UNEP

A SYNTHESIS REPORT

CHINA'S GREEN LONG MARCH

A STUDY OF RENEWABLE ENERGY, ENVIRONMENTAL INDUSTRY AND CEMENT SECTORS

Citation

UNEP, 2013, China's Green Long March

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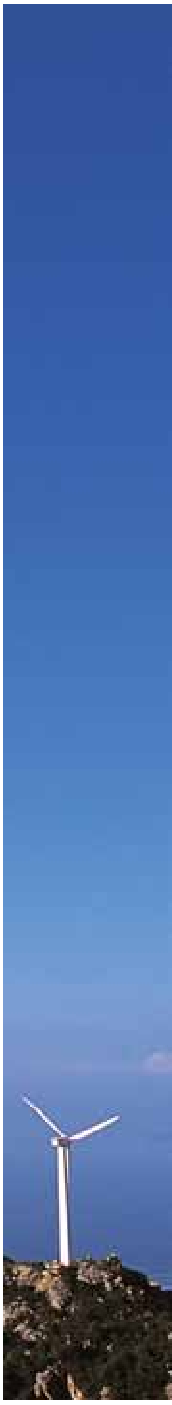
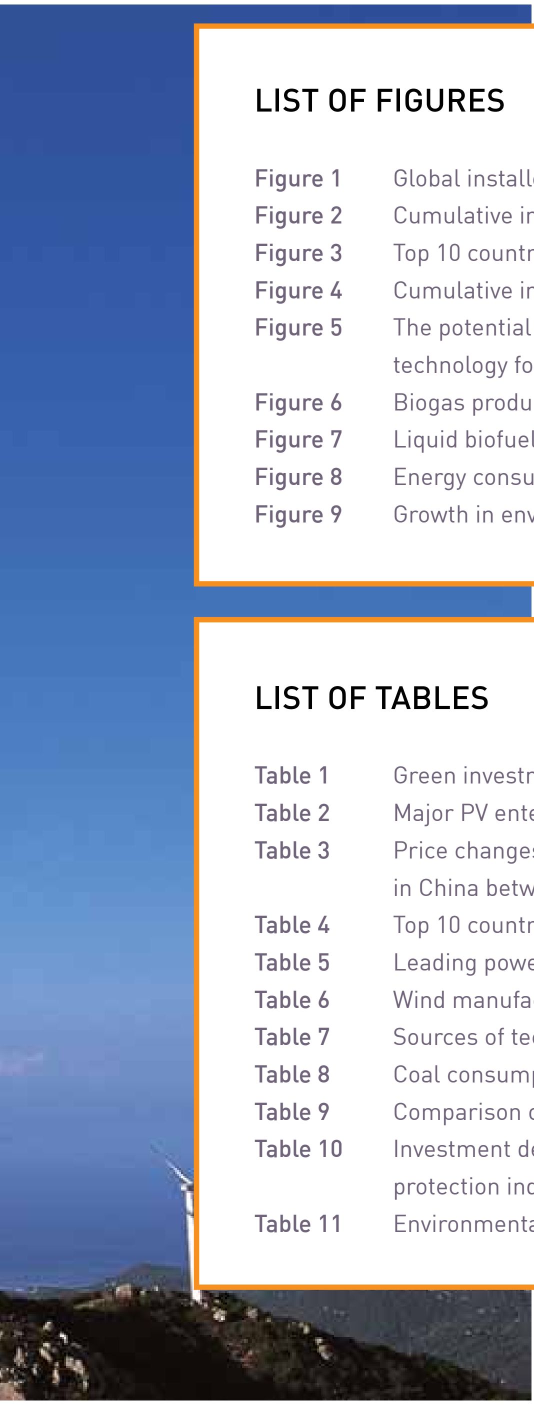
LIST OF ACRONYMS

BIPV	Building-integrated photovoltaics
BNEF	Bloomberg New Energy Finance
BP	British Petroleum
CBMF	China Building Material Federation
CBRC	China Banking Regulatory Commission
CDM	Clean Development Mechanism
CIECCPA	China Industrial Energy Conservation and Cleaner Production Association
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
CWEA	Chinese Wind Energy Association
EMC	Energy Management Company
FYP	Five-Year Plan
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GW	Gigawatt
IP	Intellectual Property
IPCC	Intergovernmental Panel On Climate Change
KGCE/t	Kilograms of Coal Equivalent/tonne
kWh	Kilowatt Hour
MEP	Ministry of Environmental Protection
MIIT	Ministry of Industry and Information Technology
MW	Megawatt
MWp	Megawatt Peak
NDRC	National Development and Reform Commission
NEA	National Energy Administration
NO_x	Nitrous Oxide
PRECEE	Policy Research Centre for Environment and Economy
PV	Photovoltaic
R&D	Research and Development
RGS	Royal Geographical Society
RMB	Renminbi (Chinese currency)
SO_2	Sulphur Dioxide
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USD	United States Dollar
VAT	Value Added Tax
WHR	Waste Heat Recovery
WWF/DRC	World Wide Fund for Nature/ Development Research Centre





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ACKNOWLEDGEMENTS

This synthesis report is based on a comprehensive study conducted by Chinese experts on the green development of specific sectors. The study (in Chinese), co-sponsored by UNEP and the Chinese Ministry of Environmental Protection (MEP), was jointly managed by Yu Hai of the Policy Research Centre for Environment and Economy (PRECEE) and Sheng Fulai of UNEP. Zhang Jieqing of the MEP provided invaluable guidance.

Principle authors of the original study include Liu Zhiyi of Renmin University (solar energy), Huang Haifeng and Sun Yi of Beijing University of Technology (wind energy), Ma Hengyun of Henan Agricultural University (bio-energy), Tong Hefeng of the Institute of Science and Technology Information of China (cement), and Chazhong Ge and Xiaoliang Li of Chinese Academy for Environmental Planning (environmental industry).

Yu Hai and his team at PRCEE, Zhang Yongliang, Yang Chao and Liu Jia, provided significant contributions, not only in the management of the study but also by undertaking the additional research required for its completion. Jiang Nanqing and Qu Zhengzheng of UNEP China office also provided substantive support. Richard Scotney (UNEP) conducted additional research and wrote this synthesis report. Diwata Hunziker and Leigh Ann Hurt (UNEP) edited the report. The design and layout was done by Thomas Gianinazzi. Administrative support was provided by Désirée Léon, Fatma Pandey and Rahila Somra.

Lastly, the authors are especially thankful to the following reviewers for their insights, suggestions and comments: Gao Zhiwen (Climate Bridge); Wang Bin (Everbright Securities); Rainer Quitzow (Freie Universität Berlin); Claudia Assmann, Giles Chappell, Stefanos Fotiou and Li Shaoyi (UNEP); and Zhang Xuehua, Chen Boping and Lu Lunyan (World Wide Fund for Nature – China Programme Office).

FOREWORD

In the past 20 years, China's economy has increased tenfold. This growth has lifted 660 million people out of extreme poverty. However, it has had an environmental cost. China is the world's largest producer of greenhouse gas (GHG) emissions, more than 90 per cent of its urban water bodies are thought to be polluted and outdoor air pollution is estimated to contribute to over a million premature deaths per year in China.

The Chinese government recognizes that in order to sustain its economic growth without further damaging the environment, it must change its policies. The government made impressive efforts in a transition towards a green economy under the 11th Five-Year Plan (2006-2010), and its strategies under the 12th Five-Year Plan are even more ambitious.

As this study identifies, China is making significant progress in developing renewable energy technologies, greening industry, and promoting the environmental goods and services sector. These activities are creating jobs, economic growth and improved well-being for citizens. However, many challenges still persist, such as fossil fuel reliance, inadequate enforcement of environmental regulations and misplaced incentives.

This report was conducted in cooperation with the Policy Research Centre for Environment and Economy, a subsidiary of the Chinese Ministry of Environmental Protection. It examines five sectors – solar, wind, biofuels, cement and environmental industry - providing information on recent progress and policies that are driving green development in these industries. The report also underscores some remaining issues and puts forward recommendations on how to overcome them.

"China's Long Green March" provides the opportunity to firmly anchor the environmental dimensions of sustainable development into the social and economic agenda of the country, and pave the way for further in-depth assessment to illustrate how a transition towards an inclusive green economy can accelerate the attainment of national development goals in China.

Achim Steiner
UN Under-Secretary General
and Executive Director,
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EXECUTIVE SUMMARY

In the last decade, China has witnessed growth in a wide range of sectors that have contributed to a green economy transition – from wind, solar and other renewable energies, to the environmental industry. In all these sectors, however, significant challenges remain to ensure further progress.

China has invested heavily across the clean energy and environmental industry sectors, particularly following the post-financial crisis stimulus plan.

China has become the world leader in renewable technology investment. China has the world's largest installed capacity of wind farms. It is the world's leading manufacturer of solar PV modules, and it produces more hydroelectricity than any other country (BP, 2012). In 2012, renewable energy investment in China stood at US$67.7 billion (BNEF, 2013), the highest in the world, and double the level of investments in 2009 (see Chapters 2, 3 and 4 for further information).

During the 11th Five-Year Plan (2006-2010), significant investments were made in industrial energy efficiency. These efforts resulted in a 19.1 per cent fall in energy intensity per unit of GDP (Yuan et al, 2011). The cement sector, in particular, was successful at increasing its efficiency. Over the 11th Five-Year Plan, the amount of energy required to produce a tonne of cement fell by 41 per cent (see Chapter 5).

'Green' investment formed a significant part of China's RMB 4 trillion (US$570 billion)[1] post-financial crisis stimulus plan. Following the onset of the global financial crisis, the Chinese government launched a large-scale investment programme to avert an economic slowdown. An estimated 5 per cent of the stimulus, or RMB 210 billion, was directly spent on the environmental industry[2] (WWF/DRC, 2010).

As a result of this stimulus, the environmental industry has grown, and now represents over 3 per cent of GDP (Feng, 2010). Annual investment in the water treatment and forestry sector almost doubled from 2009 to 2011, while investment in the urban environmental sector increased by 70 per cent between 2008 and 2009 (MEP, 2010, see Chapter 6).

China still faces significant environmental challenges, from a carbon-intensive energy mix to local water and air pollution.

China is the world's largest emitter of greenhouse gases (GHG). Due to China's heavy reliance on coal and oil – which accounts for nearly 90 per cent of energy consumption (BP, 2012) – China emits more carbon dioxide (CO_2) than any other country. In 2011, China's GDP accounted for only 10 per cent of the world's CO_2 output, yet it consumed 60 per cent of the cement, 49 per cent of the iron and steel and 20 per cent of the energy (China Environment News, 2012). Without action, large levels of CO_2 emissions will result in dangerous climate change, to which China is predictably vulnerable (Cruz et al., 2007).

China's development requirements mean that without the necessary policies, economic growth will continue to put a strain on the environment. Despite high GDP growth rates, China remains a middle income country with Gross National Income (GNI) per capita still well under the US$10,000, the benchmark for high income country status (World Bank, 2013). Most economists predict further growth, resulting in even greater demand for energy, cement, steel and other resource-intensive products.

Local pollution, particularly to air and water, is significant in China. It is estimated that 90 per cent of the urban water bodies are polluted, and outdoor air pollution is estimated to contribute to 1.2 million premature deaths per year (Cohen et al., 2005). Moreover, it is estimated that 10 million hectares of farmland are contaminated (Chen, 2009), and the amount of waste sent to landfills is also rising. Local pollution is serious, and negatively impacts the daily lives of Chinese citizens. Each year, local environmental protests have increased by 29 per cent (Feng and Wang, 2012), demonstrating the high levels of public concern related to the environment.

Table 1. Green investment under China's 12th Five-Year Plan

Field	Investment (RMB billion)	Investment (USD billion)
Environmental management	1 530	249
Ecological protection facilities and biodiversity protection (including conversion of cropland to forest, grassland and wetland protection)	1 200	195
Renewable energy	1 500	244
Energy saving	500	81
Sustainable urban transportation	1 400	228
Green building	400 (est.)	65
Total	**6 530**	**1 062**

Source: Wang et al., 2009.

China's government has a series of ambitious targets that aim to tackle these significant environmental challenges.

China aims to reduce the carbon intensity per unit of GDP by 40-45 per cent by 2020 compared to 2005 levels. For the first time, under the 12th Five-Year Plan, China has established a target and under the Copenhagen Accord, submitted it to the United Nations Framework Convention on Climate Change (UNFCCC) (UNFCCC, 2010).

China plans to produce 15 per cent of its energy from non-fossil fuel sources by 2020 (State Council, 2011). The government has set ambitious targets across the green energy sector. In addition to the above target, China aims to have 140 GW of wind capacity and 21 GW of solar by 2015 (National Energy Administration, 2012).

CHINA IS MAKING SIGNIFICANT PROGRESS IN DEVELOPING RENEWABLE ENERGY TECHNOLOGIES, GREENING INDUSTRY AND PROMOTING THE ENVIRONMENTAL GOODS AND SERVICES SECTOR.

The 12th Five-Year plan (2011-2015) puts emphasis on green investment. Across industries, ambitious green investment development plans are evident. For example, in the cement sector, China aims to phase out 250 million tonnes of inefficient capacity (CBMF, 2012). Table 1 shows the split of planned investment across key sectors.

China has a strong policy framework to support a green economy transition.

Feed-in tariffs have spurred clean energy investment. In China, producers of renewable energy receive a price above the rate given for electricity generated from traditional sources. In the case of solar energy, the tariff is more than double the amount paid for electricity from coal-fired plants, while biomass projects receive a 50 per cent premium (Ma, 2011). Wind previously received a high tariff but as costs have fallen, the tariff is now at a similar rate to other energy sources (see Chapter 3 for a full discussion).

At both the local and central government levels, significant subsidies and tax advantages exist to stimulate green investment. For example, Energy Management Companies (EMCs), such as those that invest in energy reduction measures in the cement sector, can make a claim for 100 per cent reimbursement of the VAT and a three-year income tax waiver, followed by a three-year half corporate income tax reduction (Ministry of Finance, 2010). This helps drive energy efficiency in the cement sector, as seen in Chapter 5.

Regulation also plays a role in helping China transition to a green economy. In the cement sector, strict regulations resulted in a large-scale phasing out of inefficient plants. In the environmental industry sector, increasingly strict regulations on water pollution, air quality and waste management are driving investment (see Chapters 5 and 6).

This report finds that across the sectors analysed, significant challenges remain.

There is often a divergence of interests between local and national authorities. As the world's most populous country, China faces governance challenges, including disparities between central government demands and action at the local level. In particular, local governments are often more focused on short-term economic growth rather than longer-term environmental concerns or broader national priorities. This difference in interests has contributed to, amongst other impacts, a non-enforcement of certain environmental regulations and a lack of investment in the environmental industry. Resolving the contradictions between local and central interests remains an important policy challenge.

China requires increased investment in research and development (R&D), both to tackle the country's significant environmental challenges and to ensure that its green industries can compete globally. Across every sector studied, a technology gap between Chinese firms and their industrialised-world competitors exists. The government needs to encourage longer term investment in R&D, and further support domestic innovation.

The government needs to send clearer policy signals, particularly through fiscal incentives, to guarantee green investment. Where the Chinese authorities have established clear policies, such as feed-in tariffs in the wind, biomass and solar sectors, or regulations to eliminate inefficient capacity in the cement industry, green investment has followed. However in other areas, such as grid capacity construction, sewage treatment and local pollution of the cement sector, stronger policy measures are required to drive green development in these sectors.

Stricter enforcement of environmental regulations is also required. In the solar, cement and the environmental industry sectors, local-level enforcement of environmental regulations remains a long-standing issue. Poor enforcement results in underinvestment in environmental technologies and environmental damage.

SOLAR PV

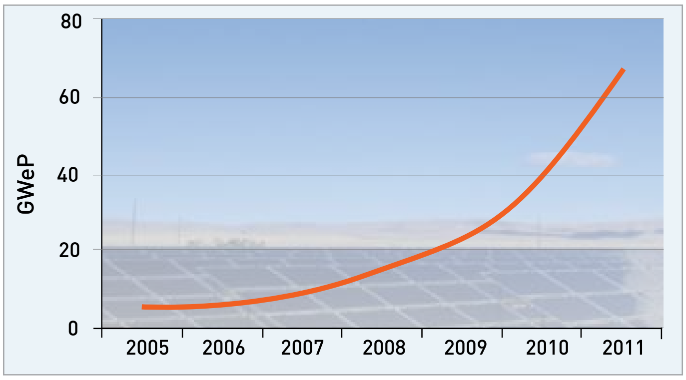
Since 2006, China has witnessed significant investment in solar photovoltaic (PV) manufacturing. After a slow start, the number of domestic solar power plants is increasing rapidly, particularly in western China. However, challenges remain in terms of innovation, manufacturing overcapacity and accompanied environmental problems.

Investment in the Chinese manufacturing has been high.

China has become the world's largest producer of solar energy equipment. Between 2006 and 2011, policy support from European governments, particularly Germany, Spain and Italy, led to a global boom in solar PV. The global PV market added 27.7 GW of new power capacity in 2011, and by the end of the same year, the global cumulative installed capacity exceeded 67.4 GW, compared to only 7.3 GW in 2006 (EPIA, 2012) (Figure 1). Chinese firms were able to capture a large part of this market, with solar exports of US$35.8 billion in 2011, more than its exports of shoes (Scotney et al., 2012).

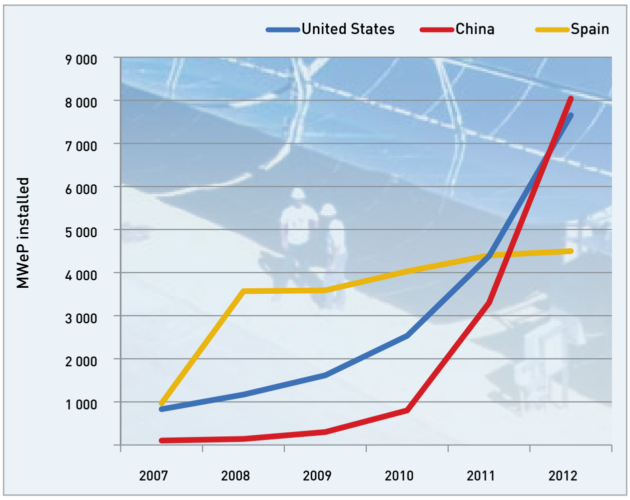
Chinese companies, such as Yingli and Trina, have become world leaders in solar PV manufacturing. In 2011, mainland China production of solar cells reached 17 GW, accounting for 48.5 per cent of the total world production (Ofweek Research, 2012). Indeed, China was the world's largest manufacturer for four consecutive years from 2008 to 2011, capturing an ever greater market share. While in recent years several Chinese solar companies have gone through difficulties, including the bankruptcy

Figure 1. Global installed solar PV capacity



Source: EPIA, 2012.

Figure 2. Cumulative installed capacity solar PV – selected countries



Source: EPIA, 2012.

of several high profile companies, China remains the world's leading manufacturer in solar PV.

Chinese firms initially began in solar cell production, but increasingly are involved in all parts of the value chain. In the early days of the solar boom, Chinese firms were unable to compete in the wafer and polysilicon sections of the market. In 2006, national demand for polysilicon was 5,000 tonnes, and the actual output produced in China was less than 300 tonnes (CICD Consulting, 2008). However many companies in China, such as LDK Solar and GCL Enterprise, have invested heavily in the polysilicon market, and prices have fallen accordingly, as shown in Table 2. As a result, in 2012, 40 per cent of global polysilicon and 76 per cent of wafers were produced in China (Solarbuzz, 2012).

Investment in domestic solar project construction started slowly but has grown substantially since 2010.

China's solar manufacturers initially relied on export markets, with more than 90 per cent of production sent abroad (MIIT, 2012). Historically, this was due to financial support for solar power in European countries being so much stronger than in the Chinese domestic market.

Recent growth in China means the country now has the third largest amount of solar capacity in the world, ahead of the United States. A boom in solar power installations occurred between 2010 and 2012, and China is now the world's third country in terms of installed capacity of solar power, after Italy and Germany. In 2011 alone, China installed 2,250 MWp, an annual growth rate of 500 per cent. Figure 2. shows the growth in China's solar power industry. At current growth rates, China will soon overtake Italy to be the world's second largest PV market.

The domestic market growth has been driven by dramatic falls in cost, as well as support from the government. Between 2008 and 2012, the price of installing solar panels fell by approximately 40 per cent, as demonstrated in Table 3.

Table 2. Major PV enterprises and industry chain in China

■ Main product ▨ Other products ░ Product line

Enterprises	Silicon	Ingots	Wafers	Photovoltaic	Cells	Solar
Yingli Solar	░	░	░	░	■	
Suntech Power				▨	■	▨
Trina Solar		░	░	░	■	
LDK Solar	░	░	■	░		
Jingko Solar	░	░	▨	▨		
GLC Poly	■	░		░		
JA Solar						

Sources: : Li et al., 2011.

Table 3. Estimated price changes (RMB) for solar PV plant installation in China between 2010-2012

Component	2010	2012
Component prices (RMB)	11.0-13.0	5.0-7.0
Inverter price (RMB)	1.2-1.4	0.8-1.0
Installation, commissioning and network testing (RMB)	7.0-9.0	3.0-7.0
Total investment (RMB)	19.0-24.0	9.0-15.0
Cost of power generation (kw/RMB)	1.2-1.5	0.8-0.95

Source: Sealand Securities Institute, 2012.

Domestic solar power capacity investment is driven by national policy, while manufacturing investment has predominantly been driven by export markets and local government support.

China initially relied on a solar concession program for domestic solar projects. In 2009, China began to implement solar PV building demonstration projects under the Golden Sun demonstration programme. The Golden Sun initiative offered a concession in a given area, and companies submitted a bid for the projects, with the authorities selecting the winning bid. However, during this period, levels of solar PV installation remained low.

The main policy lever is now through a high feed-in tariff. Today, solar farm installers receive a tariff of RMB 1 for every kWh they produce (NDRC, 2011), a 100 per cent premium on the price that hydropower or coal power producers receive. As costs of solar power have fallen, this tariff remained at RMB 1 per kWh, meaning a large number of projects became profitable. This spurred the recent growth seen in Figure 2.

The significant investment into PV manufacturing is mainly a result of tariff support policies outside of China. The major driver for the boom in the Chinese manufacturing sector was export markets following the generous government support for solar in Germany, Spain and later the United States. These subsidies led to fast growth in the sector, of which Chinese manufacturers were able to take advantage .

Local governments have also helped their companies to expand rapidly. In the early stages, the Chinese solar PV manufacturers received support from local government in the form of financing and access to land. For example, the Wuxi government had a significant stake in Suntech (Kan, 2010). However, this government support, as discussed below, eventually had distorting consequences.

The solar PV sector faces a number of significant financial and environmental challenges posed by the manufacturing process, including overinvestment.

Overinvestment has been high in the manufacturing sector, and many of the large solar PV firms face considerable losses. Huge investment in manufacturing capacity across the PV value chain resulted in the dramatic fall in panel prices outlined above, pushing down profit margins to the point that many firms suffered significant losses. The former market leader, Suntech, began bankruptcy proceedings in early 2013.

Chinese firms still remain behind the global technology frontier. While Chinese firms have been able to successfully compete internationally, they fall behind their western competitors in many technological aspects. For example, China is behind other firms in its development of thin film solar panels. On average, as a percentage of revenues, Chinese firms tend to invest less in R&D than their western counterparts (De la Tour et al., 2011).

Underinvestment in grid capacity is likely to cause problems in the coming years. Solar PV projects in China are located in the relatively underdeveloped western region. A grid connection is, therefore, required to transmit power to the more developed eastern region, where demand for energy is greatest. However, in recent years, grid investment has only been 34.1 per cent of that on capacity installation (MIIT, 2012). A 10 MW solar power plant can be constructed in less than six months, while a grid transmission project can take three to four years (MIIT, 2012). With solar power continuing to boom, this capacity issue may be a bottleneck in the near future, as it has been in the wind sector (see next section).

Solar manufacturing facilities have caused local level environment pollution. If not properly controlled, the solar production process can result in air and water pollution. Due to the lack of strict enforcement of environmental regulation, the speed of growth in production and low profit margins, many solar firms have often not properly invested in pollution control. Instead, firms tend to rely on 'end-of-pipe' treatment, rather than controlling for pollution earlier, and there have been reports that some firms do not even perform end of pipe treatment (see Case study 1).

Rooftop solar PV remains undeveloped in China. China has favoured large-scale grid connected solar projects. This is principally due to economic considerations, as the cost of installing rooftop projects is higher and because the sunlight is stronger in the remote west of China. However, as noted before, the principal power demand is from coastal regions. Therefore, building rooftop solar projects may be a promising avenue to pursue. Indeed, in October 2012, the National Energy Administration announced that the Stage Grid will connect small scale rooftop solar powers to the grid free of charge (Xinhua, 2012)

> To mitigate the environmental, financial and technological problems of the solar PV sector, the Chinese government needs to encourage innovation and improve coordination between the local and national level.

Government needs to provide more incentives for firms to invest in R&D. Such investment can lead to a virtuous cycle of higher profit margins and further investment in R&D. To continue to compete internationally, Chinese firms need to stay close to the global technology frontier. Increased R&D investment can help develop innovative forms of solar power, such as Building Integrated PV (BIPV). At present, China is a follower, not a leader, in the technology of the solar sector. The Chinese authorities could offer further incentives, such as tax breaks and better intellectual property protection, to encourage an increase in investment.

Local governments need to be provided to be with incentives to reduce overinvestment. At present, lack of alignment between the central and local-level governments is an important driver of the overinvestment that has occurred in the solar manufacturing sector. Local government officials, who are often more interested in achieving economic growth than ensuring firms are managed according to market principles, need to understand the impacts of these decisions.

Stricter enforcement of environmental regulations in the solar production chain is necessary. The intense competition and lack of enforcement in the solar sector has meant that some solar facilities have caused local air and water pollution (see Case study 1). More attention needs to be placed on minimizing this pollution and, in particular, strengthening the effectiveness of local environmental protection agencies.

CASE STUDY 1

Jingko Solar and local water pollution in Haining village

On 15 September 2011, villagers gathered outside of the Jingko Solar factory in Haining township. The villagers blamed the factory for contaminating a local creek that led to the death of the local fish stock. An investigation was carried out by the local environmental bureau. It was found that the factory was releasing fluoride content that exceeded the national standard by a factor of 10. Jingko was fined RMB 470,000 and the factory was shut down until it could prove the problem had been resolved.

(Source: Greenpeace, 2011)

WIND

China has witnessed rapid growth in wind power investment and now has the world's highest installed capacity. Furthermore, two of the top three global wind turbine manufacturers are Chinese. But a lack of grid investment poses a significant challenge to the industry.

China's wind capacity is now the world's largest, with over 60 GW of domestic capacity installed.

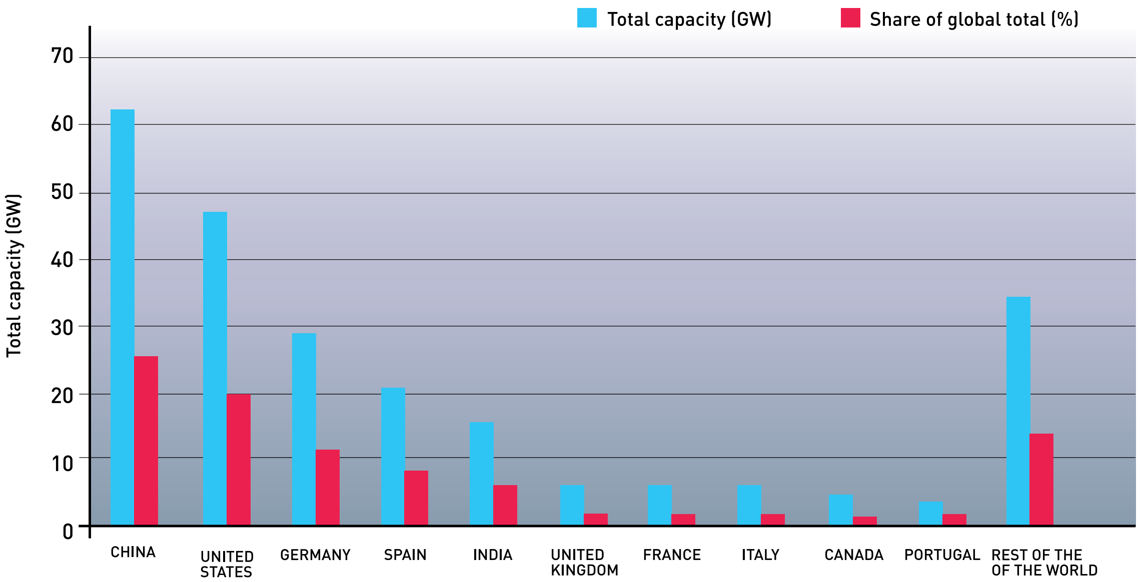
In only five years, China has gone from being a minor player in the wind power sector into the world's largest market. Wind capacity in China now stands at over 60 GW. Year-on-year growth in 2011 alone was 40 per cent, with over 11,000 turbines installed (CWEA, 2011). Of China's installed capacity in 2011, 4.89 per cent was from wind, and the sector recently became the third largest energy source in China (behind thermal and hydropower). In 2011,

Table 4. Top 10 countries by total installed wind capacity

Countries	Total capacity (GW)	Share of global total (%)
China	62.4	25.9
America	47.1	19.5
Germany	29.2	12.1
Spain	21.3	8.9
India	16.2	6.7
UK	7.1	3.0
France	6.8	2.8
Italy	6.7	2.8
Canada	5.2	2.2
Portugal	4.2	1.7
Rest of the world	34.4	14.29
World total	**241.0**	**100.0**

Source: BTM Consult, 2011.

Figure 3. Top 10 countries by total installed capacity



Source: BTM Consult, 2012.

China's investment into wind stood at US$30 billion, accounting for 42 per cent of the world's wind investment (The Pew Charitable Trust, 2011).

The wind industry will create millions of green jobs. Estimates from the Ministry of Environmental Protection suggest 1.93 million green jobs will have been created cumulatively by 2015 (Energy Research Institute of NDRC, 2010).

Wind power in China is concentrated in the northern and western regions of the country. Inner Mongolia Autonomous Region leads the way, with almost three times more turbines installed than any other provinces or autonomous regions in 2011. Certain zones have been allocated for large-scale wind farm development. The Gansu Jiuquan project, situated on the edge of the Gobi desert, will be the world's largest wind farm, with a capacity of 10 GW, larger than the entire installed capacity of wind in the United Kingdom (China Hydropower, 2012).

Table 5. Leading power firms investing in wind capacity

No.	Enterprise	Total installed capacity (GW)*
1	Guodian	8.9
2	Huaneng	6.3
3	Datang	5.6
4	Huadian	2.6
5	Guangdong Nuclear	2.4
6	Guohua	2.3

Source: CWEA, 2011. *2010

Most of the wind farms have been constructed by the large state-owned power companies. To date, the so-called 'Big Five' power companies dominate wind investment in China. A 49.5 MW wind farm, the typical size for a wind power plant in China, requires an upfront investment of close to RMB 300 million, a drop from the past costs of over RMB 500 million (UNEP Risoe, 2013), allowing companies with access to large amounts of capital to naturally dominate the market. Private firms represent less than 5 per cent of total grid capacity (Li et al., 2012).

The major power companies are also investing in offshore installations. China's first offshore wind farm – the Shanghai Donghai Bridge 10 MW offshore wind farm – began generating power in June 2010. While overall offshore capacity remains low at the moment, the fact that offshore farms can be situated close to the densely populated coastal areas offers an exciting opportunity for China.

The boom in wind capacity has been coupled with an increase in domestic manufacturing production.

A number of world leading Chinese companies have emerged in the wind turbine manufacturing industry. Domestic wind manufacturers have been the main beneficiaries of the growth in wind farms in China. As

Table 6. Wind manufacturers by China domestic market share

Rank	Company	Nationality	Total installed capacity (GW)	Market share (%)
1	Sinovel	China	12.9	20.8
2	Goldwind	China	12.7	20.3
3	Dongqi	China	6.9	11.1
4	United Power	China	5.3	8.5
5	Vestas	Denmark	3.6	5.7
6	Mingyang	China	3.1	5.0
7	Gamesa	Spain	2.8	4.5
8	XEMC	China	1.8	2.9
9	Shanghai Electric	China	1.8	2.9
10	GE	United States	1.6	2.5

Source: CWEA, 2011.

shown in Table 6, local firms dominate the market, with the top three manufacturers accounting for over 50 per cent of the market.

Chinese manufacturers have been able to cut costs of production, spurring further growth. The cost of constructing a wind farm in China fell by approximately 12 per cent in 2011 (Li et al., 2012). By making wind power more affordable, sites with less abundant wind resources become viable, paving the way for further investment.

Chinese manufacturers have predominantly relied on licensed foreign technology but are moving into innovative areas. Chinese firms are now capable of building offshore turbines and are building increasingly large ones with capacities of 3 MW and above. However, Chinese wind manufacturers have mainly relied on foreign technology licenses for their products. Table 7 shows the sources of technology for a selection of wind turbine models.

Wind development in China has been driven by ambitious targets and strong policy support.

China has set ambitious targets for wind production. By 2015, China aims to have connected 100 GW of installed wind capacity to the grid, under the 12th Five-Year Plan. The government had also set targets before that to drive wind power growth which were consistently overachieved.

Tariff support has been the principal policy driver of wind farm growth. The earliest demonstration projects in the early 2000 could receive tariffs as high as 1.2 RMB per kWh. Later tariffs were decided on a bidding concession process. More recently, projects receive a fixed feed-in tariff of between RMB 0.51-RMB 0.61 per kWh, depending on location (UNFCCC, 2011). This tariff remains higher than the price for coal-fired electricity (see Ma, 2011 and Li & Hu, 2007 for a more detailed discussion of the evolution of wind tariffs in China).

In the offshore wind sector, the government chose a competitive bidding process to drive investment rather than a feed-in tariff. To be given the right to construct an offshore wind plant, consortiums bid for who can operate at the lowest tariff, in a competitive bidding scenario. To date, the large state-owned power enterprises such as Datang and China Power Investment (Huaneng) have been the main winners of these bidding processes.

Other fiscal incentives are also offered to wind power producers. For example, wind farms receive a 50 per cent VAT rebate for wind generated electricity, while tax breaks are also offered for R&D into new manufacturing processes (Zhang et al., 2009).

A lack of investment in the grid is the largest challenge facing the industry, though a lack of investment in R&D and innovation poses a longer term threat.

Table 7. Sources of technology of selected China major wind turbine manufacturers

Entreprise	Models (MW)	Technology source
Xinjiang Jinfeng Technology Co.,Ltd.	1.5	Vensy
Sinovel Technology Co., Ltd.	1.5	Fuhrlander
	3.5	Cooperated with Windtec from Austria
Dongfang Steam Turbine Co., Ltd.	1.5	Repower
Guangdong Mingyang Wind Power Technology Co., Ltd.	1.5	Cooperated with Areodyn from Germany

Source: CWEA, 2011.

Grid capacity has not kept up with growth in turbine installation. At the end of 2011, 52 GW of wind capacity was installed, but only 45 GW was connected to the grid (CWEA, 2011). Furthermore, during certain periods, wind farms are unable to transmit all the power they produce due to the grid's inability to handle intermittent renewable energy supply. The majority of wind power projects are away from populous areas, and while new transmission lines are being built, there is a significant lag before China can fully benefit from all the wind power it is capable of producing.

Chinese manufacturers still rely on foreign imports for several high-end components. A 2012 report estimated that 50 per cent of the high-added-value critical parts and components were imported (Li et al., 2012). For example, control systems, hydraulic systems and main shaft bearings are often still imported. More R&D investment is required so that Chinese firms can move into the highest end bracket of the value chain.

Chinese manufacturers are yet to start exporting on a large scale. To date, Chinese firms have concentrated on the domestic market. To compete internationally, the after-sales support service will need to improve. It remains to be seen whether Chinese firms will successfully export their products at a significant scale.

The wind industry may suffer bottlenecks due to a lack of qualified staff. Relatively few universities currently offer specialised training in wind technology, particularly compared to the number of engineers who study thermal, nuclear and hydropower. With ambitious wind expansion plans, the government needs to ensure that the higher education system is training enough wind power engineers.

Although the main policy priority is to invest in grid capacity, further R&D investment should also be encouraged.

The Chinese authorities need to establish strong support policies for grid construction. There are ambitious targets for grid construction, and the government has a target of grid-connected wind capacity of 100 GW by 2015 and 150 GW by 2020 (BOC International, 2011). However, clear policy support is needed, particularly to give the main grid company the incentive to construct reliable transmission networks.

The clear policy signals to wind power development need to continue. The Chinese wind industry has been one of the greatest clean energy success stories of the last decade. Strong policy support through ambitious targets and financial incentives, notably high feed-in tariffs, was the principal driver of this growth. The government needs to continue this unambiguous policy support.

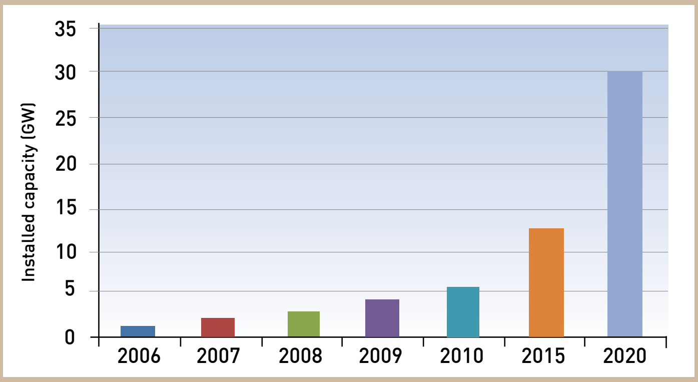
BIOENERGY

The Chinese bioenergy industry has experienced strong growth over the last five years, particularly in the fields of biomass and biogas from methane capture. Investment in liquid biofuels has been much more limited due to concerns about food security.

Investment has been strong in biomass, and is expected to grow over the next decade.

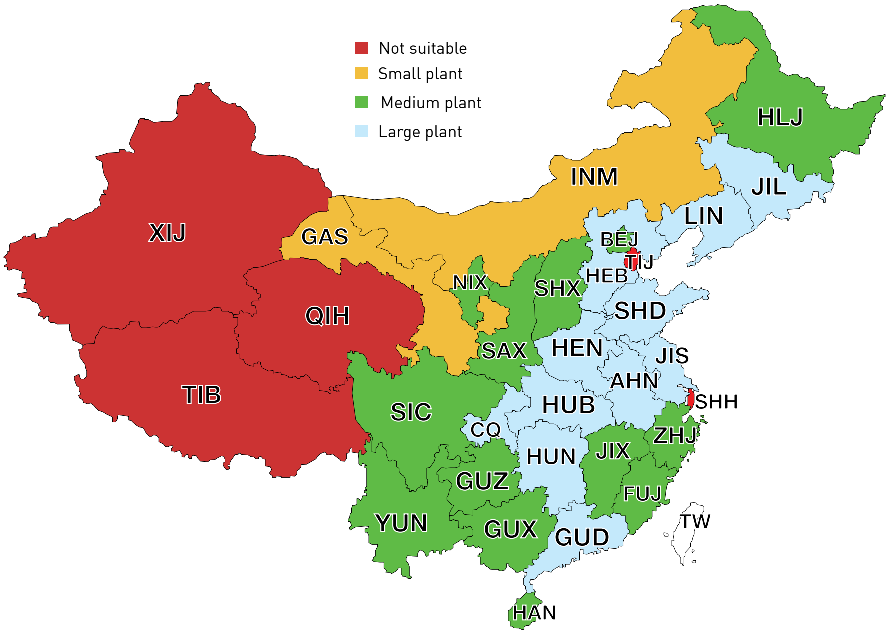
Biomass investment has been strong and ambitious targets have been set for the next decade. Electricity production from biomass involves the collection of agricultural products such as straw and rice husk which are burned in a boiler, in turn driving a turbine and generator, producing usable electricity. Chinese production of electricity from biomass has increased dramatically in the last five years, and is set for further

Figure 4. Cumulative installed biomass capacity – 2006-2020



Source: Gao, Y., 2011.

Figure 5. The potential distribution of crop straw resource and processing technology for bioenergy production



Source: Song, 2010.

growth. Figure 4 shows this expansion in biomass capacity, as well as the ambitious future plans for biomass growth in China.

Biomass projects are located throughout China, but with a concentration in eastern regions. Biomass projects tend to be located in areas of agricultural production where the most feedstock is available. In China, the most fertile land is situated in the eastern coastal provinces where there is also the most demand for energy, so the majority of projects have been built there.

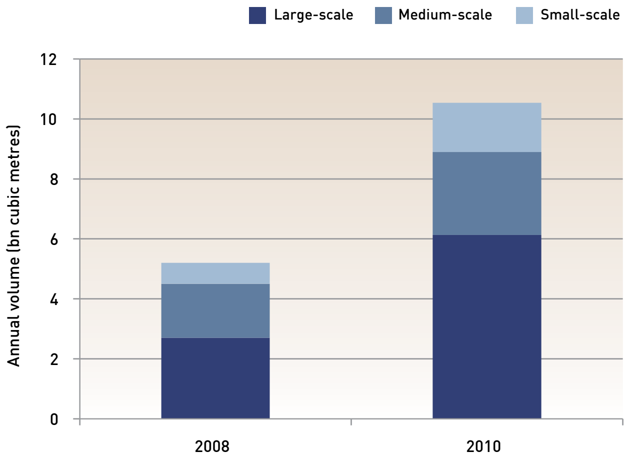
Biogas methane projects, particularly use of animal waste for power generation, have also seen strong growth.

Between 2008 and 2010 annual production of this biogas doubled (Ma et al., 2012). Biogas methane projects trap the gas produced by agricultural or industrial waste and convert this gas into useful energy, usually electricity. With increased demand for meat in China the potential for biogas capture from animal waste has particularly strong growth opportunities. Figure 6 depicts the rapid increase in biogas facilities, with production doubling between 2008 and 2010.

Biogas projects using industrial wastewater are becoming increasingly common. In the alcohol, citric acid and paper sectors, companies are able to capture the methane from industrial processes and turn it into usable energy. These projects use anaerobic digestion, and can provide factories with power for internal use or distribute energy to the grid.

Biomethane projects are particularly important for combatting climate change, due to the GHG warming potential of methane. Methane is 25 times more potent than CO_2 in terms of GHG intensity – therefore trapping the methane also reduces GHG emissions that contribute to climate change (IPCC, 2007). Moreover, biogas projects reduce local air pollution. For example a biomethane project at a pig farm traps the hazardous and foul-smelling gas from animal waste, improving the welfare of local residents and farm workers.

Figure 6. Biogas production increases in China, 2008-2010



Source: CRES, 2011.

Biogas and biomass projects increase rural incomes. In China, thousands of small-scale farmers are typically involved in the collection of biomass for electricity generation. For example, the Henan Tianguan biomass project generates RMB 60 million per year in additional income for farmers who are paid for every kg of biomass they supply to the plant (Sun, 2012). Ninety thousand people are involved in biomass collection for this one project alone, supplementing rural incomes.

Growth in biofuels has been weaker than other sectors due to concerns on food security.

The use of liquid biofuels such as bioethanol and biodiesel has also grown. Production of biofuel ethanol which is mixed with gasoline to power automobiles doubled between 2005 and 2010 (Huang and Qiu, 2010). Figure 7 shows this growth.

However, China's long term plans for biofuels are relatively unambitious compared to other countries, such as the United States and Brazil. In the United States, energy from biofuels is expected to reach 106 million tonnes by 2017, while in China production is only planned to be 10 million tonnes from bioethanol and 2 million tonnes from biodiesel, just over 10 per cent of the goal set by the United States (Ji and Yu, 2008).

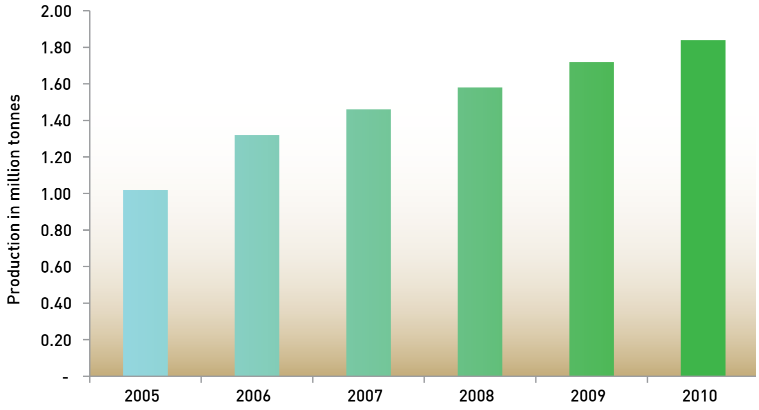
The reluctance to invest heavily in biodiesel is driven by concerns over food security. Due to China's relative scarcity of agricultural land for crop growing, the government has been extremely reluctant to allow unmanaged growth in the biofuel sector. Yang et al. estimate that to produce 10 million tonnes of bioethanol in 2020, about 5-10 per cent of China's farmland would be occupied for feedstock production. China has, therefore, tried to encourage development of non-grain biodiesel, but this technology is relatively undeveloped.

Biomass and biogas investment has predominantly been encouraged through feed-in tariffs, though international finance has also played a role.

Generous feed-in tariffs were introduced for biomass and biomethane projects. The Chinese government set a tariff of RMB 0.75 per kWh for all electricity from biomass and biogas production in 2011 (Zhou et al., 2012). This policy has led to a boom in construction of both biomass and biogas projects, and provides a stable investment climate.

The Clean Development Mechanism (CDM) has also provided extra incomes for bioenergy producers. By the end of 2012, over 150 biomass projects and almost 100 methane capture projects applied for financing under the CDM, where projects receive a price for every tonne of carbon reduced. Collectively these projects represent over 4 GW of installed capacity and US$6 billion of investment (UNEP Risoe, 2013).

Figure 7. Liquid biofuel production increases, 2005-2010



Source: CRES, 2011.

Due to concerns over food security, the Chinese authorities have offered less subsidy support for biofuels. Whereas producers of biomass energy in China receive a premium for the electricity they produce, biofuels producers receive lower subsidies. The price offered for biodiesel is 17 per cent lower than in the United States (Zhang and Zhou, 2010).

Challenges associated with cost and food shortages remain significant.

The main challenge for biomass production is the cost of feedstock. As biomass electricity boiler and generator technologies are relatively mature, the critical cost is feedstock. Whereas straw is relatively affordable, the cost of other biomass forms, such as corncobs and peanuts, remains high in China.

The boom in the number of biomass plants has resulted in increased scarcity of feedstock in certain areas such as straw and rice husk. This drives up the price of the feedstock which represents over 70 per cent of the operating cost of biomass electricity production (Ma et al., 2012). High feedstock prices make many plants unprofitable.

Biomass feedstock processing is less advanced in China than elsewhere. In Europe, biomass tends to be in the transformed into efficient pellets and briquettes. In China, this processing technology is not advanced, meaning the efficiency of biomass production plants is lower than in developed countries.

Food security remains a risk for China. As is widely known, China has 22 per cent of the world's population but only 7 per cent of the arable land (Piao et al., 2010). While growth in biomass electricity production in China has been strong, this trend does not affect food security. To date, biomass plants use waste agricultural residues, like straw, rice husk and fallen tree branches. Further expansion into biomass that relies on new crop planting will threaten food security.

Bioethanol costs are also high in China, while the price paid for biofuels is low. According to a study by Zhang and Zhou (2010), bioethanol production costs in China are 17 per cent higher than those in the United States, yet the price paid for bioethanol is 18 per cent lower. This means profits are low and companies are unwilling to invest in biofuel production.

Certain biofuels in China, particularly jatropha, may have significant growth potential, but remain undeveloped. According to studies by the China Biomass Association, jatropha is the biofuel source with the most significant potential in China. It can be grown throughout western China and can in theory produce usable biofuel without impacting on crops as it can grow in areas many other plants cannot. However, recent studies have shown that for jatropha plants to produce the seeds containing biofuel, fertile conditions are in fact needed. Thus, jatropha may not be the 'miracle plant' many thought it would be. Sweet sorghum, cassava and sweet potato are also non-grains which may not compete directly with food supplies. However, further research is required (World Bank, 2012).

The strong policy support for biomass and biomethane should continue along with careful attention to the threat of biofuels on food security.

Ongoing policy support is required. The feed-in tariff of RMB 0.75 per kWh, a premium of over 50 per cent on the price paid for coal-based electricity triggered a boom in biomass production. But according to a recent study, production costs can be upwards of RMB 0.84 per kWh (Zhang and Zhou, 2011). Though costs may be reduced due to technology improvements, the government should continue to ensure stable, strong financial support to investors through a feed-in tariff.

The authorities need to continue to balance the food security risk from biofuels, and invest in research into non-grain alternative feedstock. Chinese policy makers need to continue to monitor the threat of bioenergy projects on food stocks. A lack of arable land and problems of law enforcement at the local level mean that authorities should pay close attention to the threat of biofuel production on edible farmland.

R&D into sustainable bioenergies are required. In both the biomass and biofuel sector, new sources of feedstock are required if the sector wants to become an important energy provider in China. Finding crops that can be grown economically, but do not threaten food security is a difficult challenge. Through scientific research, however, and investment in further research and development into alternative fuels, bioenergy has the potential to play an important part in China's energy future.

CEMENT INDUSTRY

Given the cement industry's high level of GHG emissions and its contribution to local air and water pollution, greening the cement sector is an important task for China in its transition to a green economy. To date, Chinese cement enterprises have successfully increased the energy efficiency of production, and reduced the amount of other pollutants emitted. However, given the high levels of growth, further investment is required to mitigate the negative environmental impacts of the sector.

The cement industry has increased energy efficiency over the last five years.

Energy efficiency has increased dramatically in the cement sector. Energy consumption per unit of industrial value added output fell by 41 per cent from 2005 to 2010 (QEACBM, 2011).

There has been significant investment into new, cleaner modes of cement production. In 2002, only 16.8 per cent of plants used dry process kilns, and most used more inefficient wet process rotary or vertical kilns. Today, more than 89 per cent of plants use dry process kilns, replacing 150 million tonnes of inefficient production capacity (CBMF, 2012). Table 8 shows the typical impact of investment in these new process types in terms of energy efficiency, demonstrating the improved performance of new dry process kilns.

Investment into Waste Heat Recovery (WHR) has also been high. Cogeneration units that trap the waste heat from the production process and reuse it into useful energy were installed on 692 new dry process kiln production

Table 8. Coal consumption of the processes of cement industry

PROCESS	Clinker use (KGCE/T)	Raw coal use
New dry process kiln	115	161
Vertical kiln	160	224
Hollow dry kiln	186	260
Wet rotary kiln	200	280

Source: Zeng, 2007.

lines (Zeng, 2011), accounting for 75 per cent of the total lines that were feasible for such an installation (Wang, 2012). These projects significantly reduce emissions of the plant, with a 7.5 MW installation reducing almost 50,000 tonnes of CO_2 a year.

A large number of small inefficient factories have been phased out. Since 2006, China has begun phasing out backward production. During the 11th Five-Year Plan period (2006-2010), China phased out 250 million tonnes of backward production capacity (MIIT, 2011). The industry has also consolidated in the last 10 years, with the largest cement manufacturer accounting for over 25 per cent of production (NDRC, 2012). The top 10 manufacturers had only accounted for around 10 per cent of production in 2005.

China is still behind other countries in terms of pollution mitigation and efficiency as demand continues to increase.

China's cement production is the largest in the world. The level of production was 2.06 billion tonnes in 2011 (National Bureau of Statistics, 2013), accounting for approximately 60 per cent of the global total. Cement contributes to 5.08 per cent of China's GHG emissions and over 2 per cent of global emissions (PBL Netherlands Environment Assessment Agency, 2012). Figure 8 shows that while energy efficiency has increased, energy consumption continues to rise.

Growth projections continue to be high for the sector, further increasing the need for increased investment in environmentally protection technologies. The rising demand for infrastructure, particularly for housing and transport, means that the demand for cement will continue to grow following the pattern of the last few years (International Cement Review, 2012).

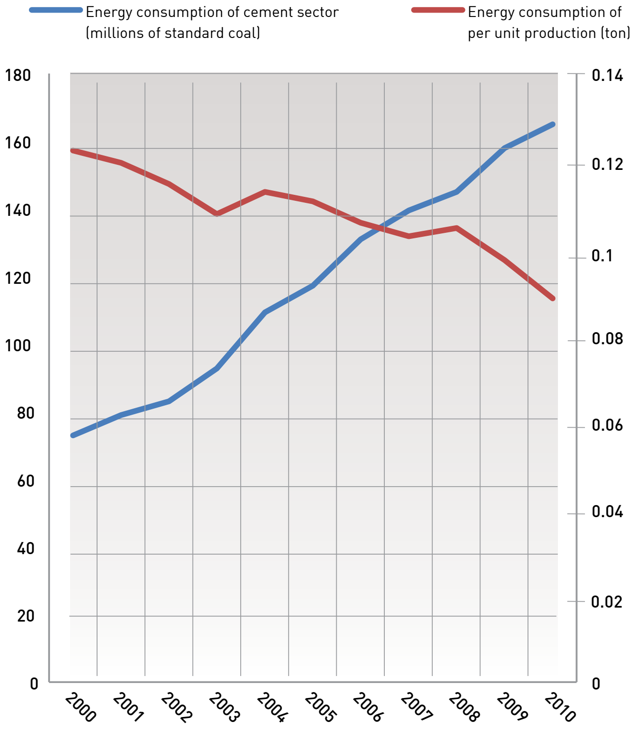
China's cement sector is estimated to require at least RMB 280 billion of investment to undergo a green transformation in line with its broader targets (Rock, 2008). This amount would be required to maintain the necessary production capacity while cutting CO_2 emissions by 45 per cent, in line with the cement sector's commitment under the 12th Five-Year Plan.

Regulations have been the main driver of green investment in the sector.

Extensive regulatory measures have been taken to increase efficiency in the cement sector. Over 40 directives have been issued on greening the cement industry, including strict regulations on efficiency requirements of new power plants, to ensure old technologies are gradually phased out. Over the 11th Five-Year Plan period, 1,000 factories were closed despite production increasing 80 per cent from 2006 to 2010).

Regulatory measures have also been imposed to reduce pollution. In new 2005, standards were set for the regulation of $N0_2$ emissions, which were in line with international standards in developing countries (MEP, 2012). However, as discussed below, a lack of fiscal incentives or pollution taxes means firms are not incentivised financially to reduce their pollution.

Figure 8. Energy consumption in the Chinese cement industry



Source: National Bureau of Statistics, 2011.

The 12th Five-Year Plan for the cement industry lays out further ambitious goals. Under these plans China aims to eliminate 250 million tonnes of cement capacity and increase the industry concentration ratio to 35 per cent (MIIT, 2011).

China's cement firms are less efficient than their Western competitors and cause more stress on the local environment.

Chinese producers remain behind the international energy efficiency frontier, particularly compared to Western and Japanese firms. The average energy consumption of new dry process kiln production lines in China is 15 to 25 per cent higher than the international average. Even advanced plants are 5 per cent more energy intensive than their international counterparts (Cui et al., 2010).

Chinese firms still use fewer alternative fuels than their Western counterparts. Waste materials such as fly ash, calcium carbide slag and construction waste can all be used to replace clinker, reducing the energy input required to produce a unit of cement. Table 9 provides a comparison between major countries of waste efficiency measures in the cement industry, and demonstrates that China still lags behind developed countries.

Environmental problems, other than GHGs, are also significant and more investment is required. Cement industry accounts for about 10 per cent of China's national nitrous oxide (NO_x) emissions (NDRC, 2012). Denitration technology is expensive - costing between RMB 20 to 40 per ton of production to install. However, the profit in the cement sector is typically only RMB 50 per ton, so firms are unwilling to bear the cost (NDRC, 2012). There are very few subsidies for denitration technologies, meaning that NO_x emissions in the industry remain high.

The Energy Management Contract (EMC) market needs to expand. EMC firms invest in industrial energy efficiency technologies on behalf of large energy users and then are paid back through energy savings. The number of such firms has grown dramatically in China in recent years. However, banks in China impose strict conditions on payback and EMC firms must repay their loans in a relatively short time period. These constraints slow the growth of the market (IFC, 2011).

Increasing energy efficiency and reducing negative environmental externalities should be the main policy priority.

Further policy incentives are required to drive the greening of the sector. It is estimated that RMB 280 billion (US$43 billion) is required for the green transformation of China's cement industry (Rock, 2008). At present fiscal incentives in the sector are too small to drive these activities. Local governments are reluctant to put levies on firms for fear of jeopardising local employment and economic growth. Strong central policies are required to ensure that this green investment takes place.

To resolve the significant environmental damage of the cement industry, both stricter regulation and further incentives are required. As discussed above, the local pollution impacts of the cement industry are significant and greening of the cement industry is more than just energy efficiency. NO_x emissions are particularly high, yet current regulations and incentives have not proved effective at reducing NO_x emissions.

Companies need to have better access to credit to finance energy efficiency projects. The payback for energy efficiency measures can be long. Usually small cement firms do not have the access to the necessary credit to fund these long term projects. The authorities need to encourage the growth of investment products that support energy efficiency, such as through green credit and contracts.

Table 9. Comparison of waste efficiency measures across cement producing countries

COUNTRY	Clinker coefficient (%)	Proportion of alternative raw materials	Proportion of alternative fuels (%)
China	63.4	80	0.09
Germany	80.2	160	78
Japan	82.5	234	41
America	89.1	107	35

Source: Gao, C., 2011.

Demand also needs to be reduced through regulations such as improved building standards. The cement industry has grown in China due to large increases in demand for housing and transport infrastructure. Buildings typically have a service life of thirty years, while in the UK the average lifetime of a house is 132 years. Extending the average lifetime of buildings would reduce cement demand by tens of millions of tonnes. Moreover, China may also consider constructing relatively smaller living areas, which reduce demand for cement.

CASE STUDY

The Chinese railways cause soaring demand for cement

The Beijing-Shanghai high-speed elevated railway line has 1,318 km of viaduct, manufactured from 16.52 million tonnes of cement. There are twenty-two stations along the line which required an estimated 2.2 million tonnes of cement, assuming 100,000 tonnes of cement per station. In total, cement consumption for the high-speed railway is 18.72 million tonnes. In 2010, the whole of East Africa (Kenya, Tanzania Uganda, Rwanda and Burundi), only produced 8 million tonnes of cement.

ENVIRONMENTAL INDUSTRY

Growth in the environmental industry has been strong over the last decade and grew even faster as a result of the post-financial crisis stimulus plan. However, a lack of enforcement of environmental regulations and undeveloped fiscal mechanisms for supporting investment restrict growth prospects.

The environmental industry, encompassing a wide range of industries from waste management to low energy light bulb manufacturers, has grown significantly in China, particularly following the post-financial crisis stimulus package.

The environmental industry refers to a myriad of industries that improve environmental conditions. Key sectors include water treatment, air pollution control equipment, energy monitoring and waste recycling.

The Chinese authorities divide the sector into four components:

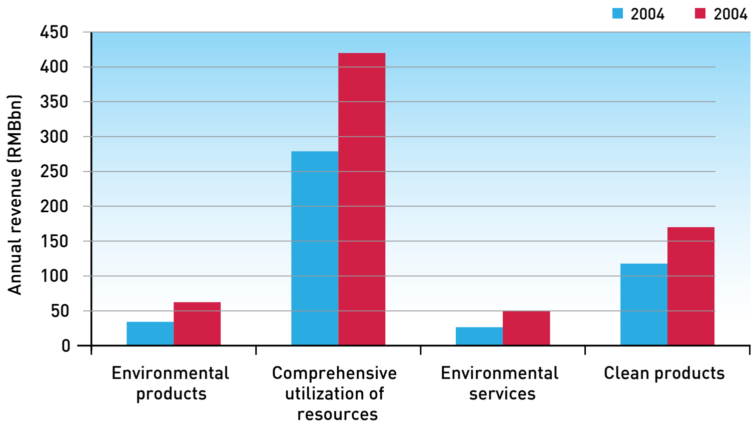
1) Environmental goods – e.g., equipment and material used for pollution control, water treatment technologies, energy monitoring equipment;

2) Comprehensive utilization of resources – e.g., waste management industry, industrial waste heat re-use projects, recycling companies;

3) Environmental services – e.g., environmental consulting, research institutes; and

4) Clean products – e.g., energy saving light bulbs, biodegradable materials.

Figure 9. Growth in environmental industry, 2004-2007



Source: SEPA and NDRC, 2006; GESEP, 2010.

Investment in the environmental industry meant that between 1997 and 2006, the industry grew from revenues of RMB 45.92 billion to RMB 600 billion, a tenfold increase. In 2010, it was estimated to be 1 trillion (Li and Guo, 2012).

Following the stimulus package, environmental industries grew even faster. Between 2009 and 2011, the water treatment industry increased from RMB 170 billion to RMB 334 billion, almost doubling in size (Water Development Statistics Bulletin, 2005-2010). Meanwhile, the urban environmental infrastructure sector also saw substantial growth in the same period, rising from RMB 98.72 to RMB 155 billion (National Environmental Statistics Bulletin, 2005-2010).

The environmental industry has also become a significant creator of green jobs, with over 3 million people employed in 2008. In 2004, only 1.53 million employees were involved in the environmental industry (CIECCPA, 2010).

Several sectors have become major industries in China. The resource recycling industry alone was worth RMB 660 billion in 2008. Figure 9 shows the growth of different areas of the environmental sector from 2004 to 2007.

China's environmental challenges remain huge, and the requirements for further investments in this sector in the coming years are planned.

Water, land and air pollution remain a problem requiring growth in the environmental industry sector. Seventy per cent of the country's major surface water systems have been polluted (Zhang, 2011), and 55.5 per cent of major rivers are classified as below grade III, the standard for water with acceptable quality. Meanwhile, air pollution has become a critical issue for China's urban population, with outdoor air pollution estimated to contribute to 1.2 million premature deaths per year (Cohen et al., 2005),

Waste management is also a major challenge for the Chinese authorities. In the last decade, China has witnessed the largest and fastest increase in solid waste. The number of landfills has risen rapidly in recent years, but rubbish is often dumped illegally. Increased investment in more modern waste management is required.

The investment requirements for the 12th Five-Year Plan are also large. Table 10 demonstrates the estimated large levels of investment required to meet the targets in the 12th Five-Year Plan.

The environment industry depends on government support and regulation also plays a role in driving investment.

Table 10. Investment demand for key industries in the environmental protection industry (RMB billion)

Key fields	Investment demand	Operating cost of new projects	Operating costs of all facilities
Urban wastewater treatment	436	33	57
Contaminated soil remediation	315	N/A	N/A
Desulfurization and denitration	135	42	103
Urban garbage disposal	94	12	87
Environmental regulation and emergency capacity	70	30	30
Other	151	44	63
Total	**1 202**	**161**	**342**

Source: Wang et al., 2010.

Central government programmes, such as the 863 Programme, have allocated funds to the development of the sector. The National Science and Technology Support Plan and 863 Programme funded the environment industry with approximately RMB 4 billion. During the 11th Five-Year Plan, the water pollution control and management plan received central funds of over RMB 3 billion (US$500 million).

Table 11. Environmental protection targets in 12th Five-Year Plan

	Indicators	2010	2015	Comparison (%)
1	Total discharge of COD (million tons)	25.517	23.476	-8.0
2	Total discharge of ammonia (million tons)	2.644	2.380	-10.0
3	Total discharge of SO_2 (million tons)	22.678	20.864	-8.0
4	Total discharge of NO_x (million tons)	22.736	20.462	-10.0
5	The percentage of state-controlled surface water sections with inferior Grade 5 – the lowest grade (%)	17.7	<15.0	-2.7
6	The percentage of state-controlled sections in seven major river systems greater than Grade 3 (%)	55.0	>60	+5.0
7	The percentage of cities where air quality reaches Grade 2 (%)	72.0	≥80	+8.0

Source: State Council, 2011.

Strict regulations and targets also lead to growth in the sector. Over the last decade China has put in a series of regulatory policies to improve the environment. For example, the 'total pollution load control' policy reduces SO_2 (sulphur dioxide) and CO_2 pollutants by distributing a limited number of discharge permits that reduces every year. Firms are then given incentivised to invest in pollution control equipment. Between 2005 and 2010, a 10 per cent reduction target for COD and SO_2 was achieved (UNEP, 2011). Table 11 depicts the environmental protection targets found within the Five-Year Plan.

The Chinese government has set a series of tough targets, which will drive growth in the environmental industry. Table 11 details some of the most important environment targets under the 12th Five-Year Plan.

Low charges on pollution, a lack of innovation and insufficient industry consolidation hinder growth in the sector.

Charges for pollution remain low, restricting the growth of the environmental industry. For example, charges for pollution discharge and sewage and garbage are too low to justify further investment in cleaner treatment measures. At the same time, the preferential tax incentives for such investment are also limited.

Non-enforcement of environmental regulations remains an ongoing problem. The enforcement of environmental regulations is a well-documented issue (Economy, 2010). Without proper enforcement, firms will not invest in the most effective environmental technologies. For example, waste disposal companies in China do not always properly manage garbage due to ineffective oversight from local officials.

China remains behind in terms of independent innovation. A lack of investment in R&D and an insufficient amount of world-class researchers means the progress in the environment technology field has been lower than in the developed world.

World-class environment firms are yet to emerge in China. In France, just three major enterprises are mainly responsible for operation of sewage and garbage disposal. These three firms are all world-class in terms of technology and operations. In China, wastes companies are scattered around the country and often do not have the same level of service. Generally speaking, the environment industry has suffered from regional protectionism preventing the emergence and growth of world-class firms.

Banks could be unwilling to lend to environmental industry projects. Projects in the sector, particularly in the waste management industry, tend to have low returns and a long payback period. They are also highly dependent on regulatory incentives. Moreover, as waste projects do not involve the construction of property it is harder for firms to put up collateral. Banks, therefore, have been reluctant to lend to the environmental industry. China spends less than 1.5 per cent of GDP on environmental protection investment whereas many Western countries spend 2-3 per cent (Wang et al., 2010).

The government can boost further investment in the sector by establishing firmer environmental protection policies and promoting market competition.

Increased market competition in the sector and industry consolidation is required. The environmental industry in China continues to be extremely dispersed. The government needs to encourage competition in the sector so that national-level firms can emerge. In particular, the sourcing process by local governments needs to increase its transparency to favour regional competition.

The authorities should consider introducing increased fiscal policy support for the environmental industry. At times, a lack of clear policy guidelines has restricted investment in the sector. While targets are ambitious, there can be a lack of transparency in the incentives offered to environmental protection firms. The government can introduce preferential income tax policies such as VAT relief for firms. In addition, prices for waste treatment and sewage processing could be raised to improve the profitability of the sector.

Banks need to be incentivised to provide greater access to finance for firms in the environmental industry. To encourage increased financing to the sector, banks need to be encouraged to lend more to environmental protection firms and green credit programmes. In 2012, the China Banking Regulatory Commission issued the first green credit guidelines for Chinese banks to promote energy saving and environmental protection investments (CBRC, 2012).

CONCLUSION

The report synthesizes the studies in five sectors to gain an insight into China's green economy transition. Overall, China has seen spectacular green development in all these industries over the last decade. China leads the world in wind energy production and has witnessed rapid growth in the solar, bioenergy and environmental industries. In the cement sector, greening measures have taken place to increase the industry's energy efficiency and reduce pollution.

The growth in these sectors has been driven by a strong policy framework. In renewable energy, strong feed-in tariffs combined with falling costs have led to growth in the installed capacity in the wind, solar, biomass and biomethane projects. Increasingly stringent regulations are also driving energy efficiency measures and investment across the environmental industry.

However, across the sectors studied major challenges remain. China's carbon emissions are the largest in the world. Despite recent advances in renewable energy, China still relies on coal and oil for 90 per cent of their energy needs. Air and water pollution damage the quality of life and health of people. An underdeveloped waste management sector poses further environmental risks. Finally, Chinese firms across the sectors studied still remain below the international technology frontier.

The paper finds a number of policy challenges that will need to be addressed to continue China's green economy march. Firstly, a divergence in interests between local governments and national institutions has, amongst other impacts, slowed growth in the environmental industry and caused underinvestment in grid capacity in the wind industry. Secondly, weak enforcement of environmental regulations means firms are not incentivised to invest in environmental protection technologies. Finally, underinvestment in R&D means Chinese firms are behind the international technology frontier in most of the industries studied.

The paper finds that the Chinese authorities are already taking measures to address these issues, such as the recent announcements from Premier Li Keqiang on new regulations to reduce air pollution. Continuing efforts are required to ensure China's green economy transition. However the paper finds that the Chinese authorities are already taking measures to address these issues, such as the recent announcements from Premier Li Keqiang on new regulations to reduce air pollution. With such measures, China's green march will continue to improve the lives of the Chinese people, and the environment in which they live in.

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Notes on page 9

[1] 2009 exchange rate.

[2] The environmental industry contains those businesses where revenue generation is associated with environmental protection. It includes, but is not limited to air pollution mitigation, water treatment, waste management, environmental consultation.

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