR WIND POWER PROJECTS; THE PRICE DIFFERENTIAL BETWEEN WIND GENERATED AND CONVENTIONAL ELECTRICITY TO BE SPREAD ACROSS POWER CONSUMPTION; AND GRID-CONNECTION EXPENSES FOR WIND-FARMS CAN BE INCORPORATED INTO THE PRICE FOR ELECTRICITY
REGULATIONS ON SUPERVISING AND MANAGING PURCHASE OF ELECTRICITY GENERATED FROM RENEWABLE ENERGY BY GRID ENTERPRISES	REQUIRES POWER GRID COMPANIES TO PURCHASE ENERGY GENERATED FROM RENEWABLE SOURCES, WHICH LARGELY ENCOURAGES THE GRID CONNECTION OF RENEWABLE ENERGY

In addition to these policies, the government has created a mandatory feed-in wind power quota. National renewable energy quotas require that, by 2010 developers whose wind farms have an installed power generating capacity of more than 5,000 MW, should have a non-hydroelectric renewable energy generating capacity of 3% or more; and by 2020, this should be 8% or more.

**VAT AND INCOME TAX REDUCTIONS:** Value-added tax (VAT) and income tax relief are available to encourage development of renewable energies. VAT on wind power technologies has been reduced to 8.5% (from 17%), and income tax on wind power projects has been cut to 15% from 33%.

Wind power turbines of low and medium capacity are the norm in China, but market trends favor higher capacity turbines. To encourage Chinese companies to develop high-capacity wind turbines, the MOF in April 2007 announced the Adjusted Import Tax on High Power Wind Turbine Units and Key Components and Raw Materials. From 1 January 2008, refunds would apply on import duties and VAT paid by Chinese enterprises for key parts and raw materials to manufacture individual units with a power capacity of not less than 1.2 MW, supporting innovation and the development of new products. From 1 May 2008, the duty-free status of imported wind power was removed for systems lower than 2.5 MW.

#### CHINA LEADS WIND POWER TECHNOLOGY DEVELOPMENT

At present, China's small- and medium-sized wind power generating technology and its wind/PV hybrid system are in the lead internationally. In these and in all other aspects along the value chain, there are many opportunities for investment and growth, from the manufacture of components and wind-turbines to the development of wind farms and their operation.

**COMPONENTS:** Chinese turbines are low-capacity, so innovation of core components such as bearings, blades and gearboxes has benefited the most from the requirement that 70% of components be locally produced. These are relatively high-tech items that add value.

**TURBINES:** Fewer large-capacity units on a wind farm are needed to produce the same amount of energy, saving on transportation, installation and cable connection costs. Although foreign technology is ahead, several domestic Chinese enterprises have the expertise to manufacture small and medium-sized turbines and to pursue long-term R&D investment, and will benefit from the MOF policies. Poor roads and construction conditions in remote areas in China still favor small and medium sized units, which are easier to transport and install.

Goldwind has benefited strongly from national policies. The company makes money from product design, development, assembly, marketing and service and subcontracts for the manufacture of components. Fully 99% of the cost of Goldwind's main product, the 750kW wind turbine, goes for parts procurement, while labor and electricity account for only 1%.

**WIND FARMS:** China already has several 10 million kW wind farms in Inner Mongolia, Gansu, Xinjiang, Hebei, Jiangsu, and other places. Grid infrastructure and utility company support is still needed to ensure that these generate 100 million kW of electricity by 2020.

Xinjiang Xin Feng Co., established in 2006 specifically to provide wind farm services, had achieved revenues of 100 million Yuan (US\$ 15 million)<sup>70</sup> by 2008, showing the market possibilities for these farms. Wind farms can either be self-run or shared among investors. Once suitable locations are found, sales of equity in wind farms are a source of revenue that can finance growth, while some builders withdraw from the market taking their profit. Foreign enterprises may only enter the Chinese wind-farm market by cooperating with domestic enterprises, for example by purchasing equity in farms and becoming operators. For example, BP has a 49% share in a joint venture with subsidiaries of Goldwind. Once a project has been approved, BP purchases 49% of the project's assets, plus up to 20 million Yuan (US\$ 2.9 million) in stock appreciation.

Plans are underway to build the world's largest wind farm in Jiuquan, Gansu. It is estimated that the project will cost around 110-120 billion Yuan (US\$ 16-18 billion) of commercial capital. The project has attracted interest from over 20 domestic companies. It is expected that the project will be completed by 2020, with an installed capacity of 13.6 million kW. However, Gansu's grid infrastructure is relatively weak, so ensuring that the wind-generated electricity can be connected to a large-scale grid presents a major challenge for utility companies.

**OFFSHORE WIND FARMS:** China's offshore wind-energy possibilities are about 750 million kW – three times available land-based resources.<sup>71</sup> China's first offshore wind farm with NDRC approval, Shanghai's 100MW East Sea Bridge project, is scheduled for completion in 2009. The electricity will go to Shanghai's power grid. This demonstration project will have 50 wind turbines at an estimated cost of 2.1 billion Yuan (US\$ 307 million), with a payback period of 10-20 years. The designed capacity is 100 MW, with a stand-alone capacity of no less than 2,000 kW. The franchising period is 28 years.<sup>72</sup> Larger projects are being planned to serve areas where oil and coal is scarce.

Offshore wind farms have the advantages of not taking up land, freedom from topographical problems, higher wind speeds, higher capacity turbine units and more annual hours in operation. The East China Sea Bridge wind farm, for example, has more than 8,000 annual hours of useful wind. Generating efficiency is more than 30% higher than that of land-based wind farms.

On the downside, offshore wind farms face far greater technical difficulties and are about ten years behind the construction technology for onshore ones, with costs two to three times higher than for land construction. Technology entry levels are also much higher than they are for solar energy. Grid-connection barriers and profit-sharing conflicts have still to be resolved before offshore wind projects can be industrialized on a large scale.

Solutions for the instability of offshore wind power include building a large storage plant, building a smart grid and developing off-grid electricity generating technology. These three approaches are still at the R&D level, but as soon as the technology properly matures, there will be a big push for offshore wind projects.<sup>73</sup>

**HYBRID WIND/PV:** Hybrid wind/PV systems have some clear, advantages especially in remote areas:

- The hybrid system can provide a more reliable and stable supply of electricity to the grid.
- It optimizes the use of land resources, as wind power generating equipment benefits from high-altitude, while PV power may be generated on the ground.
- It shares transmission and distribution equipment, improving efficiency and lowering project and operating costs.
- A hybrid system reduces the amount of cable that is needed, which is especially useful in remote areas. It also minimizes excavation and construction. Smaller power station distribution networks benefit particularly, avoiding the disadvantages of a vast number of industrial controls and the costs involved in a conventional power station.
- In the west and centre of China, 30 million people lack access to electricity. Hybrid systems are appropriate to provide for their needs for lighting and providing electricity for public facilities, highway lights and signals, border posts, etc.

China's first on-grid wind/PV hybrid power generation project, a 100 kW photovoltaic solar power system at the Huaneng Nan'ao wind farm, was integrated into the local grid in December 2005. Huaneng Renewable Energy built the plant using solar panels and inverters produced by the Shell and Germany's SMA. With no national design standards for such a hybrid system, the company focused on solar/PV power generation, high-voltage grid technology, wind/PV hybrid technology, electric-power systems and various wind/PV technical operation and optimization parameters.

A wind/PV/hydroelectric-power system was independently developed by a research team at China Agriculture University's Information and Electrical Engineering College as a stand-alone, or complementary, system to provide wind, hydroelectric and photovoltaic power. The team designed its own 'solar-power and wind-resource monitoring and recording system', which was demonstrated in June 2007, providing valuable data for the study of low-speed wind characteristics and the distribution of solar power resources.

#### CHALLENGES IN ACHIEVING WIND POWER'S FULL POTENTIAL

To meet the 70% local-production target, more foreign capital has gone into factories to increase local production. However, this has consisted mainly of assembly with little transfer of real technology or R&D to China; although it has resulted in rapid growth of local production, it has not increased the core competitiveness of Chinese wind power equipment on the world stage.

For example, in March 2009 A-Power Energy Generation Systems Ltd, with headquarters in Shenyang, planned to put up the world's first wind turbine with an electricity-generating capacity of 2.7 MW, but this 30 to 40-floor structure did not contain a single domestically-produced component.

Despite heavy investment from government and business, there remains a wide gap to be filled in China, compared with international firms. Given the market tendency towards wanting large-capacity turbines, this gap may widen unless steps are taken. Some low quality products have only 20-30% of the efficiency of foreign ones<sup>74</sup> and even Goldwind, a leader in wind power, depends heavily on imported technology.

Product quality has long been a problem for Chinese enterprises. Wind turbine manufacturers rushed into the business because of rapid development and market demand. Although China does have wind turbine testing and certification agencies for domestic production, no official system has yet been set up, so testing and certification of wind turbines is the manufacturer's sole responsibility. The result is that a considerable number of domestic wind turbines have appeared on the market, without testing or certification.

Due to problems related to quality and to the technical performance of turbines, several wind farms have not been able to integrate with the grid or to operate normally. It has also been noted that the quality of domestic turbines is not up to that of foreign-funded enterprises or joint ventures. This usually had to do with technical problems that the domestic turbines encountered at the experimental stage, resulting in a longer period of downtime and often needing months to achieve their best performance.

The majority of wind farms have found themselves with weak profits or even faced losses for a number of reasons: an unstable tax and subsidy policy; erratic wind resources; disorderly development of wind farms and the lagging behind of grid construction; and extreme competition resulting in unrealistically low pricing.

To remove outstanding market barriers, the government is considering replacing its bidding system with benchmark prices and extending its VAT reform. According to deputy director of the National Energy Administration's Renewable Energy Division, Mr. Shi Lishan,<sup>75</sup> the benchmark price for each region would be determined by the bidding price and market conditions, instead of having one fixed price for all regions, and that this would encourage the development of good resources.

As the domestic market share of wind turbines increases, China plans to establish a wind power 'Industry Product Testing Center', a quality-assurance and control system, and a certification system, as quickly as possible. Improvements in domestic services and the quality of units would benefit competition, both at home and abroad. Government thinking is that quality should no longer be an obstacle to rapid development.

China's wind power industry has the advantages of resources and active government support and protection, but for the industry to grow technical improvements are necessary, in particular to the quality of large capacity fans for turbines. More construction work is also needed downstream and the operation and maintenance costs of wind-farms must be improved, which would provide plenty of opportunities for the industry. With the financial crisis and the challenges of climate change, improving domestic demand is a way to provide local opportunities for China's wind power industry.

## GEOTHERMAL HEAT PUMPS: RAPID DEVELOPMENT

The Geothermal Heat Pump (GHP) sector has developed rapidly in China, with installed heating capacity in 2007 at 1,900 MWt\* behind only the US, Sweden, Germany and France.

A special government construction fund had subsidized over 100 projects by 2008. Local government has also subsidized the use of GHP in buildings. A rapid growth in applications has been seen in cities such as Shenyang, Beijing, and Guangdong. For example, by the end of 2008 Shenyang had 29 million m<sup>2</sup> in applications, with plans for this to rise to at least 65 million m<sup>2</sup> by the end of 2010, accounting for 32.5% of the entire city's heat supply.

To meet the sector's full potential, several challenges will need to be overcome, including reducing installation costs, which are still high compared with conventional heating systems – even though operating costs are 25-50% lower. Greater consumer awareness is also needed.

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\*MWt refers to thermal power produced

Geothermal (or Ground Source) Heat Pumps (GHP) have economic and technical advantages in providing heating and air-conditioning. GHPs are electrically powered, home heating and cooling heat pumps, which transfer heat to and from the earth via a refrigeration process. During winter operation heat energy is absorbed from the ground via underground tubing or by pumping well water to the heat pump. The heat pump mechanism concentrates this energy and delivers it to the home in the form of warm air or hot water. During summer, the process is reversed: warm air is collected from the home and transferred to the cooler earth.

After about ten years of development in China, the technology has evolved to include air conditioning and heating (of space and water). The technology can work with ground water (from underground water, rivers, streams, lakes and sea), air and untreated sewage-source heat pumps.

#### RAPID DEVELOPMENT OF GEOTHERMAL HEAT PUMPS ACROSS CHINA

GHP has developed rapidly in China. The nationwide area for developing heating (and some cooling) through the use of GHP rose from 7.67 million m<sup>2</sup> in 2004 to 38 million m<sup>2</sup> in 2007.<sup>76</sup> The installed heating capacity of China in 2007 was 1,900 MWt (assessed from equipment heating capacity using the international statistical method), behind only the US, Sweden, Germany and France.<sup>77</sup> The US National Renewable Energy Laboratory forecast that by 2010, Chinese sales of the GHP systems would amount to 7.65 billion Yuan (US\$ 1.1 billion), up 116% from 2005. The projected sales for Chinese provinces are shown in Table 4. One analysis estimates an annual growth in GHP sales in China of 20%.<sup>78</sup> At that rate, China will soon overtake Germany and France to become third in the world.

TABLE 4 – PROJECTED SALES OF GHP SYSTEMS AND UNITS IN 14 CHINESE PROVINCES<sup>79</sup> – IN MILLIONS OR BILLIONS OF YUAN (US\$)

		GHP SYSTEMS	GHP UNITS
PUBLIC BUILDINGS	2009	10.5BN (1.5BN)	4.2BN (615M)
	2010	10.92BN (1.6BN)	4.37BN (639M)
COMMERCIAL BUILDINGS	2009	1.18BN (173M)	473M (69M)
	2010	1.35BN (198M)	542M (79M)

#### POLICY SUPPORT DRIVES GROWTH

GHP technology was first introduced into China through an Agreement of Cooperation of Ground Heat Energy Production and Application, which was signed with the US government in 1997 to promote US ground-gas (water) type GHP technology in China. Following the success of that initiative, hundreds of GHP demonstration projects were set up around China. Also in 1997 domestic cooling equipment manufacturers modeled products on European water-water type units and sold their products in North China, creating a second channel for the introduction of GHP into the country. Since the manufacture of GHP units is not particularly difficult, other manufacturers began to copy them and now European water-water GHP technology accounts for at least 80% of China's GHP market.

Since 2005, various Chinese government policies and financial subsidies have encouraged energy-saving products and technology development. The Technical Specifications for GHP Systems Projects was implemented on 1 January 2006 and amended in November 2008. In 2006, the MOC and MOF jointly promulgated their Opinions on Promoting Renewable Energy Applications in Buildings and the Interim Measures for the Administration of Special Funds for Renewable Energy Applications in Buildings, which paved the way for a special construction fund. By 2008 over 100 projects had been subsidized. Architectural energy-saving management regulations have also helped to promote GHP technology.

The MOF and NDRC jointly prepared the Interim Measures for the Administration of Fiscal Reward Funds for Energy-saving Technology Innovation in August 2007. This gives enterprises a financial reward of 200-250 Yuan (US\$ 29-37) per tce saved, encouraging energy-saving technology, including GHP. The 11th Five-Year Plan provides support for the 'study and demonstration of key technology in efficient application of water and GHP'.

The MOC and MOF helped formulate Technological Guidance to Renewable-energy Applications in Construction in November 2008 and distributed this among builders of demonstration projects.

Local government has also supported GHPs, subsidizing their use in buildings for example. As a result, many enterprises entered the GHP market in China, focusing mainly on assembly and application systems.

**CITY PILOT PROJECTS DELIVER PROMISING RESULTS**

Pilot projects have stimulated local governments to support their own GHP projects.<sup>80</sup> The city of Shenyang was chosen as the nation's GHP technology pilot promotion city on 29 September 2006. In response, municipal government introduced its Opinions on Overall Advancement of GHP System Construction and Applications. By the end of 2008, Shenyang had 29 million m<sup>2</sup> in applications, with plans for this to rise to at least 65 million m<sup>2</sup> by the end of 2010, which will account for 32.5% of the entire city's heat supply.

Beijing is following in Shenyang's footsteps. It had more than 500 GHP projects by the end of 2007, using shallow ground geothermal units that cover the urban area and extend beyond the suburbs. Beijing plans to enlarge this coverage to 30 million m<sup>2</sup> by 2010, increasing annually at a rate of about 6 million m<sup>2</sup>. The city offers a one-time subsidy of 35-55 Yuan (US\$ 5-8) per m<sup>2</sup> of floor area for heat supply projects using GHP. Of the 358 'Green Olympic' projects put in place for the 2008 Games, four used GHP, three adopted water heat pumps, and two used direct geothermal energy. The demonstration of GHP applications at Olympic venues has increased demand for energy-saving technology in the property market, creating new opportunities for the industry.

In Chongqing, GHP technology applications are amongst the highest in China. Four projects have been named state-level demonstration projects for renewable energy building applications, with about 30 million Yuan (US\$ 4.4 million) in national financial assistance. Chongqing's river water heat pump units could save about 30% in energy over conventional air-conditioning. The city has introduced a subsidy of 800 Yuan (US\$ 117) per kW of rated cooling capacity for air-conditioners using heat pump units from renewable energy, and a subsidy of 900 Yuan (US\$ 132) per kW of rated heating capacity for high-temperature heat pump units that use renewable energy to provide domestic hot water.

The city of Qingdao has also promoted the use of GHP-technology while Guangdong is now the most important production and consumer center for China's heat pump industry. Statistics show there are about 197 heat pump enterprises in Guangdong at present, more than half in all of China and representing at least 65% of the nation's total capacity.

GHP is also being used along the lower reaches of the Changjiang (Yangtze River), where coal reserves are poor.

**INCREASING DOMESTIC TECHNOLOGICAL CAPACITY**

Although China continues to rely on imports of compressors, growing numbers of heat pump manufacturers are capable of producing large heat pumps with a heating (cooling) capacity of up to 2,000-3,000 kW, as well as small household models under 10 kW. But even heat pumps are often imported, for example from Climaveneta (Italy), Ciat (France) and Carrier and McQuay (USA). Some foreign brands have built production plants in China and some have entered into joint ventures to produce new brands.

Beijing Jike Energy New Technology Development Co. has developed local GHP technology of the US ground-gas type. It is now an industry leader, having supplied over 30 single buildings with large, medium and small ground-gas or ground-water GHP air-conditioning systems over an area ranging from 100 m<sup>2</sup> to 88,000 m<sup>2</sup>. It has more than 100 GHP heating and/or cooling designs and holds patents for its ground-coupling pipe optimization and burial technology, and for software it developed for ground-gas GHP systems design. Its success has helped to fill the gap between domestic and international capacity. Beijing Ruibaoli Heat Energy Science and Technology Co., Ltd. has developed the technology for heat pumps to provide air-conditioning systems from untreated sewage that overcome the problem of sewage clogging pipes and equipment.

Aside from such manufacturing successes, project design and engineering teams have made progress in the GHP market. There are now more than 70 to 80 GHP project development teams in Shenyang. Growing market demand is helping to improve standards while also enabling newcomers to enter the market. Enterprises entering the market have begun to turn from exploring new markets to improving service. Competitors are promoting their products as energy-saving, as having good after-sales service, etc. It is hoped that China's first authoritative GHP training institute set up by the China Renewable Energy Society's GHP Group in the second half of 2007 will reduce the number of quality defects in the industry.

38 domestic GHP manufacturers, designers, installers and supervisors took part in the Shenyang GHP Technology Applications Exposition in November 2006. Shenyang's market for GHP is estimated at nearly 10 billion Yuan (US\$ 1.5 billion) in the long-term. At an estimated cost of 100-150 Yuan (US\$ 15-22) per m<sup>2</sup> for GHP, even the most conservative estimate put the commercial GHP opportunities in 2007 at 1 billion Yuan (US\$ 146 million).

**CHALLENGES TO ACHIEVING WIDER USE OF GEOTHERMAL HEAT PUMPS**

Perhaps the greatest obstacle to their wider use is the high installation cost of GHP systems compared with conventional systems. But a conventional centralized heat supply only provides heating, while a centralized GHP heating system supplies hot water, heating and air-conditioning in buildings from co-generation. The other major advantage of GHP is that operating costs are 25-50% lower than conventional systems (Table 5). A GHP installation cost of 600-1,000 Yuan (US\$ 88-146)/ton is obviously high compared with electric cooling and natural-gas heating cost of 500-800 Yuan (US\$ 73-117)/ton. There are also difficulties in maintaining a GHP system that further detract from their wider use.

In their favor, however, using GHP systems to supply heat and domestic hot water cuts energy costs, while dramatically reducing greenhouse gas emissions.

**TABLE 5 – INITIAL INVESTMENT AND OPERATING COSTS OF GHP SYSTEM, COMPARED TO CENTRAL-AIR AND HEATING SYSTEM RUNNING ON NATURAL GAS<sup>91</sup>**

	GHP SYSTEM		NATURAL GAS-POWERED CENTRAL-AIR-CONDITIONING AND FURNACE	
	UNIT PRICE, YUAN (US\$)/M <sup>2</sup>	TOTAL COST, IN MILLIONS YUAN (US\$)	UNIT PRICE, YUAN (US\$)/M <sup>2</sup>	TOTAL COST, IN MILLIONS YUAN (US\$)
EQUIPMENT COSTS	224 (33)	15.72M (2.30M)	219 (32)	15.34M (2.24M)
CONSTRUCTION COSTS	136 (20)	9.52M (1.39M)	147 (22)	10.29M (1.51M)
TOTAL INVESTMENT	360 (53)	25.24M (3.69M)	366 (54)	25.63M (3.75M)
OPERATING COSTS, HEATING	12.9 (1.9)	1.5M (0.22M)	30 (4.4)	2.64M (0.39M)
OPERATING COSTS, COOLING	8.5 (1.2)	0.75M (0.11M)	14.2 (2.1)	1.25M (0.18M)
COST OF SPACE NEEDED FOR EQUIPMENT	2500 (366)	0.375M (55,000)	2500 (366)	0.875M (128,000)

Aside from high installation costs, poor quality detracts from the use of GHP in projects in China. Also, an irregular market and an unsound access system prevail despite the promulgation and amendment of a 'National Technical Standard for the Geothermal Pump System' and there is still a lack of systematic and ongoing training in the industry, where it is technologically challenging for a GHP manufacturer to provide technical services for the operation of the entire system.

GHP finds obvious application in buildings, but real estate developers are confronted with high costs and poor quality GHP equipment. Real estate developers also have no clear understanding of the technology and want to keep costs under control, while mature GHP professionals are lacking. Constraints of cost, time, technology and expertise affect their willingness to use GHP systems, which do not come with adequate assurances of standards, materials or construction. Despite the economic benefits of operating a GHP system, the construction costs are at least 50% greater than those of conventional air-conditioners, which are not easily covered by the sales price, especially when installing them causes delays to marketing the property. But air source heat pumps and natural gas and coal-fired heat sources are relatively mature technologies, giving them an advantage.

GHP systems are mainly used in schools, hospitals, government buildings, and high-end residences. More active involvement of the better GHP enterprises in the real estate sector along with the expansion of their markets would help the industry to grow. To further encourage developers, more attention from local governments, greater public awareness and greater awareness among end users of the implications of conventional energy use is needed. Support is needed from both government and consumers for the industry to grow, and steps should be taken to improve cooperation with real estate developers. Industrial codes must also be formulated. Meanwhile, ongoing improvements are required in a range of areas from product standards to their scientific evaluation.

## **BIOFUELS: STRONG BEGINNINGS, PROMISING PROSPECTS.**

Sustainable biofuels have the potential to mitigate climate change, reduce energy dependence, create profits for enterprises, bring work to a large number of farmers and develop land in an environmentally friendly way.

China produces 300,000 tons of biodiesel annually from cottonseed oil, wood oil, tea oil and used oils.

High-quality, self-cultivating energy plants like *Jatropha* are also available.

Supported by government policies, industrial technologies to transform biomass to fuel ethanol and biodiesel have matured, though still with much room for improvement. Costs in the future could be 25-45% lower than at present. In addition, cellulosic ethanol can be produced from straw and forestry waste, of which there are 600 million usable tons produced each year in China.

There is a clear intent to promote the commercialization of biofuels, but the government has sent a signal to China's biofuel ethanol industry to use only non-food crops to help protect food security and to manage price and supply.

Several technology and raw material supply challenges must be overcome if biofuels are to reach their full potential.

Biomass has many applications in China – biogas, direct-fired biomass power generation, biomass gasification and blended biomass combustion. This report focuses on biofuels, the liquid fuels that derive from growing crops and their residues.

#### SUPPORTIVE POLICIES DRIVE BIOFUEL DEVELOPMENT

A national scientific and technological plan was developed in 2004 by MOST, as part of China's 10th Five-year Plan. This initiated the 'biofuel technology development' project. The Renewable Energy Law of 2005 supported the development of biofuels. In December 2006, the NDRC and MOF issued a joint Notification on the Administration of Biofuel Ethanol Projects and the Promotion of Healthy Development of the Biofuel Industry. This required that the biofuel ethanol industry not use edible grains. Subsequently, China issued its Interim Measures for Subsidies for Raw material Bio-energy and Bio-chemical Bases to encourage the planting of non-grain crops through subsidies. More policies promoting the industry are expected to appear soon.

There are also several policies in place that manage the market. In September 2006 the MOF, NDRC, Ministry of Agriculture, State Administration of Taxation and the State Forestry Administration jointly issued the Opinions on Supportive Taxation for the Bio-energy and Bio-chemical Industries, which included biodiesel fuel. In December 2006 the NDRC and MOF issued their Notification on the Administration of Biofuel Ethanol Projects and Promotion of Healthy Development of the Biofuel Industry. This document requires that biofuel ethanol projects have investment approval and that production capacity may not be increased without government permission. This sent a clear signal that China's biofuel ethanol industry was to use only non-food crops, to help protect food security and to manage price and supply.

In May 2007, national standards for biodiesel were announced by the National General Administration on Quality Supervision. In September 2007, the MOF issued its Interim Measures for Subsidies for Raw-material Bio-energy and Bio-chemical Bases. To encourage the planting of non-food crops, the government established a subsidy of 200 Yuan (US\$ 29) per mu\* for the use of forestry raw materials and 180 Yuan (US\$ 26) per mu for the use of agricultural raw materials. In January 2008, the State Forestry Administration established a leading group and bio-energy forestry office, developing a 'national energy-forest development plan' and '11th Five-year development plan for biodiesel-fuel raw materials forestry bases'. For the gradual establishment of 'forest-oil integration' and 'forest-electricity integration' (which includes raw materials cultivation, processing, production and sales) China will have demonstration projects during the period of the 11th Five-year Plan. By 2010, China will have an annual production of 200,000-300,000 tons of raw materials for biodiesel fuel. By 2020, the energy-forest area will cover more than 13 million ha, with an annual production capacity of approximately 6 million tons of raw materials for biodiesel fuel.<sup>82</sup>

The Ministry of Agriculture (responsible for food security) and the State Forestry Administration (responsible for the development of cellulosic ethanol) are involved in the fuel ethanol industry.

**TAX BREAK FOR VEHICLES USING ETHANOL:** The government provides favorable tax policies for bio-energy and bio-chemical enterprises where necessary. During the long pilot-project period, four government-approved, denatured-fuel ethanol companies – Jilin Fuel Ethanol, Henan Tianguan Group, the Anhui BBKA Biochemical Co. and the Heilongjiang China Resources Alcohol Corp. – were each given a 5% consumer tax exemption.

**GRADUAL SUBSIDY REDUCTION:** In 2007 the government lowered the subsidy of ethanol to 1,373 Yuan (US\$ 101) per ton, which was 255 Yuan (US\$ 37) less than for the previous year and 500 Yuan (US\$ 73) less than that for 2005. By the end of 2008 subsidies were again adjusted. The assumption is that as the technology matures and there is increased commercial production, prices will drop with less need for subsidies.

**RISK FUND:** Corporate and national venture funds provide flexible subsidies for biofuel enterprises through government risk-sharing.

**EXPANDING THE MARKET:** The 11th Five-year Development Plan for Biofuel Ethanol and Ethanol Gasoline and the Biofuel Ethanol Industry Development Policy include plans to expand the use of ethanol gasoline.

Under the present circumstances, with the sharp drop in the crude oil and refined oil price, and the serious losses incurred by large-scale petrochemical enterprises, the market generally expects the government to relax price-control policies on refined oil and keep raising prices, so that they will eventually converge with international crude oil prices and reflect the true resource price. Over the long-term, oil prices will continue to rise and considerably reduce stress on the price of bio-fuels. Since the price of bio-diesel fuel is less than that of ordinary diesel oil by about 600 Yuan per ton (US\$ 88), the government's increased refined oil prices will make bio-diesel prices rise, take pressure off the high biodiesel fuel enterprise costs, improve the business environment and increase profits.

A larger domestic auto market with increased fuel demands is to be expected from the government's 'Restructuring and Revitalization Plan for the Automobile Industry' of early 2009. This will benefit ethanol gas production. So will the consumer tax exemption and VAT rebate, the 'oil-forest integration' development model and the risk fund system.

Since 2007 forests have developed rapidly in China, with more than 200 million mu planted in forests specifically for energy generation. In June 2008 the NDRC approved three biodiesel demonstration projects on an industrialization scale with small Polycaraea seed as raw material, under the guidance of China Petroleum, Sinopec and China National Offshore Oil Corp (CNOOC). These three projects have an annual production capacity of 170,000 tons overall, with a small supporting Polycaraea base of more than 1.5 million mu.

\*1 mu = 666 square meters

**PROSPECTS FOR CELLULOSIC ETHANOL**

Developing cellulosic ethanol ('second-generation biofuel') is a way to avoid shortages in the supply of raw materials, but many large energy companies are still trying to improve the technology. As a result there are no cellulosic ethanol manufacturers producing on a commercial scale due to technical limitations that have yet to be overcome. Steps towards commercialization are accelerating<sup>83</sup> around the world. The US Energy Department announced in February 2007 that six refinery projects were to get US\$ 385 million, of which US\$ 33.8 million will support the development of a viable commercial enzyme to produce cellulosic ethanol. Research is also under way in Europe, Canada and other developed countries.

There is only a gap of about five years in R&D between China and the most advanced bio-technology in the world. COFCO and Henan Tianguan are at the center of China's biofuel ethanol development and dedicated to accelerating its commercialization. Fourteen of COFCO's 36 patents in the fuel ethanol field are related to cellulosic ethanol. In May 2008, the Henan Tianguan Group completed China's first ethanol production line, with an annual production capacity of 5,000 tons, producing the first batch of fiber ethanol. Through a process of bio-fermentation, it can transform more than 30,000 tons of crop straw into fuel ethanol annually. At present, it has systematic fiber-ethanol production technology and a number of patents. By the end of 2012 it expects to have ten plants, and, by 2020, about 100 with mass production capacity. In addition, a series of 'Biological gasoline' production programs were recently started by the Santai Wine Group in Jimsar with Zhejiang HaoQi bio-energy technology Co. and the Xinjiang Shache county government. In early 2008 GM formed strategic alliances with an American energy company, Coskata, and the Mascoma Corp. to develop a new generation of technology to help commercialization, estimating that their cellulosic ethanol fuel production costs will be lower than US\$ 1 per gallon. Integrated biochemical technology, when applied to extracting ethanol from cellulosic materials, can greatly reduce the use of additives and enzymes, cutting manufacturing costs.<sup>84</sup>

**PROSPECTS FOR BIODIESEL**

The future of biodiesel fuel depends on technology improvements, in the diversification of materials and in stabilizing the supply of raw materials. According to 2007 statistics, China's biodiesel production was only 300,000 tons, with only 10% of the output capacity being used. By the end of 2007 China had dozens of biodiesel enterprises, with a total annual production capacity of more than three million tons. There is now wider acceptance of the use of discarded oil and edible oils and fats, and the use of oil crops such as *Jatropha*. These could provide the needed impetus for market development. It is generally believed that waste oil will be the main raw material for a while. Meanwhile, the long-term use of Chinese Pistache and *Jatropha* has room for growth. In this, the sophisticated Fischer-Tropsch technology, which uses bio-synthesis, is already mature. According to New Energy Finance, by 2020, about 50% of Chinese biodiesel fuel will come from applications of this technology.

Suitable raw materials for biodiesel fuel in China are *Jatropha*, Chinese Pistache, *Swida*, *Xanthoceras* and the Chinese tallow tree. Preliminary studies have shown an area of more than 1.35 million hectares of these species, with an annual fruit production of more than 1 million tons. If that amount of fruit could be processed, it would provide more than 400,000 tons of biodiesel fuel.

In addition, there are more than 54 million hectares of barren hills and wasteland. If 20% of that land were used, it could provide as much as 200 million tons of bio materials annually, which is equivalent to 100 million tons of standard coal. With improvements, saline-alkali or sandy land and mining and oil reclamation land that is not suited for agricultural production could be used. The development of China's forest bio-energy potential will gradually become a leading bio-energy field, with broad prospects.<sup>85</sup>

As micro-algae engineering technology matures, algae-farming in shallow sea areas along China's coasts is also a possible source of materials. Sinopec and the Chinese Academy of Sciences have together developed micro-algae biodiesel technology and have recently completed several small pilot studies, but problems of scale and cost make this a long-term possibility.

**CHINA'S ADVANTAGE:** Domestic equipment is still relatively inferior in quality, but with lower prices and good use of raw materials, this could be managed by SMEs. Unlike large-scale biodiesel equipment used in the west, Chinese equipment is suited to the specific supply of raw materials, providing flexibility to deal with a variety of raw materials of differing quality. At present, Chinese equipment costs much less than a complete set-up from abroad, allowing room for movement.

China has the comparative advantage of diversification in processing and production. China is ahead of other countries in a number of practical processes and techniques, each with its own expertise and advantages. The main method of biodiesel production currently being used is chemical trans-esterification, but a few enterprises use bio-enzyme technology. In the long term, bio-enzyme technology will be more widely used. 'Made-in-China' does not only mean inexpensive; but also high-quality, flexible and adaptable.

**MARKET DEVELOPMENTS:** National enterprises have made progress in developing capacity and securing raw material to produce biodiesel:

- In 2006 CNPC's refinery and chemical plant in Nanchong, Sichuan, designed a biodiesel-fuel project to produce 60,000 tons per year. The first phase of 10,000 tons is under construction. The main raw material is locally-produced *Jatropha* fruit. To ensure adequate supplies, CNPC has plans to develop 40 million mu; and 180 million mu for trees.
- In July 2006 Sinopec set up a biodiesel-fuel refinery with an annual capacity of 100,000 tons, and a corresponding energy forest of 400,000-500,000 mu.
- In October 2007 Sinopec signed an agreement with Guizhou province's Development and Reform Commission to develop a *Jatropha* project producing 50,000 tons of biodiesel per year.
- In September 2006, CNOOC also signed an agreement with the city of Panzihua for a 'Panxi-area *Jatropha* biodiesel-fuel industrial development project', which involved spending 2.347 billion Yuan (US\$ 343 billion) on a 500,000 mu, small *Polycaraea* tree base to be completed in 2010. By then it will have an annual production capacity of 100,000 tons of biodiesel. CNOOC is also planning to build the first phase of a biodiesel-fuel refinery with an annual production capacity of 60,000 tons, in Dongfang, on Hainan Island, and to plant several tens of thousands of hectares in *Jatropha*.<sup>86</sup>

Energy giants from US, UK, Austria and other countries are actively developing biodiesel markets in China. The financial resources, advanced technology and management level of these foreign companies will pose a great challenge to local biodiesel companies in the future.

The key to liquid biofuels lies in the control over and costs of raw materials. Private enterprises are more sensitive to market changes and tend to be more flexible in their production. Familiar with agriculture and farmers, they can deal with details that large state-owned enterprises can't and have experience bargaining with local governments and farmers. The transition from edible grains to non-food sources has given them an opportunity with which they can identify. They can also control costs down to a narrow margin. At present there are flexible government subsidies to cover losses. So as long as an enterprise operates at the industrial average, it won't suffer from price fluctuations in crude oil, whereas they will reap benefits if they are ahead of the industrial average in the development or use of by-products.

Shenyu's approach is to build a factory where there is sufficient land to meet the factory's needs, (at least 100,000 mu to meet the annual production capacity of 20,000 tons of raw materials). Farmers are confident of planting when they see the factories; and the seedlings are purchased by the company. This 'core planting' enables control of cost and source of materials.

The current scarcity and high prices of raw-materials cause private biodiesel enterprises to become polarized: the stronger ones cut costs by using more advanced technologies, such as companies like Hunan's Hainabaichuan bio-engineering Co. Ltd; while those with a larger production capacity can cut costs by using economies of scale, such as Sichuan's Gushan Oil Chemical Co. or China Biodiesel International Holdings Co. Ltd. Those with enough financial strength spend large sums cultivating a biodiesel raw-material forest base, e.g. *Jatropha*, such as Liuzhou Minghui biofuels Ltd.

#### CHALLENGES IN COMMERCIALIZING BIOFUELS

Beyond specific technical issues, the supply of raw-materials and the sale of refined oil are constraints on the development of biofuels and are proving to be a major obstacle to commercialization. Despite the 'Renewable Energy Law' and national standards for biodiesel, private-enterprises are still unable to sell through state gas outlets and the bulk of biodiesel sells at the price of low-quality oil. The price per ton of biodiesel is 600 Yuan (US\$ 88) lower than that of regular diesel, seriously limiting profits.

Although the country has its '11th Five-year development plan for biofuel ethanol and ethanol gasoline for vehicles' and the 'Biofuel ethanol industry development' policy, the delay in implementing them means that biodiesel has an unfavorable image in the market. Manufacturers cannot increase prices because of state control over the price of refined-oil. Compared with the EU, the US and elsewhere, Chinese policies are not supportive enough.

Increasing the supply of raw materials and removing the policy obstacles are necessary for China's biofuel industry. The government should continue to improve its policy guidelines for biofuels and help more enterprises at the development stage. The future of biofuels is bright and enterprises and R&D on biofuels offers many opportunities. Biofuel development can mitigate climate change, reduce energy dependence, bring work to a large number of farmers and develop rural resources in an environmentally friendly way.

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**CHAPTER 4:  
LOW CARBON  
CONSTRUCTION AND  
URBAN DESIGN**

China's policies and regulations are promoting low-cost, high-benefit solutions to reduce the carbon requirements for buildings. These include low carbon urban planning, low carbon building standards and labels, redevelopment, renovation and retrofit of cities and buildings, and building energy management systems.

Their Medium and Long Term Energy Conservation Plan has set ambitious energy conservation goals that include a 50% energy conservation standard for all new buildings and a 65% standard for the new buildings in some major cities by 2010. The Plan puts emphasis on low carbon building materials and renewable energy, especially solar energy and heat pumps, and green building labels.

Many major low carbon construction projects have been completed successfully, but after a decade of remarkable growth, China's property market is now in slump. Although this creates challenges, it also provides an opportunity for low carbon buildings to lead a more sustainable revival of the property market.

The future success of low carbon buildings will depend on overcoming a lack of public awareness and reducing costs, so that they become much more widely attractive and accessible.

Low carbon buildings are seen as a way to boost domestic demand and create jobs to help deal with the global economic downturn, while mitigating China's energy-intensive growth.

While the concept of 'smart building' is not well known in China, related concepts such as energy efficiency, emissions reduction and green buildings are, at least among decision-makers and business leaders. The spread of these concepts is helping to encourage policies and the development of smart buildings, paving the way for their broader commercialization. Energy efficiency is a frequent topic among government leaders. At first, this concept affected industrial codes, but more recently it has become a key component of state energy planning and legislation.

China's market leadership in low-carbon building technologies already include energy saving lamps, solar water heaters and solar PV products that have spurred regulators to encourage the use of these technologies, with specific rules and subsidies for building integration of solar energy systems (BIPV). Because of its potential, foreign companies are interested in participating in the growth of this technology in China.

This chapter discusses the potential for low carbon buildings in China, highlights government policies encouraging their development, and profiles several case studies of successful low carbon construction projects. Finally, it sets out the challenges that must be addressed if low carbon buildings are to be developed at wider scale.

**“THE PROPERTY MARKET IS NOW IN A SLUMP, BUT GREEN REAL ESTATE COULD BE A CURE FOR THE AILING INDUSTRY. IN THE FACE OF SUCH AN IMMENSE CHALLENGE, THE REAL ESTATE BUSINESS NEEDS TECHNOLOGICAL INNOVATION FROM THE MAJOR PLAYERS. WE NEED TO DELIVER A UNIQUE PRODUCT TO SAVE OURSELVES AND COPE WITH THE FINANCIAL CRISIS.”**  
**ZHANG ZAIDONG** CHAIRMAN AND GM, BEIJING TIPTOP REAL ESTATE

**THE POTENTIAL FOR LOW CARBON BUILDINGS IN CHINA**

There is huge potential for low carbon buildings in China, both new build and retrofitting, see Chart 7.

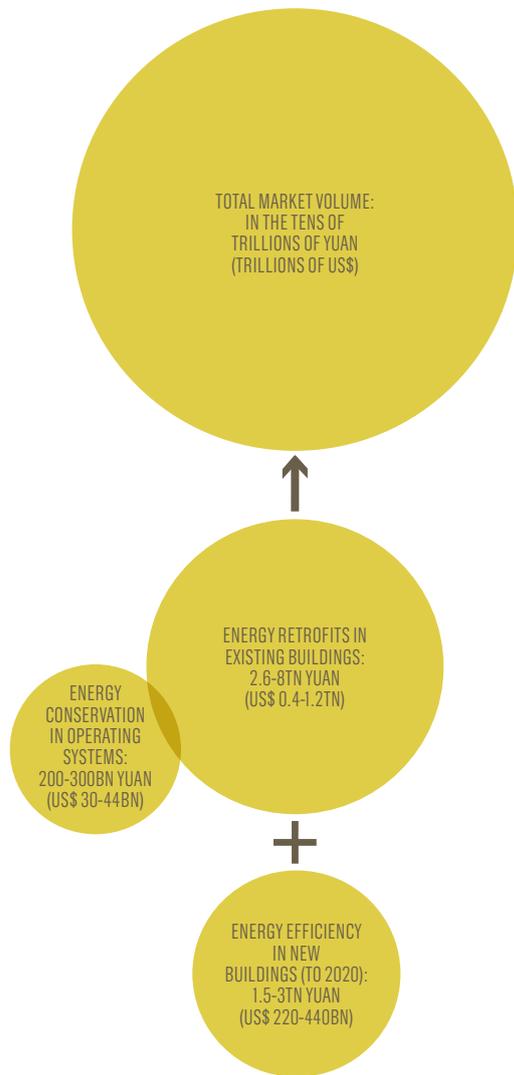
**NEW BUILDINGS:** Total floor space in China, currently 40 billion m<sup>2</sup>, is expected to reach 70 billion m<sup>2</sup> by 2020. At an estimated 100 Yuan (US\$ 15) per m<sup>2</sup> cost increase,\* the market potential of low carbon buildings would amount to 1.5 trillion Yuan (US\$ 220 billion) if half of new buildings apply low carbon solutions or 3 trillion Yuan (US\$ 439 billion) with greater stringency.

**RETROFITTING EXISTING BUILDINGS:** At least one-third of buildings in China need an energy performance upgrade. At 200 Yuan (US\$ 29) per m<sup>2</sup> on average, this upgrade could easily exceed 2.6 trillion Yuan (US\$ 381 billion)\*\*

Meanwhile, the government has for some years been encouraging heating improvements in building operating systems. In the northern parts of the country about 150 million m<sup>2</sup> of buildings need a heating system retrofit, which would cost about 200-300 billion Yuan (US\$ 29-44 billion).<sup>88</sup>

The China Medium and Long Term Energy Conservation Plan sets short-term goals for the incorporation of significant increases in energy-conservation design standards in new buildings. Some optimistic estimates on spending put the upper limit in the tens of trillions of Yuan.

**CHART 7 – MARKET VOLUME FOR SMART BUILDING**



**70BN**  
 TOTAL FLOOR SPACE IN CHINA, CURRENTLY 40 BILLION M2, IS EXPECTED TO REACH 70 BILLION M2 BY 2020.

\*TCG analysis, based on news report by Sun Rongfei, 'To Boost the 500 billion Building Energy Conservation Market, Two Ministries Turn to Carrot and Stick', Wu Chong, Vice Director for Science and Technology Division, Ministry of Housing and Urban-Rural Development, said 'Take Beijing for example, complying to 50% energy conservation design standard, about 100-120 Yuan (US\$ 14.6 - 17.5) per square meter cost increase would be needed, a further 30 Yuan (US\$ 4.4) would be necessary if 65% standard complied.' China BusinessNews, Shanghai, 21 November 2007, viewed on 28 March 2009, <http://www.china-cbn.com/s/n/000002/20071121/02000060831.shtml>. US\$ figure based on exchange rate of 1US\$ to 6.84 Yuan, correct at 6 August 2009.  
 \*\*According to a news conference speech by Qiu Baoxing, Vice Minister of Housing and Urban-Rural Development, News Conference on China's Building Energy Conservation and Green Buildings, hosted by State Council Information Office, Beijing, 16 February 2006, viewed on 25 March 2009, [http://www.gov.cn/xwfb/2006-02/16/content\\_200965.htm](http://www.gov.cn/xwfb/2006-02/16/content_200965.htm). US\$ figure based on exchange rate of 1US\$ to 6.84 Yuan, correct at 6 August 2009.

Each stage in the life of buildings presents many business opportunities, from design, construction, operations and maintenance to ultimate demolition. Low carbon buildings also provide clear benefits for a range of stakeholders, including government, developers, and consumers, see Table 6.

TABLE 6 – STAKEHOLDER BENEFITS FROM LOW CARBON BUILDINGS

PARTY	BENEFITS
GOVERNMENT	<ul style="list-style-type: none"> <li>– RESPONSIBLE IMAGE, BOTH AT HOME AND ABROAD</li> <li>– MORE BUSINESS OPPORTUNITIES AND GREEN JOBS</li> <li>– BETTER ENERGY PERFORMANCE WITH LOWER MAINTENANCE COSTS FOR PUBLIC BUILDINGS AND FOR GOVERNMENT OWNED, LOW-COST HOUSING</li> </ul>
DEVELOPER	<ul style="list-style-type: none"> <li>– IMPROVED BUILDING QUALITY FOR CUSTOMERS</li> <li>– REDUCED CONSTRUCTION TIME, IMPROVED COST-EFFECTIVENESS, IMPROVED CASH-FLOW RATE, INCREASED PROFITS</li> <li>– IMPROVED BRAND IMAGE</li> </ul>
RELATED INDUSTRIES	<ul style="list-style-type: none"> <li>– MANUFACTURING: NEW BUILDING MATERIALS LIKE HIGH-PERFORMANCE CONCRETE, HIGH-STRENGTH STEEL, FITTINGS LIKE DOORS AND WINDOWS</li> <li>– CONSTRUCTION: PLANNING, ARCHITECTURAL DESIGN, PROJECT MANAGEMENT, CONTRACTING AND CONSTRUCTION</li> <li>– SERVICES: HOLISTIC SOLUTIONS, ASSET MANAGEMENT, QUALITY CONTROL, ENERGY-PERFORMANCE MONITORING AND ASSESSMENT, QUALIFICATION AUTHENTICATION, TRAINING</li> <li>– RENEWABLE ENERGY: HEAT PUMPS, SOLAR THERMAL PANELS, SOLAR PV</li> </ul>
CONSUMER	<ul style="list-style-type: none"> <li>– HIGHER QUALITY/PRICE RATIO AND LONGER LIFE CYCLE, MORE ENERGY EFFICIENCY, MORE COMFORT, AND REDUCED COSTS OF MAINTENANCE</li> </ul>

**GOVERNMENT POLICIES DRIVE ENERGY CONSERVATION IN BUILDINGS**

China’s Medium and Long Term Energy Conservation Plan, as part of the 11th Five-Year Plan, sets major energy conservation goals including a 50% energy conservation standard for all new buildings and a 65% standard for new buildings in four municipalities and some major cities. It also calls for cuts of 120 million tons of coal used, to meet 21% of China’s entire energy conservation targets.

The Ministry of Housing and Urban-Rural Development (MOHURD), the MOF, and the NDRC have passed laws and regulations over the past few years that specify standards for buildings and public institutions to promote energy conservation and that create certain subsidies.

Legislators have also identified a number of low-cost, high-benefit energy conservation measures for Chinese buildings that have state and local financial support for a range of demonstration projects, shown in Chart 8.

CHART 8 – CHINA’S SMART BUILDING POLICIES

LEGAL ENVIRONMENT	SIX KEY AREAS
– PLAN: CHINA MEDIUM AND LONG TERM ENERGY CONSERVATION PLAN	– 50% ENERGY CONSERVATION DESIGN STANDARD FOR NEW BUILDINGS
– LAWS: RENEWABLE ENERGY LAW, ENERGY CONSERVATION LAW	– HEATING SYSTEM METERING AND RETROFITTING, NORTH CHINA
– REGULATIONS: ENERGY CONSERVATION REGULATION FOR CIVIL BUILDINGS, ENERGY CONSERVATION FOR STATE-FUNDED INSTITUTIONS	– ENERGY CONSERVATION IN GOVERNMENT AND PUBLIC BUILDINGS
– SUPPORT MEASURES: SPECIAL FUNDS, STANDARDS, LABELING, ASSESSMENT, QUALITY CONTROL	– SOLAR AND GEOTHERMAL RENEWABLES
	– NEW BUILDING MATERIALS
	– BUILDING ENERGY AUDITING AND ASSESSMENT



DEMONSTRATION PROJECTS	FINANCIAL MECHANISM
– ENERGY CONSERVATION AND RETROFIT DEMONSTRATIONS FOR GOVERNMENT AND PUBLIC BUILDINGS IN 24 PROVINCES AND MUNICIPALITIES	– GOVERNMENT SUPPORTED SPECIAL FUNDS: RENEWABLE ENERGY APPLICATIONS IN BUILDINGS ENERGY CONSERVATION FOR GOVERNMENT AND PUBLIC BUILDINGS HEATING SYSTEM METERING AND RETROFIT FOR EXISTING BUILDINGS IN NORTH CHINA RENEWABLE ENERGY-SAVING BUILDING MATERIALS BIPV
– HEATING SYSTEM METERING AND RETROFIT DEMONSTRATION FOR EXISTING BUILDINGS IN 15 PROVINCES AND MUNICIPALITIES IN NORTH CHINA	– PRIVATE SECTOR: EMC
– 212 DEMONSTRATIONS AND PROMOTION PROJECTS FOR RENEWABLE ENERGY APPLICATIONS IN BUILDINGS IN 25 MILLION M <sup>2</sup>	
– 100 DEMONSTRATION PROJECTS FOR GREEN BUILDINGS AND 100 DEMONSTRATION PROJECTS FOR LOW-ENERGY-CONSUMING BUILDINGS	
– ENERGY EFFICIENCY AUDITING AND LABELING FOR CIVIL BUILDINGS IN 18 PROVINCES AND MUNICIPALITIES	
– SOLAR ROOF PLAN	

The principle behind China's Medium and Long Term Energy Conservation Plans for smart buildings is that energy conservation in buildings should strictly follow prescribed design standards. Equal emphasis is placed on technical solutions and the metering and evaluation of behavioral changes. The former emphasizes new building materials and renewable sources, especially solar energy and heat pumps, while the latter emphasizes the green building label. China's green building labeling system was first introduced in 2006-2007, during the peak in the real estate market when green issues were becoming fashionable, necessitating the establishment of government criteria.

**GREEN LABELS FOR BUILDINGS:** In 2006 the Ministry of Construction (MOC) established the Evaluation Standard for Green Buildings. This was the country's first state evaluation standard for green buildings based on the full life cycle of residences and public buildings.

TABLE 7 - MARKET POTENTIAL OF KEY TECHNOLOGIES<sup>69</sup> OF SMART BUILDINGS

CATEGORY	TECHNOLOGY	MARKET OPPORTUNITIES	MARKET POTENTIAL
HEAT PRESERVATION AND INSULATION OF ENVELOPE STRUCTURES	ENVELOPE INSULATION	TO MEET ENERGY CONSERVATION DESIGN STANDARDS, THE ENVELOPE STRUCTURE WILL ACCOUNT FOR 70% OF TOTAL REDUCTION. IN DEVELOPED COUNTRIES, ABOUT 49% OF INSULATION MATERIALS ARE POLYURETHANE (PU), WHILE IN CHINA, PU ACCOUNTS FOR LESS THAN 10%. THE GOVERNMENT IS NOW PROMOTING PU AS A SUBSTITUTE FOR TRADITIONAL MATERIALS.	BY 2020, THE DEMAND FOR INSULATION MATERIALS SHOULD REACH 30 BILLION M <sup>2</sup> , WITH 24 BILLION M <sup>2</sup> OF THAT FOR EXTERIOR PROTECTION, MOSTLY FROM PU MATERIALS.
	SHADING		
	DOUBLE-SKIN FAÇADE		
	EMBEDDED VENTILATION SYSTEM		
HVAC (HEATING, VENTILATING AND AIR CONDITIONING)	METERING AND ADJUSTMENT	HVAC ENERGY CONSUMPTION CONTRIBUTES 30-50% OF A BUILDING'S TOTAL. ABOUT 150 MILLION M <sup>2</sup> OF BUILDINGS IN NORTH CHINA NEED A METERING FACILITY RETROFIT FOR THEIR HEATING SYSTEMS, A MARKET THAT COULD AMOUNT TO 200 TO 300 BILLION YUAN (US\$ 29-44 BILLION). MOHURD STATISTICS SHOW THAT, BY OCTOBER 2008, APPROXIMATELY 100 MILLION M <sup>2</sup> OF CHINA'S FLOOR SPACE WAS USING SHALLOW GEOTHERMAL ENERGY	THE MARKET FOR METERING AND RETROFITTING OF HEATING SYSTEMS IN NORTH CHINA COULD BE WORTH 200-300 BILLION YUAN (US\$ 29-44 BILLION).
	HEAT RECOVERY		
	BCHP (BUILDING COOLING, HEATING AND POWER)		
RENEWABLE ENERGY	SOLAR (THERMAL AND PV)	CHINA IS ALREADY THE WORLD'S LARGEST MANUFACTURER OF SOLAR WATER HEATERS AND SOLAR PV PRODUCTS. CHINA'S LAWS AND REGULATIONS ENCOURAGE THE USE OF RENEWABLE ENERGY, ESPECIALLY SOLAR AND GEOTHERMAL ENERGY, IN THE PROPERTY SECTOR. IN SEPTEMBER 2006, THE MOC AND MOF SET UP SPECIAL FUNDS FOR RENEWABLE ENERGY BUILDING APPLICATIONS. THIS WAS FOLLOWED IN MARCH 2009 BY SPECIFIC RULES AND SUBSIDIES FOR BIPV. MOHURD STATISTICS SHOW THAT, BY OCTOBER 2008, THE AMOUNT OF FLOOR SPACE USING SOLAR ENERGY HAD REACHED 1.03 BILLION M <sup>2</sup> , AND SHALLOW GEOTHERMAL ENERGY COVERED APPROXIMATELY 100 MILLION M <sup>2</sup> .	BY 2015, 20-30% OF CHINESE HOUSEHOLDS ARE EXPECTED TO BE USING SOLAR WATER HEATERS. CHINA'S BIPV MARKET VOLUME IS EXPECTED TO REACH INTO THE TRILLIONS OF YUAN, BASED ON STUDIES OF WESTERN COUNTRIES.
	HEAT PUMPS		
LIGHTING SYSTEM	NATURAL LIGHTING	CHINA IS THE WORLD'S LARGEST MANUFACTURER OF ENERGY-SAVING LAMPS. HOWEVER, THE CONSUMER MARKET IS NOT WELL DEVELOPED (BELOW 20% OF MARKET). AT THE BEGINNING OF 2008, THE MOF AND NDRC ISSUED PROVISIONAL RULES ON FUNDS TO PROMOTE THE USE OF EFFICIENT LIGHTING PRODUCTS, AND OFFERED SUBSIDIES TO PURCHASERS OF ENERGY-EFFICIENT LAMPS. IN 2009, THE CENTRAL GOVERNMENT WILL LAUNCH THE LARGE-SCALE PROMOTION OF EFFICIENT LIGHTING PRODUCTS (ABOUT 100 MILLION LIGHTS, TWICE THE 2008 AMOUNT).	LED TECHNOLOGY'S EFFECT ON ENERGY CONSERVATION WILL BE SIGNIFICANT IN A FEW YEARS. BY 2015, THE COST OF LED LIGHTS IS EXPECTED TO BE CUT TO 20% OF THE CURRENT AMOUNT. <sup>69</sup> BY 2020, IF THE TECHNOLOGY IS MATURE ENOUGH, LEDS COULD SAVE 100 BILLION KWH OF ELECTRICITY.
	LIGHTING CONTROL SYSTEM		
	EFFICIENT LIGHTING PRODUCTS		
BMS (BUILDING MANAGEMENT SYSTEM)		A PROPERLY-INSTALLED AND PROPERLY-OPERATED BMS CAN CUT 20% OF A BUILDING'S ENERGY CONSUMPTION, BUT THE COST IS RELATIVELY HIGH.	THE BMS ABATEMENT POTENTIAL IS STILL CONTROVERSIAL, SINCE MANY BELIEVE THAT OTHER LOW-COST MEASURES LIKE BEHAVIORAL CHANGES MIGHT HAVE SIMILAR POTENTIAL. BUT MOST EXPERTS REMAIN OPTIMISTIC ABOUT BMS <sup>69</sup> AND INSIST THAT CHINA'S MODERN BUILDINGS HAVE A CENTRAL CONTROL SYSTEM THAT THEY BELIEVE TO BE NECESSARY, ALTHOUGH COSTLY.
MODULAR BUILDING		CHINA'S BUILDING INDUSTRY STILL LAGS BEHIND THE DEVELOPED WORLD SOMEWHAT, WITH ITS USE OF TRADITIONAL LABOR-INTENSIVE PRODUCTION METHODS INSTEAD OF TECHNOLOGY-INTENSIVE ONES. MODULAR CONSTRUCTION FITS WELL WITH THE GOVERNMENT'S POLICIES THAT HAVE PROMOTED MODERNIZATION SINCE THE 1990s.	THE ABATEMENT POTENTIAL OF MODULAR BUILDING IS ENORMOUS. BUT BECAUSE OF THE MASSIVE INITIAL INPUT COST, THE BENEFITS OF ECONOMIES OF SCALE HAVE NOT BEEN REACHED. VANKE, CHINA'S NO.1 DEVELOPER, IS THE ONLY BIG PLAYER IN SUCH PROJECTS. BUT, VANKE'S LEADING POSITION COULD HELP TO DRIVE THE DEVELOPMENT OF MODULAR CONSTRUCTION.
IT-BASED DESIGN AND LIFE CYCLE MANAGEMENT	BIM (BUILDING INFORMATION MODEL)	INNOVATIVE DESIGN, CONSTRUCTION, AND MANAGEMENT TECHNIQUES WILL BE NEEDED IN ORDER TO CARRY OUT SMART BUILDING PROJECTS. IT MODELS CAN PROVIDE HIGH-QUALITY, REAL-TIME INFORMATION ON PROGRESS ON THE PROJECT AND ITS COST, WITH VISUALIZATIONS OF LIFE-CYCLE MANAGEMENT SUPPORT.	IT-BASED DESIGN AND LIFE-CYCLE MANAGEMENT COULD MAKE THE WHOLE BUILDING INDUSTRY MORE INTELLIGENT. MARKET PROJECTIONS FOR RELATED SOFTWARE AND HARDWARE PRODUCTS ARE QUITE OPTIMISTIC.
	BLM (BUILDING LIFE CYCLE MANAGEMENT)		

In 2007 the MOC released its Detailed Technical Rules for Green Building Evaluation (for a trial period) and Administrative Measures for Green Building Evaluation Labels. Prior to this, the US LEED and UK BREEAM standards were used. Using LEED as a reference point, China's green building labels are based on six major subsystems: space savings and outdoor environment; energy-savings and energy utilization; water savings and water resource utilization; material savings and material resource utilization; indoor environmental quality; and operations management. There are categories for buildings at the planning stage, and for buildings that are already in use and being evaluated. Up to three stars are given for greater efficiency.

#### ADVANCES IN SMART BUILDING TECHNOLOGIES

Smart building technologies have improved significantly and have reached world-class standards in many areas in some core technologies, see Table 7. With good market potential, these will be served by energy efficiency policies and standards.

Integrated smart buildings are still rare in China, despite available technology. Technology improvements could bring more benefits, but are not the only solution. It is essential that a low carbon philosophy be adopted from the start, which means proper development strategies, correct designs, use of appropriate technological combinations and effective management.

The abatement potential and implementation costs of major smart building technologies and strategies are as described in Table 8 below.

Table 8 shows that there is a high return from planning and design strategies from the outset of the building's life cycle – high-tech solutions are not the only option. China's smart buildings policies give priority to solutions that are low-cost and high-benefit, such as low carbon urban planning, low carbon standards and labels, redevelopment, renovation, the retrofit of cities and buildings, natural and passive design and energy management systems.

**“GREEN BUILDINGS DO NOT NECESSARILY MEAN HIGH-COST, HIGH-TECH BUILDINGS. WE NEED TO CLEAR UP THAT MISUNDERSTANDING. IN OUR VISITS TO WELL-KNOWN ENERGY EFFICIENT BUILDINGS ABROAD, WE FOUND SIMPLE, MATURE TECHNOLOGIES, INSTEAD OF ENTIRELY CUTTING EDGE HIGH-TECH ONES. INSULATED DOORS AND WINDOWS AND AN EXTERIOR, PROTECTED CONSTRUCTION SYSTEM HAVE BEEN IN USE IN CHINA SINCE THE 1970s.”**  
ZHANG YUE CHAIRMAN AND PRESIDENT, BROAD AIR CONDITIONING

TABLE 8 – COST-BENEFIT ANALYSIS OF SMART BUILDING TECHNOLOGIES AND STRATEGIES<sup>93</sup>

	ABATEMENT POTENTIAL		
	LOW	MEDIUM	HIGH
LOW COST	—	BUILDING OPERATION MANAGEMENT: ENERGY CONSUMPTION PLANS; ENERGY PERFORMANCE MEASUREMENT BY HOUSEHOLD AND BY VOLUME; ENERGY CONSUMPTION MONITORING AND INFORMATION DISCLOSURE; ENERGY-SAVINGS TRAINING. SMART BUILDING LABELS: ENERGY CONSUMPTION LABELS FOR ENERGY SYSTEMS LIKE HVAC, AS WELL AS FOR BUILDINGS' ENERGY MONITORING AND ASSESSMENT SYSTEMS.	LOW CARBON URBAN PLANNING: APPROPRIATE BLENDING OF FUNCTIONAL ZONES; REDUCED VOLUME OF CITY TRANSPORTATION; LESS PRIVATE TRANSPORTATION; LESS BUILDING SPACE OVERALL. NATURAL BUILDING DESIGN: HEAT INSULATION AND PRESERVATION; SHADING; NATURAL LIGHTING; NATURAL VENTILATION; LOW-E GLASS; WATER CONSERVATION FACILITIES; LIGHTWEIGHT STRUCTURE; WOODEN STRUCTURE; RENEWABLE BUILDING MATERIALS; ECOLOGICAL POND; PERMEABLE SURFACES; GREEN LANDSCAPE.
MEDIUM COST	—	PASSIVE DESIGN AND MIXED BUILDING DESIGNS: MOVABLE SHADING; SOLAR THERMAL STORAGE WALLS; VENTILATION TOWER; EVAPORATION COOLER; PSALI (PERMANENT SUPPLEMENTARY ARTIFICIAL LIGHTING INTERIOR) CONTROL; MIXED LIGHTING SYSTEM; GEOTHERMAL ENERGY UTILIZATION; SOLAR WATER HEATER; RAIN WATER UTILIZATION. THREE 'R'S OF BUILDING MATERIALS: REDUCE, REUSE AND RECYCLE RESOURCES; USE LOCAL MATERIALS. ENERGY RETROFIT OF EXISTING BUILDINGS: ELECTRICITY SUPPLY; HVAC; WATER SUPPLY; DRAINAGE SYSTEM; LIGHTING; ENVELOPE STRUCTURE; BMS.	LOW CARBON STANDARDS FOR BUILDINGS: ELEVATED ENERGY CONSERVATION STANDARDS FOR URBAN PLANNING AND BUILDINGS, WHICH ARE STRICTLY ENFORCED. OLDER BUILDING RETROFIT: MAXIMUM EFFECTIVE USE OF EXISTING STRUCTURE AND FRAMEWORK TO AVOID REBUILDING.
HIGH COST	ACTIVE DESIGN, MECHANICAL DESIGN: SOLAR PV APPLICATION; WIND POWER; ICE STORAGE TANK SYSTEM; GREY-WATER SYSTEM; FIBER-OPTIC LIGHTING SYSTEM.	ACTIVE DESIGN, MECHANICAL DESIGN: SOLAR PV APPLICATION; WIND POWER; ICE STORAGE TANK SYSTEM; GREY-WATER SYSTEM; FIBER-OPTIC LIGHTING SYSTEM.	CITY REDEVELOPMENT: DEVELOPED DISTRICTS WITH REDEVELOPMENT POTENTIAL AS CONSTRUCTION SITES. BROWNFIELD REDEVELOPMENT: BROWNFIELD AREAS WITH HAZARDOUS WASTE CONTAMINATION OR POLLUTION GET CLEANED UP AND REUSED; LESS STRESS ON FIELDS THAT HAVE NOT BEEN DEVELOPED. CONSTRUCTION METHODS: MODULAR BUILDINGS, PREBUILT HOUSES.

## LOW CARBON BUILDINGS AND URBAN DESIGN – SOME CASE STUDIES

Major domestic developers, representing the largest share of China's building market, have initiated commercial projects that have energy efficiency and environmental benefits at the heart of their sales strategies. Examples of such developers are Tiptop, Vanke, Landsea and Merchants. These projects received good public attention and high sales, which has in turn attracted more developers. Commercial and public building owners have also shown initiative in greening their buildings, helping to influence others. The government plays a role both as owner and as supervisor, using its influence in public housing projects to demonstrate green advantages.

Chinese and foreign technology providers have gone some way to achieving a stake in the market, and are eager to further explore the property market. BIPV, geothermal technology, new envelope materials and LED companies are thriving, thanks to favorable policies. Examples include Himin Solar, Suntech and Broad Air Conditioning. Some leading companies are entering the market by co-developing real estate projects in the expectation of growing demand.

The following examples of new or retrofitted residential or commercial building projects have all used multiple low carbon technologies in an integrated way, complying with local climate and building conditions and helping to set the trend of the future.

**PROJECT NAME: NOKIA BDA CAMPUS, BEIJING****OWNER: NOKIA (CHINA) INVESTMENT CO., LTD.****HIGHLIGHTS: CHINA'S FIRST NEW LEED-GOLD-CERTIFIED COMMERCIAL BUILDING**

The Nokia BDA Campus, built in April 2008, is the first newly-built LEED-Gold commercial building in China. The six-story building covering 70,000 m<sup>2</sup> has a double-skin facade, wood floors from fast-growing forests, environmental dust-control, and some 30 other unique environmentally friendly designs. A major feature is that 77% of the building's lighting comes from natural light. It uses 20% less energy than ordinary commercial buildings and 37% less water, with only a 2% increase in cost\*.

**PROJECT NAME: VANKE EVEREST TOWN, BUILDINGS 20 AND 21, SHANGHAI****DEVELOPER: CHINA VANKE CO., LTD.****HIGHLIGHTS: INDUSTRIALIZED, LOW ENERGY CONSUMPTION, RAPID CONSTRUCTION**

In 2003, Vanke started building standardization and set up a standardized database. In 2004, it established an industrialization center and began research on modular residential buildings. In November 2007, Vanke Architecture Research Center started a series of R&D projects and the group's first market-based, industrialized project went on the market. These buildings were based on modular building models from Hong Kong and Japan, respectively. The construction cycle was shortened from a conventional 360 days to 290. Materials came directly from Shanghai suppliers. Vanke Everest Town is above 60% in its energy-saving capacity. The project was certified by the US's RESNET (residential energy services network). In 2008, Vanke started nine new modular residential projects in Shanghai, Shenzhen and Beijing, with a total area of more than 600,000 m<sup>2</sup>.

**PROJECT NAME: BEIJING TIPTOP INTERNATIONAL APARTMENT****DEVELOPER: TIPTOP LTD.****HIGHLIGHTS: HIGH-TECH, HIGH COST, HIGH PRICE**

The Beijing Tiptop International Apartment is located in Wanliu, in the northwestern part of Beijing. It was one of the first apartment projects in China to apply high-standard European design codes and to avoid using the traditional air conditioning and heating system. Buildings D, E, and F were specifically designed to meet high-convenience, low-energy consumption standards. The total floor space is 51,000 m<sup>2</sup>. The project, whose contractor was Beijing Construction Engineering Group Co., Ltd., was completed in April 2003.

The International Apartment is loaded with high-tech additions. Heat pumps are used for the core technology to provide heating and air conditioning, supported by a natural ventilation system and an exterior-protected construction system made of composite polystyrene materials. Other innovations are the window insulation, noise proofing, a garbage processing system, and a grey water system.

The International Apartment is recognized as a 'National Comfortable Housing Demonstration Project', the highest prize in the MOC awards. It is also the only project in China that received technological support and monitoring from the AGS (Alliance for Global Sustainability).

\*The benchmarks for Nokia energy and water conservation are different to China's local standard, as Nokia's standard is referenced to LEED requirements. As for the calculation method, the results are measured by energy cost saving, instead of energy demand saving, based on ASHRAE Standard 90.1-2004 version.

**PROJECT NAME:** TAIGE APARTMENTS, SHENZHEN**DEVELOPER:** CHINA MERCHANTS PROPERTY DEVELOPMENT CO., LTD. (CMPD)**HIGHLIGHTS:** CHINA'S FIRST LEED-SILVER-CERTIFIED RESIDENTIAL BUILDING AND AN ASSEMBLY OF FEASIBLE ENERGY-SAVING TECHNOLOGIES FOR SOUTH CHINA

The TaiGe Apartments built in 2004 integrated various green technologies and were China's first LEED-Silver-certified residential buildings. From the early stage of the project, CMPD's design focused on eco-friendly measures and managed to preserve original vegetation of the surrounding area.

The apartments employed many green technologies, such as envelope insulation, Low-E glass, eco-friendly paint, heat pump water heaters, space-saving elevator and solar energy. They consume 40 kWh per m<sup>2</sup> about 1/3 that of similar buildings in Shenzhen. They have saved more than one million kWh each year, more than 63% of the total energy bill. The energy conservation applications cost approximately 10 million Yuan (US\$ 1.5 million), or about 6% of the total cost. This is paid off, within a 6-year period, from improved energy efficiency.

**PROJECT NAME:** ENERGY RETROFIT OF JINGYAN HOTEL, BEIJING**OWNER:** JINGYAN HOTEL**SOLUTION PROVIDER:** BEIJING BUILDING TECHNOLOGY DEVELOPMENT CO., LTD.**HIGHLIGHTS:** ENERGY RETROFITS FOR A LARGE CORPORATE BUILDING, LOCAL TECHNOLOGIES, SUPPORT FROM GOVERNMENT SUBSIDIES

Jingyan, a 3-star hotel built in the 1980s, began the first phase of its energy retrofit in March 2007. This was also intended as a demonstration project for public building retrofits and was supported by the municipal government. It mainly used a Beijing sewage source heat pump and Broad non-electric air conditioner, but also adapted other technologies like heat-proof windows, a building control system, a grey water system, energy-saving tubes for the air-conditioner, energy-efficient lighting and a water-saving sanitation system. Total cost of the sewage source heat pump system was 10 million Yuan (US\$ 1.5 million), or about a quarter of the cost of the whole energy retrofit.

After completion, annual energy consumption costs at the Jingyan Hotel were half what they had previously been, dropping from 4 million to 2 million Yuan (US\$ 0.6 million to 0.3 million). Because it was a demonstration project, it received 2.3 million Yuan (US\$ 0.3 million) in government subsidies, 1.4 million Yuan (US\$ 0.2 million) of that for renewable energy, and 0.9 million Yuan (US\$ 130 thousand) for the energy performance monitoring system.

**PROJECT NAME:** RENOVATION AND EXPANSION OF SUN YAT-SEN LIBRARY, GUANGDONG PROVINCE, PHASE I**OWNER:** SUN YAT-SEN LIBRARY**SOLUTION PROVIDER:** GUANGZHOU DESIGN INSTITUTE**HIGHLIGHTS:** RENOVATION AND EXPANSION OF A LARGE PUBLIC BUILDING, 150 KWP BIPV

This renovation and expansion project covered a total floor space of 103,600 m<sup>2</sup> Phase I, which was completed in December 2008, covered 76,300 m<sup>2</sup>. It was recognized by MOHURD and the Energy Foundation as one of the 'Ten Best Designs in Low Energy Consumption Building', in March of that year. The project uses three BIPV systems on the roofs. If we suppose that the 150 kWp BIPV system were to operate for 3.5 hours per day on average, it would result in a 26% savings in electricity costs for lighting during the day. In addition, the following energy-saving technologies were used: envelope insulation, an HVAC retrofit and smart lighting controls. Total energy consumption was cut by 68.9%, to 2.9 million kWh/a, which is equivalent to 1900.56 t/a in coal, while CO<sub>2</sub> emissions were cut by 5,131 t/a.

Building projects at the city level have also involved low carbon. The first internationally known eco-city was Chongming's Dongtan, starting in 2005, but there are other pioneers, such as Tianjin, Tangshan's Caofeidian, Beijing's Daxing and the Changsha-Zhuzhou-Xiangtan area in Hunan.

**PROJECT NAME:** CHANGXING ECO-CITY, BEIJING**DEVELOPER:** VANION REAL ESTATE CO., LTD.**SOLUTION PROVIDER:** ARUP, BEIJING MUNICIPAL INSTITUTE OF CITY PLANNING & DESIGN**HIGHLIGHTS:** BEIJING'S FIRST ECO-CITY PROJECT, ONE OF THE FIRST PRIVATE-SECTOR-LED ECO-CITY PROJECTS IN CHINA, IN-SITU VILLAGE RENOVATION

Changxing Eco-city in Beijing involves an area of 500 ha and a projected population of 76,600. One of the first eco-city projects in China promoted in the private-sector, it includes a comprehensive and holistic sustainability framework, with a set of quantifiable indicators on master planning, urban design and green infrastructure. It will reduce water and energy consumption and the project will serve as a demonstration case for areas around Beijing.

**CHALLENGES IN THE WAY OF DEVELOPING LOW CARBON BUILDINGS AT SCALE**

Developing smart buildings on a large scale will require increased public awareness, cost reduction and removing entry barriers to the market.

**LACK OF AWARENESS:** Unlike other industries, the low carbon opportunity in the property sector does not rely on the progress of a handful of key technologies. Although technologies are certainly important, the key factor is changing building design philosophy and urban planning, in a way that encompasses all stages, from design to maintenance. Public awareness can play a crucial role in achieving this.

During its 30 years of rapid growth, China skylines have catered to a modernizing trend that replaced traditional structures with western-style glass boxes and extravagant skyscrapers. Such 'modern' high-tech solutions are often preferred above simpler, easier and cheaper ones. The availability of cheap energy has also been counterproductive to a growth in efficient buildings.

**HIGH COST:** The high costs involved in smart buildings, for reasons shown in Table 9 are also a huge obstacle.

TABLE 9 – BARRIERS TO LOW CARBON BUILDINGS<sup>84</sup>

FACTORS	DESCRIPTION
POLICIES, STANDARDS, THE MEDIA	TAXATION, GOVERNMENT SUBSIDIES, AND THE MARKET ENTRY THRESHOLD ARE STILL NOT DESIGNED TO PROMOTE SMART BUILDINGS, SO CONVENTIONAL BUILDINGS STILL SOMEHOW INVOLVE LOWER CONSTRUCTION AND OPERATING COSTS. AT THE SAME TIME, THE MEDIA HAVE NOT SUPPORTED THE GREEN BUILDING INITIATIVE.
ECONOMY	MOST CURRENT SMART BUILDING PROJECTS ARE IN RELATIVELY DEVELOPED PARTS OF CHINA. IN WESTERN PARTS, LOW-COST GREEN BUILDINGS ADJUSTED TO LOCAL ECONOMIC AND ENVIRONMENTAL CONDITIONS ARE QUITE RARE.
TECHNOLOGICAL MATURITY	EVEN ALLOWING FOR AN OPTIMISTIC OUTLOOK, MANY GREEN BUILDING TECHNOLOGIES ARE STILL IN THE INITIAL STAGES OF COMMERCIALIZATION. HIGH COSTS STILL KEEP LARGER NUMBERS OF CONSUMERS FROM PURCHASING CERTAIN LOW CARBON PRODUCTS LIKE LEDS AND COMPACT FLUORESCENT LAMPS.
ECONOMIES OF SCALE	IN A NEW MARKET, THE SMALL SCALE USUALLY LEADS TO HIGH COSTS. MODULAR RESIDENTIAL BUILDINGS ARE ONE EXAMPLE: THE COST CAN BE 15%-20% ABOVE THAT OF A CONVENTIONAL BUILDING, EVEN AFTER MATURITY. BUT WITH A LARGER MARKET SCALE, MAINTENANCE COSTS AND THE CONSTRUCTION PERIOD CAN BE SIGNIFICANTLY REDUCED.
VALUE CHAIN	MANY LOCAL VENDORS AT THE UPPER AND LOWER ENDS OF THE CHAIN ARE NOT YET ABLE TO DELIVER MATURE PRODUCTS. DEVELOPERS, THEREFORE, HAVE TO RELY HEAVILY ON IMPORTED PRODUCTS AND PARTS TO COMPLETE LOW CARBON PROJECTS.
PRICE	REAL ESTATE PRICES DEPEND MAINLY ON THE LOCATION AND FAIL TO REFLECT THE ADDED VALUE OF LOW CARBON DEVELOPMENTS.

**MARKET BARRIERS:** To gain access to the market, both up and down the chain, vendors and consumers have to go through developers who block low carbon strategies. Recently, there have been some indications of a shift in power towards home-buyers and technology providers, which could change that situation. For example, where governments own low-rent apartments or consumers form groupings, sometimes involving tens of thousands of people.

In addition to education and various other campaigns, one of the most important methods to overcome these challenges would be legislation, especially in the area of setting mandatory industry standards, including directives on planning and design strategies. China now has an initial legal framework governing smart buildings, with various standards and a labeling system. Once these guidelines are thoroughly in place, the resulting changes could be immediate.

Improvements along the whole value chain, accelerated by more adequate policy support, could reduce the high costs involved. For example, in March 2009 subsidies for the integration of solar energy systems (BIPV) cut the cost by more than half. Policy support could be used to stimulate more attention in the media, help to build a better economic foundation for smart buildings, encourage technological maturity, reduce costs through improved economies of scale, help the bargaining power of industries and businesses up and down the chain and focus on improving the pricing mechanism. Increased restrictions on conventional buildings would also help to bring down prices for smart buildings. In addition, financing mechanisms need to be more creative; although limited, government funding still plays the most important role and the use of private sector capital needs to be encouraged.

Ways of breaking down entry barriers could include a vendor alliance, a communication platform for all major players, or the use of media and other third-party interventions.

Smart building technologies should be improved in the areas of product quality, systematization, integration and services. Sophisticated solutions providers are also too scarce in China. Foreign companies and investment institutions are too focused on high-end areas such as design, total solutions and core technologies, while Chinese enterprises that put all their effort into manufacturing and the export trade need to pay more attention to domestic consumer demand.

Despite enormous potential, smart buildings face a tough future in overcoming the obstacles. There are various challenges to make smart buildings mainstream, but clear guidance and promotion of government rules and policies related to green buildings have won the attention of some developers and customers. The next step after energy efficient buildings will involve engaging cities in cross-functional, low-carbon practices from building to transportation to communication.

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#### THE CLIMATE GROUP CONTRIBUTORS:

##### PROJECT DIRECTORS:

Changhua Wu, Greater China Director  
Mark Kenber, Policy Director

##### AUTHORS:

Lorraine Yin, Project Development Manager, Greater China  
Zheng Huang, Research Analyst, Greater China  
Henan Xu, Research Analyst, Greater China  
Peijie Li, Research Analyst, Greater China

##### OTHER CONTRIBUTORS:

Winnie L.Y. Lu, Program Development Management, Greater China  
Jiajia Luo, Media Manager, Greater China  
Lauren Bird, Senior Press Officer, London Headquarters  
Tom Howard-Vyse, Head of Media Europe  
Han Wang, Administrative Assistant, Greater China

##### EDITORS OF INTERNATIONAL EDITION:

Colin Douglas  
Barry Kantor

**EXTERNAL CONTRIBUTORS:**

Scott Cai Associate, SAIF Partners China, Bin Hao, Head, Senior Engineer, Division of Industrial Development, Center of Energy Efficiency in Buildings, Ministry of Housing and Urban-Rural Development, China, Junpeng Huang, Project Manager of Building Energy Management, International Copper Association Ltd. China, China, Xinguang Jia, Principle Commentator, Auto Magazine, China, Phillip LaRocco, Executive Director, E+Co, United States, Qidong Wei, Professor and Secretary General of Jiangsu PV Industry Association, China, Stanley Yip, Director Planning and Development, Arup International Consultants (Shanghai) Co. Ltd, China, Shi Zhong, Vice Chief Editor, Shanghai Oriental Auto Magazines Agency Co., Ltd, China, Fengqi Zhou, Former Director-General, Energy Research Institute, NDRC, China, Roger Bradshaw.

**ABOUT THE CLIMATE GROUP**

The Climate Group is the world's first international NGO focused exclusively on the solutions to climate change. The Climate Group's mission is to accelerate the low carbon economy by building close partnerships with the world's leading businesses and governments, by engaging and convening the world's most influential individuals on the carbon intensity of the world's economy, and by launching and incubating a number of strategic initiatives with our members and partners. The Climate Group focuses on the links between reduced greenhouse gas emissions and improved financial and economic performance. The Climate Group is the hub for a network for corporate and policy leaders who can identify, implement, and support effective strategies and policies. In just four years The Climate Group has grown from a three person office in southwest London to an 80-person organisation in seven countries/regions (UK, US, Greater China, Hong Kong, India, Australia and Belgium), working with more than 50 significant member companies and governments.

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**HEADQUARTERS: LONDON.**

The Tower Building, 3rd Floor, 11 York Road,  
London SE1 7NX, United Kingdom.  
T: +44 (0)20 7960 2970  
F: +44 (0)20 7960 2971

**GREATER CHINA: BEIJING.**

Suite 1501, Golden Tower, 1 Xibahe South Road,  
Chaoyang District, Beijing, China. 100028  
T: +86 10 64403639  
F: +86 10 64403749

**NORTH AMERICA: NEW YORK.**

444 Park Avenue South, 2nd Floor,  
New York NY 10016, USA.  
T: +1 (646) 233 0550  
F: +1 (646) 861 4606

**AUSTRALIA: MELBOURNE.**

Level 17, 1 Nicholson Street,  
Melbourne VIC 3000, Australia.  
T: +61 (0)3 9668 5798  
F: +61 (0)3 9663 1546

**INDIA: NEW DELHI.**

215, Suneja Tower II,  
District Centre, Janak Puri,  
New Delhi 110058, India.

[www.theclimategroup.org](http://www.theclimategroup.org)

Feedback and requests for information should be sent to:  
[info@theclimategroup.org](mailto:info@theclimategroup.org)