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China Greentech Initiative
Strategic Insights, Industry Collaboration, Market Acceleration

# THE CHINA GREENTECH REPORT™ 2012

## Faced with Challenges, China Accelerates Greentech Growth

BY THE CHINA GREENTECH INITIATIVE

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***Managing Directors:***

Elle Carberry ( 柯凯丽 )

Randall S. Hancock ( 汉瑞德 )

Alan S. Beebe ( 毕艾伦 )


*The China Greentech Initiative (CGTI) accelerates the success of our Chinese and international Partner companies in China's greentech markets. Leveraging our insight-enabled community, we help our Partners make informed decisions on emerging market opportunities, identify commercial partnerships based on meaningful industry and policy relationships, position themselves as thought leaders, and educate stakeholders with the co-branded China Greentech Report and other publications. CGTI does this by integrating commercial and policy organizations with strategic capabilities as an insight-enabled community, which is serviced via two product offerings: the China Greentech Partner Program and CGTI Advisory Services. Please visit www.china-greentech.com for more information.*

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Editors: Alan S. Beebe (毕艾伦), Randall S. Hancock (汉瑞德), Anders W. Hove (侯安德), Cina Loarie and Piper Stover (蓝沛文)
Lead writers: Julien Bédin (朱立安), Lini Fu (付莉霓), Anders W. Hove (侯安德), Junda Lin (林骏达), Piper Stover (蓝沛文), Jing Wang (王静), Sean Wang (王效) and Lixuan Zhou (周丽璇)

Project Manager: Lixuan Zhou (周丽璇)
Report Design: Audrey Salmon (奥德丽) and Tina Li (李婷)
Photography: All rights reserved. Steve Bale, Chelsea Eakin (艾巧思), Jim Gourley, Anders W. Hove (侯安德) and Bruce Wu (吴少先)
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Additional Research Support: Michael Brewer (麦克), Ana Chiong, Han Hao (郝瀚), Amy Wan (万婧) and Yaoqi Zhu (朱瑶琪)

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# THE CHINA GREENTECH REPORT™ 2012

## Faced with Challenges, China Accelerates Greentech Growth

Researched and Produced by:
Greentech Networks Limited in collaboration with MangoStrategy, LLC


# Navigation Guide

The *China Greentech Report 2012* is organized into four sections for readers to access and use the findings easily.

**Executive Summary**
Summarizes the entire Report's findings succinctly.

**Introduction**
Describes how, despite challenges, China's greentech market is healthy and developing rapidly, propelled by government policy and urgent needs.

**Greentech Sector Chapters**
Covers each of the six greentech sectors (Cleaner Conventional Energy, Renewable Energy, Electric Power Infrastructure, Green Building, Cleaner Transportation, and Clean Water) on which the China Greentech Initiative focused in 2011. Each sector chapter includes:

- **Market Updates and Opportunities**
  Insights on how each sector has evolved and where it is going, including high-level analysis on market opportunities over the next 3 to 5 years.
- **Opportunity Assessments**
  High-level findings of prioritized sector opportunities, based on detailed proprietary research and analysis developed in collaboration with the organizations participating in the China Greentech Initiative's 2011 Partner Program.

**Resources**
Provides resources which support the Report findings and help readers learn more about China's greentech markets, including an overview of the research methodology, glossary of terms and definitions of acronyms.

*Steve Bale*

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# PREFACE

Dear Reader,

It is with great pleasure that we bring you the *China Greentech Report 2012*. This publication is the China Greentech Initiative's (CGTI) third edition of the *China Greentech Report*. The Report is a product of the China Greentech Partner Program, through which well-informed, well-connected and highly-involved industry executives, policymakers and other experts participate in CGTI's strategic research and collaborate on activities. Together, we are working to accelerate China's green growth.

CGTI's *China Greentech Report* is published annually with the objectives of educating the public, aligning stakeholders, and raising awareness about the opportunities and challenges facing China's greentech markets. While participants in the China Greentech Partner Program have access to CGTI's proprietary in-depth market analyses, Working Sessions and senior executive events throughout the year, the annual *China Greentech Report* summarizes insights from the previous year's work in a single publication. The Report gives readers a broad perspective of changes underway in China's greentech markets relating to demand, competition, policies, regulations, financing and technologies.

After its launch at the World Economic Forum, the *China Greentech Report 2009* quickly became the primer for understanding China's rapidly changing greentech markets. The *China Greentech Report* 2011 and *China Greentech Report 2012* have built upon the success of the first Report, while providing deeper insights into trends and opportunities in greentech markets. The Reports are the institutional point of view of CGTI, which is informed by 500+ decision-makers and influencers from 100+ organizations that make up the CGTI community. Without this community and the individuals that fuel it, CGTI would not hold the unique position as the most authoritative third-party neutral organization dedicated to accelerating China's green growth. Please see the Acknowledgements section of this Report where we offer our appreciation of contributing Partner companies, organizations and individuals.

The Report, distributed free online, gets further disseminated via CGTI Partner channels and can be purchased in printed form by individuals via the CGTI website. To date, the *China Greentech Report* has affected tens of thousands of people and, as a result, CGTI's Partner companies and organizations have become recognized for their leadership in accelerating China's greentech markets.

The *China Greentech Report 2012* has many uses—as context for corporate decision-making, as material for educating market participants, as a repository of market information, and as a basis for shaping policies. By reading this Report you are making the choice to join forces with the China greentech community, and to contribute to the acceleration of China's green growth. We hope that you find the Report valuable and invite you to continue the journey with CGTI by engaging in future discussions and activities. Visit www.china-greentech.com to learn more.

Elle Carberry (柯凯丽), Randall S. Hancock (汉瑞德) and Alan S. Beebe (毕艾伦)

***Managing Directors,***
***The China Greentech Initiative***
***May 2012***


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# EXECUTIVE SUMMARY

**The *China Greentech Report 2012* is the culmination of an open source, commercial collaboration of over 100 of the world's leading technology companies, entrepreneurs, investors, NGOs and policy advisors who participated in the China Greentech Initiative's 2011 Partner Program. These organizations commit their expertise, time and funding to address the many ongoing opportunities and challenges in China's complex, rapidly-changing greentech markets.**

This Report builds upon the 2009 and 2011 editions of the *China Greentech Report*. Since China Greentech Initiative (CGTI) launched the 2009 edition at the World Economic Forum in Dalian, China, the *China Greentech Report* has been established as the primer on China's greentech markets. This edition provides an updated view on those markets, focusing on the following themes:

- Macroeconomic challenges facing China's greentech markets in 2011 and 2012
- China's strengthened greentech policies
- Growing public engagement on environmental issues
- China's outbound investment trends
- Greentech market opportunities

Following these themes, the Report summarizes proprietary analysis provided to CGTI's Partner companies and organizations that participated in the 2011 Partner Program. This Report should be viewed as a complement to the 2009 and 2011 editions. Whereas the 2009 edition focused on defining the China greentech landscape and solutions, the 2011 and 2012 Reports provide deeper analysis on some of the most important greentech opportunities in China today.

### Defining China's Greentech Markets

**Greentech** refers to technologies, products and services that deliver benefits to users of equal or greater value than those of conventional alternatives, while limiting the impact on the natural environment as well as maximizing the efficient and sustainable use of energy, water and other resources. In this Report, the China Greentech Initiative focuses on six greentech sectors: Cleaner Conventional Energy, Renewable Energy, Electric Power Infrastructure, Green Building, Cleaner Transportation, and Clean Water.


*Source: CGTI analysis*

## China's Evolving Greentech Markets

**China has emerged as a global greentech leader within a period of just a few years, as predicted in the *China Greentech Report 2009*. In this year's Report, CGTI discusses how China is coping with broad economic challenges facing its greentech markets, even as policy and public awareness are driving greentech markets ever forward. In addition, the Report discusses China outbound investment trends and implications for policymakers and commercial players in foreign countries.**

- ### Economic Forces Challenged China's Greentech Sector in 2011

  **2011 was another year of growth and expansion for China's greentech markets, as the government continued to adopt and implement policies to meet urgent energy and environmental needs.** But as a result of external macro-economic factors, more observers began predicting an economic hard-landing in China. Though these fears have largely proved untrue, real worries remain about short- and long-term risks to economic growth, including many that affect the greentech sector. Slowing exports have particularly hurt manufacturers, such as wind and solar manufacturers. Tight monetary policy has hurt financing for renewable energy, cleaner conventional energy, rail, green buildings and overall greentech-related research and innovation. A gradual decline in investment and infrastructure spending growth has led to long-range concerns—likely misplaced—about investing in greentech. Demographic shifts are increasing labor costs across the greentech sector, which will lead to greater innovation and automation in renewable energy manufacturing and consolidation in other energy fields. A focus on state-led growth in the energy sector may reduce innovation and efficiency in greentech industries, especially those dominated by smaller private companies like solar or energy services. Overall, while the greentech sector faces macroeconomic challenges, China's overwhelming need for energy and environmental technology will continue to propel rapid growth in greentech markets.

- ### China's Strengthened Greentech Policies

  **China's ambitious energy and environmental policies will not only help overcome the challenging financing situation for infrastructure investment, but ensure China continues to lead the world in greentech.** Based on targets in the 12th Five-Year Plan, China's energy mix will slowly shift from coal to other fuels. In the *China*

**Policy measures will keep China at the forefront of energy and environmental business and investment for years to come.**

*Greentech Report 2011*, CGTI outlined the 12th Five-Year Plan's greentech-related areas in detail. In the months since the Plan's release, targets for solar and wind have been raised and funding improved. China has also lifted targets for energy efficiency and embarked on new policies in the area of energy taxes and carbon trading. In other areas, such as biofuels, nuclear and rail, progress has faced setbacks or been uneven. Yet taken together, China is accelerating its pursuit of clean energy and environmental protection, and policy measures now underway will keep the nation at the forefront of energy and environmental business and investment for years to come.

- ## Public Awareness of Urgent Environmental Problems Is Growing

  **One of the reasons China has moved so quickly on energy and environmental policy is that China's needs in both areas are urgent.** In energy, China must now import over half of its oil, and the country is overly reliant on coal, which produces high emissions of carbon and other air and water pollutants. On the environment, feeding China's enormous population requires improved water and soil quality, while guaranteeing the health and safety of the rapidly growing urban population requires new efforts to clean the air. Another major impetus for policy is public awareness. The past year has witnessed a number of major pollution incidents, and on micro-blogging sites the public is more engaged on environmental issues than ever.

- ## To Secure Its Energy Future, China Is Expanding Abroad

  **Given the scale and rapid growth of China's energy needs, China's leaders recognized early on that the stability, security and sustainability of energy supply would depend on active policies to support the domestic energy industry.** Now that China has achieved impressive results in geentech areas, such as renewable energy and high-speed rail, the government and companies are gradually expanding abroad to capitalize on the country's successes while continuing to secure resources and technologies. 2011 saw the continuation of an earlier trend where the energy sector dominated outbound investments, with companies going abroad for energy deals in the areas of oil and renewable energy. The deals in 2011 also highlighted a new push for investing in basic infrastructure, such as European water and power grid utilities, to achieve asset diversification and financial returns. As the developed world copes with economic challenges, China will continue to deploy its capital, labor and technology abroad, deepening international collaboration and cooperation while also occasionally capturing unflattering press attention.

# Cleaner Conventional Energy

**The size of conventional energy in China's energy mix, combined with a strong government commitment to cleaner and low-carbon practices, make conventional energy a top priority.**

Ambitious emission and energy intensity targets set by the central government will promote cleaner and more diversified energy production and use. On the energy production side, China's nuclear and gas sectors will experience strong growth while the government continues to restructure the coal mining industry, implementing efficiencies and cleaner processes. Stricter emission standards will affect coal plants, and the government will introduce carbon trading pilot programs. Gas power, especially distributed gas energy, should experience rapid growth with strong government policy support. China will also continue energy pricing reforms, especially for natural gas.

CGTI developed three in-depth Opportunity Assessments for the Cleaner Conventional Energy sector in 2011:

- ## Unconventional Gas

  **Unconventional gas could become a major contributor to China's energy mix, given the large potential supply and environmental benefits.** Although natural gas is an economically-viable and practical bridge to a low-carbon economy, China's domestic conventional gas production is stretched to the limit. Fortunately, China has vast undeveloped unconventional gas resources, primarily coal-bed methane (CBM) and shale gas. If the industry can overcome major pricing, regulatory, distribution and water challenges, China could increasingly rely on unconventional gas production to meet its booming domestic demand, likely leading to greater international cooperation in this area.

**China's vast undeveloped unconventional gas resources are primarily coal-bed methane (CBM) and shale gas.**

- ## Gas Power Generation

  **Natural gas is often referred to as a bridge fuel towards an economy fully powered by clean renewable energies. China is developing its gas power generation to meet environmental protection targets while growing its renewable energy sector. Unresolved challenges remain, such as supply shortages, insufficient infrastructure and unattractive gas price economics.** China is working to develop the country's natural gas sector to achieve pressing goals, including carbon intensity targets, reductions in other air pollutants, and improved energy security through a more diverse fuel mix. Despite large investments in the sector, China's domestic gas production has not kept up with consumption, increasing reliance on imports. Distribution infrastructure, on the other hand, is still underdeveloped even with large investments in this area. China has prioritized residential consumption for cooking and heating over gas power generation, inhibiting its growth. Government targets for the next five years call for only a 6 GW increase in utility-scale gas power capacity (representing an annual growth rate of 2.9%), and smaller-scale distributed gas power could rapidly expand if challenges can be resolved.

- ## Coal Conversion

  **The government's promotion of coal conversion means opportunity for coal producers and equipment suppliers, especially for coal-to-chemicals and water treatment technologies.** For years China's central government has promoted coal conversion technologies for energy security given the country's abundance of coal resources. Yet given concerns about water use, carbon emissions, and the economic attractiveness of certain coal conversion technologies, a disconnect has emerged between central government caution on coal conversion versus local government efforts to promote the technology to expand jobs and tax revenues. Because water represents the major impediment to coal conversion, CGTI's research suggests that water efficiency, wastewater treatment and water recycling technologies would represent a major market if government enforcement improves and issues related to intellectual property (IP) are resolved.

# Renewable Energy

**2011 was a year of dramatic change for renewable energy, as China prepares for a period of more sustainable and diverse growth, especially for solar and wind.**

In 2011, the central government set out ambitious plans for renewable energy by setting 2015 installation targets, doubling the renewable energy surcharge rate, issuing standards to mitigate grid connection problems and introducing specific carbon reduction policies. In the solar sector, the European and U.S. markets for Chinese module sales slowed, causing severe overcapacity problems and squeezing profits for Chinese module makers—which will likely lead to industry consolidation. To help absorb excess solar production, Chinese government stimulated its domestic market by setting higher 12th Five-Year Plan targets and raising the feed-in tariff (FiT) for solar power.[1] In the wind sector, about 18 GW of capacity was installed in 2011, and wind power manufacturers looked to expand globally.[2] Biomass power generation also experienced rapid growth due to favorable policies.

CGTI developed three in-depth Opportunity Assessments for the Renewable Energy sector in 2011:

- **China's Solar Photovoltaic (PV) Value Chain**
  **Given current challenges in world solar markets, China's solar PV producers seek opportunities to reduce costs and preserve gross margins through vertical integration and industry consolidation.** Solar producers face uncertain times: while global solar PV markets may continue to grow, rapidly falling prices, unstable subsidy schemes and module oversupply have resulted in falling margins across the value chain. Low-cost Chinese producers are raising production capacity to new records, in turn driving down prices and margins. At the same time, as domestic competition increases, the pressure on profits and market share has intensified. While the number of manufacturers in China may not decline in the short-term, stakeholders should expect top players with strong cost advantages to continue to grow in size and market share.

- **Waste-to-Energy (WtE)**
  **As China's waste volumes continue to rise, WtE technologies can improve waste processing capabilities and diversify China's energy sources.** The three WtE segments—municipal, agricultural and industrial—are at different stages of development. While China recognizes that using waste resources for energy generation can mitigate growing air and water pollution, major challenges remain including rising land prices, volatile landfill tipping fees and energy prices, intellectual property (IP) issues, financing limitations, waste collection constraints and local pollution concerns. However, with additional policy support and financial incentives, these issues could be addressed.

- **Financing Utility-Scale Wind and Solar Power Projects in China**
  **China's rapidly growing utility-scale wind and solar capacity will require trillions of RMB in funding from 2012 to 2020. To fund the country's ambitious renewable installation targets, China will need a variety of financing models.** Given the high cost of renewable energy projects, limited funding sources have become a bottleneck for project development. Debt, such as bank loans and bonds, is currently the main source for wind and solar financing, but good terms are only available to the largest enterprises or state-owned enterprises (SOEs). Direct government support for wind and solar includes tax credits, FiTs, preferential land-use policies and low-interest loans. However, the renewable energy surcharge is currently insufficient to make renewable energy projects financially viable.[3]

**Limited funding sources have become a bottleneck for development of utility-scale wind and solar projects in China.**

*1. Osborne, Mark, "NPD Solarbuzz: China leads solar PV demand in Asia Pacific region with 2.9GW installed in 2011," PV-Tech, January 26, 2012, www.pv-tech.cn*
*2. "Release of global wind statistics: Wind Energy Powers Ahead Despite Economic Turmoil," Global Wind Energy Council, February 7, 2012, www.gwec.net*
*3. China Greentech Initiative (CGTI) analysis and Partner interviews*

# Electric Power Infrastructure

**China began the Construction Phase of its 2009-2020 Strong and Smart Grid Plan in 2011, initiating the world's largest effort to build a reliable, efficient and smart grid.**

Energy efficiency targets, the rising share of renewable energy in the country's power mix, transmission of power between distant supply and demand sources, and expansion of electric vehicle (EV) charging infrastructure all represent tremendous challenges to the grid as it is currently designed and operated. In response, central authorities adopted in 2009 a Strong and Smart Grid Plan to establish by 2020 a complete, reliable, efficient and smart power grid. The plan relies on a range of traditional and smart grid technologies, and includes adoption of world-leading technical standards. The country's domestic industry is set to benefit most from this ambitious program, and private players may have most access to the transmission and distribution segments.

**Central authorities adopted a Strong and Smart Grid Plan to establish by 2020 a complete, reliable, efficient and smart power grid.**

CGTI developed two in-depth Opportunity Assessments for the Electric Power Infrastructure sector in 2011:

- ## China's Strong and Smart Grid Investment Plan

  **In 2011, China entered the Construction Phase of its 2009-2020 Strong and Smart Grid Plan, the world's largest attempt to build a reliable, efficient and smart grid.** Beginning in 2009, China embarked in the world's largest electric power infrastructure build-up. This Strong and Smart Grid Plan aims to build a more efficient and reliable power transmission and distribution network, as well as resolve current power transmission and distribution challenges. The Pilot Phase (2009-2010) met objectives to establish standards and launch demonstration projects across 21 solution areas and 26 provinces. In 2011, State Grid started the Construction Phase (2011-2015), including ultra-high voltage (UHV) lines and distribution networks in urban and rural areas, remote monitoring, two-way communications, and EV charging infrastructure.

- ## Energy Storage Solutions for Intermittent Power

  **Though China's energy storage market continues to grow, the largest market—utility-scale energy storage—remains in its infancy.** The energy storage market in China could reach RMB 72 billion by 2015, and is likely to continue to grow.[4] However, despite the potential for energy storage to improve the connectivity of intermittent renewables, such as wind and solar, few commercial opportunities exist for utility-scale adoption. Energy storage offers a spectrum of applications to reduce intermittent power's disturbance to the grid system. Yet high costs, unproven technology and lack of policy direction make storage a tough sell over the next few years. Wind and solar farm developers are unlikely to install energy storage infrastructure unless it offers clear financial and operational benefits. Grid companies are also reluctant to pursue storage for three reasons: storage requires installation of expensive secondary equipment; conventional power sources, such as coal, are much cheaper and easier to dispatch; and UHV construction is currently the priority for grid infrastructure spending. Without a solid customer base or income stream, technology providers are struggling to improve technologies and reduce costs.

*4. CGTI analysis; average cost calculation based on storage capacity reaching 15% of wind and solar capacity installations by 2015 (120 GW * 15% * RMB 4,000/kW = RMB 72 billion).*

# Green Building

**Though China's green building market is small, building energy efficiency policies will likely lead to rapid industry expansion over the next five years.**

Green building certifications are rapidly increasing throughout mainland China, but have fulfilled only a fraction of their potential. Government sees energy service companies (ESCOs) as a main driver of building energy efficiency, since ESCOs can bridge the disconnect between stakeholder incentives. Despite this support, ESCOs often suffer from quality and financing issues. Building energy efficiency solutions often have suboptimal economics for developers, but the relatively new concept to China of integrated design can have a significant impact on their cost effectiveness. The overall market is gaining momentum by new financing sources which are emerging to improve project economics, though the path for accessing subsidies remains difficult due to lack of clear valuation methods and weak government monitoring and enforcement capabilities.

CGTI developed three in-depth Opportunity Assessments for the Green Building sector in 2011:

- **Optimal Green Building Design**

  **China's tremendous conventional and green building growth, mounting environmental strains and strong regulatory support imply high market potential for green building design, but stakeholders must first embrace integrated design principles and overcome widespread flaws in current design practices.** To achieve energy efficiency goals, China's government is extending favorable policies for green buildings in the 12th Five-Year Plan. The mandates and incentives issued by the government have been indispensible drivers of green building design in China. Challenges to green building design include data gaps in energy simulation models, issues with local design institutes, insufficient industry expertise, inadequate post-construction monitoring, and difficulty in sourcing green building materials. Green building design techniques can integrate green building technologies to achieve environmentally and commercially sustainable objectives.

- **Building Energy Efficiency for New Construction**

  **Policies are creating an opportunity for building energy efficiency, though many technologies remain cost prohibitive.** The fundamental driver for building energy efficiency are the targets in the 12th Five-Year Plan which emphasizes five aspects: shading, heating, ventilation and air conditioning (HVAC), building envelope, integrated renewable energy, and lighting. Foreign and domestic examples show energy efficiency is viable in new construction, yet China's developers find the economics unappealing due to high upfront costs and payback periods greater than 10 years. Efficient lighting stands out as the most economically viable solution, and the market may reach RMB 80 billion by 2015. Other energy efficient technologies will rely on policy support to reach commercial scale. However current financial incentives are insufficient due to high up-front costs, low electricity prices, and misalignment of stakeholder incentives.

**Government sees ESCOs as a main driver of building energy efficiency, since ESCOs can bridge the disconnect between stakeholder incentives.**

- **Green Building Financing**

  **Building energy efficiency improvements are an economical way to meet China's energy and emissions policy goals, but present green building financing channels are insufficient to strongly encourage green buildings and energy efficiency retrofits.** China's green building market has expanded rapidly in recent years, but given tightening financing conditions for the real estate market, developers need to diversify funding sources for green buildings and retrofit projects. Government subsidies for green buildings and energy efficiency projects are the most important measures for promoting these projects. Overall, China has fewer financing channels for such projects than other countries, and introducing financing methods used outside of China—such as the platform of investment and financing companies (PIFCs), sustainable energy utilities, and utility on-bill financing—will require further financial market reform and other policies.

# Cleaner Transportation

**Cleaner Transportation is an important element of China's plan to reduce carbon emissions and fossil-fuel use.**

To reduce dependence on oil imports and cut emissions, the Chinese government is pursuing a range of transportation policies including development and adoption of new energy vehicles (NEVs), improved fuel-efficiency, high-speed rail and biofuels. NEVs were named as one of the seven strategic emerging industries (SEIs) under the 12th Five-Year Plan, translating into government financial and regulatory support.[5] China continues to raise conventional vehicle emission and fuel economy standards, and despite a major rail accident in Zhejiang the nation continues to complete new high-speed rail lines. In contrast, there have been few developments in the past year on biofuels.

CGTI developed three in-depth Opportunity Assessments for the Cleaner Transportation sector in 2011:

- **Clean Internal Combustion Engine (ICE) Vehicles**
  **The government's emissions policies are pushing the ICE vehicle market to adopt cleaner technologies, creating opportunities in China's booming automotive market.** China's automotive market is the world's largest and is growing rapidly, but despite high expectations for the growth of electric vehicles (EVs), conventional ICE vehicles will continue to dominate for the next decade. There are many mature and cost-effective technologies to make China's ICE vehicles cleaner, including alternative fuels, advanced engines and transmissions, hybrid drivetrains, exhaust after-treatment devices, and other general vehicle improvements. However, China focuses most policy support on electric vehicles, relying on increasingly stringent fuel economy and emission standards to promote cleaner ICE technologies. Regulatory challenges and a highly cost-sensitive market are the main obstacles for many advanced ICE technologies.

- **Fleet Vehicle Electrification**
  **Compared with the private consumer market, fleets have advantages for electric vehicles, but China's fleet markets are too small and fragmented to meet 2020 EV policy targets.** China's electric vehicle policy has centered on fleets from the beginning, and nearly all electric vehicles currently deployed in China can be found in public sector fleets, such as buses and taxis. There are nearly 7 million fleet vehicles in China today, but fleet segments are fragmented and some lack characteristics that would make them likely to go electric. To achieve targets of 5 million NEVs on the road by 2020, China will likely have to expand its efforts into the private consumer market and overcome obstacles including high cost, unreliable battery technology, unclear business models for charging infrastructure, and protective subsidies.

- **Electric Vehicles and Charging Infrastructure**
  **Many companies are poised to enter the charging market pending clarification of government vehicle and charging policies.** In April 2011, the long-awaited Energy Saving and New Energy Vehicle Development Plan (2011-2020), which envisions 5 million NEVs by 2020 and RMB 100 billion in investment, was submitted to the State Council for final approval. The government has pushed electrification of public vehicles, particularly transit buses, through its Tens of Cities, Thousands of Vehicles program, but the its impact is minor so far. State Grid and Southern Grid have taken the lead in the development of the battery charging segment by building infrastructure across the country. Oil companies, original equipment manufacturers (OEMs), professional services companies and even real estate developers are interested in the charging market, but are cautiously awaiting the government's ruling regarding charging infrastructure.

**The Energy Saving and New Energy Vehicle Development Plan envisions 5 million NEVs by 2020 and RMB 100 billion in investment.**

*5. "China Encourages Private Enterprises to Invest in Strategic Emerging Industries," China Briefing, August 18, 2011, www.china-briefing.com*

## Clean Water

**To address its dire water situation, including low resources per capita, severe pollution and uneven distribution, China has set water protection as a priority over the next decade.**

China's water resources are scarce, poorly distributed and heavily polluted. In January 2011, the State Council announced a RMB 4 trillion water investment plan for the next decade, and the government's 12th Five-Year Plan introduced ambitious national targets on water efficiency and pollution control. Given government support, private equity and venture capital funds invested eight times more capital in China's water sector in the first four months of 2011 than the whole of 2010.[6] State-owned enterprises (SOEs) and domestic companies raised capital and pursued acquisitions. Foreign firms faced mixed success locally. Policy trends and needs are creating market opportunities for the private sector across the water value chain.

**Private equity and venture capital funds invested eight times more capital in China's water sector in the first four months of 2011 than the whole of 2010.**

CGTI developed three in-depth Opportunity Assessments for the Clean Water sector in 2011:

- **Sludge Treatment and Disposal Markets in China**
  **Sludge treatment and disposal should represent a huge market opportunity, but the lack of a comprehensive policy framework holds back the market.** China's growing municipal wastewater treatment network has led to a rapid expansion of residual sludge. Sludge discharge has grown 5% annually over the past five years and is now estimated to reach 22 to 30 million tons annually. Microorganisms and pathogens, unpleasant odors, emission of methane ($CH_4$) gases, heavy metal content and other issues make sludge a harmful by-product of wastewater treatment that requires proper treatment and disposal. Due to inadequate incentives, the industry has continued with low-cost, potentially unsafe disposal in landfills despite the existence of technologies to convert sludge into a valuable resource.

- **Industrial Wastewater Treatment Opportunities in China**
  **The government has made industrial wastewater treatment a major priority in the 12th Five-Year Plan, but investment opportunities vary considerably by industry and region.** The 12th Five-Year Plan calls for large reductions in chemical oxygen demand (COD), ammonia nitrogen, heavy metals and water consumption per unit of GDP. Meeting targets will create opportunities for industrial wastewater treatment and reuse technologies. Many industry markets appear attractive, including pharmaceuticals, beverages, paper and pulp, raw chemicals, textiles, food processing, and ore mining, mainly in industrialized coastal provinces. Centralized treatment plants in industrial parks offer attractive prospects under strong government support.

- **Greywater System Adoption in China**
  **China has started to promote greywater recycling, but the market is still in its early stages. Major challenges remain, including lack of infrastructure, misalignment of incentives, lagging policies and low water prices.** Over half of all building wastewater could be classified as greywater—slightly polluted wastewater from sources including laundry, showers and hand-basins. While treating grey and blackwater (wastewater from toilet flushing) separately has been shown to be more efficient due to greywater's low treatment requirements, dual plumbing system is required, which has thus far inhibited wide-spread adoption.[7] Regulators are focused on building large-scale centralized wastewater treatment and reclamation plants rather than decentralized greywater systems. Low water prices are also an issue. Due to these challenges, the market remains at an early stage, despite the potential of greywater systems to help achieve China's water policy goals while offering attractive economic returns.

*6. "清洁技术投资事件数据库" [Clean Technology Deals Database], PEdaily, zdb.pedaily.cn*
*7. Allen, Lucy, et al., "Overview of Greywater Reuse: The Potential of Greywater Systems to Aid Sustainable Water Management," Pacific Institute, November 2010, www.pacinst.org*

# INTRODUCTION

Jim Gourley

Jim Gourley

# Economic Forces Challenged China's Greentech Sector in 2011

2011 was another year of growth and expansion for China's greentech sector, as the government continued to adopt and implement policies to meet urgent energy and environmental needs. But as a result of external macro-economic factors, plus the government's effort to slow price inflation, control real estate speculation, and temporarily reduce spending on high-profile energy-related projects like high-speed rail, more observers began predicting an economic hard-landing in China. Though these fears have largely proved untrue, real worries remain about short- and long-term risks to economic growth, including many that affect the greentech sector.

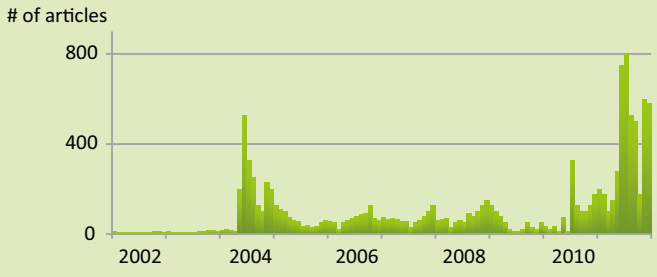
- **Slowing exports** have particularly affected manufacturers, such as wind and solar equipment-makers.
- **Tight monetary policy** has hurt financing for renewable energy, cleaner conventional energy, rail, green buildings and overall greentech research and innovation.
- **A gradual decline in investment and infrastructure spending growth** has led to long-range concerns—likely misplaced—about investing in greentech.
- **Demographic shifts** are increasing labor costs across the greentech sector, which will lead to greater automation in renewable energy manufacturing and consolidation in other energy fields.
- **A focus on state-led growth** in the energy sector may reduce innovation and efficiency in multiple greentech fields, especially those dominated by smaller private companies like solar research or energy service companies.

Overall, while the greentech sector faces macroeconomic challenges, China's overwhelming need for energy and environmental technology should continue to propel rapid growth in greentech markets.

## 2011 brought new fears of an economic hard-landing

For years a vocal group of foreign analysts has predicted an economic crash in China, but 2011 was the year when such fears really took hold in the global media.[1]

**Articles Discussing the Potential of China's "Hard Landing," number of articles, 2002-2011**




*Sources: Factiva all newspapers; BCA Research 2012*

*Director of Research Analytics Anders Hove* (侯安德) *led the writing of this chapter.*

*1. Holmes, Frank, "Investors: What The Next Decade Holds For Commodities," ETF Daily News, January 20, 2012, www.etfdailynews.com, citing data from BCA Research 2012*

On his February 2012 visit to the U.S., Vice President Xi Jinping specifically responded to these fears by saying China would not experience an economic hard-landing.[2]

Given the rise in Chinese urban real estate prices, combined with fiscal crisis in the developed world economies, global economic concerns appeared well-founded. Yet China weathered 2011 with only a minor decline in growth rates. In 2012 and 2013, short- and long-term macroeconomic issues will likely remain a central element of evaluating infrastructure investment prospects in China, including greentech investments.

## International economic uncertainty has challenged China's greentech markets

In late 2011, the International Monetary Fund (IMF) reduced its 2012 growth rate forecast for developing Asia from 8% to 7.3%, citing weaker export growth, especially to Europe. For China, the IMF's growth forecast fell from 9% to 8.2%.[3] China's industrial growth has slowed in recent months, though production is still expanding slightly according to recent industrial data.[4] China's export growth also slumped in 2011, due in part to weaker demand in Europe and, to a lesser extent, Chinese currency appreciation.[5] Weakness in developed world economies may continue for years due to debt-related fiscal austerity programs, demographics, regulatory challenges, and economic policy uncertainty. One thing is clear: continued economic turmoil in the developed world can have a major impact on China's greentech industry.

In the near-term, the most obvious area of concern is China's export of renewable energy manufactured goods, such as wind and solar equipment. Renewable energy demand depends on policies and subsidies, such as feed-in tariffs, and these face budget threats. Debt-strapped Southern European nations Spain, Portugal, Italy and Greece are the sunniest European countries—Italy is the second largest solar market after Germany.[6] In the U.S., budget deficits at the state and national level leave little room for extension of tax breaks that have encouraged wind and solar over the past three years. In addition, the collapse of U.S.-based Solyndra, a solar firm that had received large loan guarantees from the U.S. government, provoked public controversy over subsidies for renewable technology.

A push toward protectionist anti-dumping measures—seemingly an inevitable outgrowth of economic hard times—could hamper international cooperation and trade in energy technology.[7] In the wake of several solar bankruptcies, SolarWorld and several U.S. based companies submitted an anti-dumping petition to the U.S. International Trade Commission. U.S. wind-tower manufacturers also submitted a petition in 2011, and a solar anti-dumping case is underway in the European Union.[8] It is notable that the recent U.S. bankruptcies took place at firms with distinct competitive and technological disadvantages: Energy Conversion Devices and Evergreen Solar had struggled for years with low margins and poor sales volumes even as their more efficient U.S.-based competitors like FirstSolar thrived.[9] Furthermore, several Chinese-based solar firms have experienced positive gross margins even during the recent period of solar oversupply, suggesting that a demand weakness was driving the weakest players under—whether Chinese, European or American.[10] A fall 2011 analysis by the U.S. National Renewable Energy Laboratory showed that though Chinese solar

**Economic turmoil in the developed world can have a major impact on China's greentech industry.**

*2. Buckley, Chris and Edwin Chan, "Xi waves off China economy fears, triggers deals," Reuters, February 17, 2012, www.reuters.com*

*3. Rastello, Sandrine, "IMF Cuts Global Growth Forecast; Sees Recession," Bloomberg, January 24, 2012, www.bloomberg.com*

*4. Wang, Aileen, and Kevin Yao, "China PMI tops forecast, hard landing fears ease," Reuters, February 1, 2012, www.reuters.com*

*5. Panckhurst, Paul, "China Export Growth Dwindles to Slowest Pace in Seven Months as Yuan Gains," Bloomberg, October 13, 2011, www.bloomberg.com*

*6. Loo, Felicia, "Asia polysilicon makers face tough times in Q4 on oversupply," ICIS, September 23, 2011, www.icis.com*

*7. Franzen, Carl, "Solyndra Bankruptcy Wasn't China's Fault, Rival Solar CEO Says," Talking Points Memo, September 1, 2011, www.talkingpointsmemo.com*

*8. "Germany Seeking to File Anti-dumping And Anti-subsidy Charges Against Chinese PV Producers," E-to-China, February 23, 2012, www.e-to-china.com*

*9. Goossens, Ehren and Andrew Herndon, "Solar Purge Drives Weakest into Buyouts, to Spur More Deals," Bloomberg, August 31, 2011, www.bloomberg.com; "Energy Conversion files for bankruptcy protection," Bloomberg, February 14, 2012, www.bloomberg.com*

*10. Cheyney, Tom, "Inauspicious color: Top Chinese solar companies wade through red ink in latest quarterly results," PV-Tech, November 28, 2011, www.pv-tech.org; Martin, Christopher and Zachary Tracer, "China Solar Makers Face 'Suicidal' Prices on Excess Output," Bloomberg Businessweek, November 25, 2011, www.businessweek.com*

**The U.S. has run a solar trade surplus with China even as China dominated world solar markets, belying simplistic notions of zero-sum competition between the two.**

module firms in 2011 still enjoyed a small manufacturing cost advantage, and "Chinese [government] incentives dwarf U.S. efforts," shipping costs to the U.S. negated these advantages.[11] Finally, even as the anti-dumping petition proceeds, the U.S. has run a solar trade surplus with China even as China dominated world solar markets, belying simplistic notions of zero-sum competition between the two.[12]

Carbon credits are another area of concern. As the European economy has weakened, the demand for emissions credits has also eased, meaning less support for projects across the developing world. As the largest supplier of certified emission reduction (CER) credits, China has seen a major impact, particularly hurting prospects for coal-mine methane and cleaner coal projects. Given Europe's fiscal problems, European governments will likely have fewer funds available for pilot projects in China to demonstrate clean energy technologies, such as past green building projects funded by the German and French governments.

### Tightening monetary policy has hurt a variety of greentech projects

China's measures to control inflation have reduced financing to small enterprises and have posed a threat to large public infrastructure projects. To address price inflation, real affordability concerns and potential asset bubbles—housing prices tripled from 2005 to 2009—the central government has tightened monetary policy since 2010.[13] This has meant several increases in the required reserve ratio banks must hold, along with three increases in interest rates, with the last increase in July 2011 taking interest rates to 6.6%.[14] Inflation has since fallen and property prices have eased, giving rise to fears late in 2011 that China's economy could suffer a hard-landing if credit disappeared and local government financing collapsed. As a result, the central bank in December reduced bank required reserve ratios, though stating its tight monetary policy and real estate regulations would continue.[15]

China's banking sector has squeezed lending to the private sector, especially small and medium enterprises. China's state-owned banks cannot set separate interest rates for customers with higher risk, and are encouraged by the central government to continue supporting policy goals through lending to state-owned enterprises (SOEs).[16] In a recent survey of small and medium enterprises, 43% reported financing was their most pressing difficulty.[17] The lack of credit has also led to a rise in non-bank lending, sometimes through private wealth management funds and sometimes through high-interest loans. The city of Wenzhou, which was synonymous with private sector development over the past decade, has become notorious for its over-extended shadow banking loans.[18] Small and medium enterprises account for a large share of Chinese employment, and have been leaders in innovation,[19] yet state-owned banks and SOEs with access to low-interest bank financing dominate the energy sector. In the long run, this dichotomy could challenge China's ability to compete and innovate in the energy technology field. Small and medium enterprises are most active in green buildings, innovative new solar technologies, such as thin-film photovoltaic solar panels, and clean water. As funding for projects shifts back toward the state-led sector during monetary tightening, smaller private greentech firms and the innovations they support, will suffer.

*11. Goodrich, Alan, et al., "Solar PV Manufacturing Cost Analysis: U.S. Competitiveness in a Global Industry," National Renewable Energy Laboratory presentation, October 11, 2011*
*12. Ibid.*
*13. Moody, Andrew, "Dragon Dance," China Daily, January 20, 2012, usachinadaily.com.cn*
*14. Moody, Andrew, "Economy needs slack monetary policy," China Daily, January 20, 2012, usachinadaily.com.cn; "China Interest Rate," Trading Economics, July 6, 2011, tradingeconomics.com; prior to the series of rate increases, China's interest rate was below 5.5%.*
*15. Scheurer, Stefan, "China–Hard Landing?" Allianz Global Investors, November 2011, www.allianzglobalinvestors.de; Shidong, Zhang, "China's Stocks Advance, Capping Longest Stretch of Weekly Gains Since July," Bloomberg, February 3, 2012, www.bloomberg.com*
*16. Liu, Shengjun, "Private lending surge casts light on banking problems," Global Times, October 10, 2011, www.globaltimes.cn*
*17. Wang, Jing and Qu Yunxu, "Dire Straits in the Pearl River Delta," Caixin Online, January 12, 2012, caixin.com*
*18. Wenxin, Fan and Shai Oster, "China Credit Squeeze Prompts Suicides Amid Offer to Sever Finger," Bloomberg, November 15, 2011, www.bloomberg.com*
*19. "Why China's Credit Squeeze Is Big Business ... for Loan Sharks," Knowledge@Wharton, November 22, 2011, knowledge.wharton.upenn.edu*

Local government debt has been another problem facing infrastructure spending. Local governments had amassed an estimated RMB 10.7 trillion in debt, largely for infrastructure investment projects to help local growth. An estimated RMB 2.5 to 3 trillion will not be repaid, according to the central government, and the actual amount could be far higher.[20] Many banks have stopped lending to local governments and the central government has granted only limited permission for local bond issuance. Some hard-pressed local governments are turning to interesting remedies to fund infrastructure projects: the city of Wuhan not only raised tolls on three newly-built bridges, but required all car-owners to cross the bridges at least 18 times per month.[21]

Few sectors illustrate the slow-down in infrastructure spending better than high-speed rail. In the case of rail, the slow-down has also been literal: the government ordered speeds to be reduced across the system after a high-speed train collision in summer 2011. The speed reduction also helped address problems with profitability and line maintenance.[22] Since then, however, financing high-speed rail projects has become more difficult. In late 2011, regional governments were having trouble finding funds to support high-speed rail corridors and, in some cases, contractors building the projects were unable to pay worker salaries for already-completed sections.[23] Also, the lack of profits on many existing lines has led to difficulties financing newer lines—for example, though the Guangzhou-Wuhan line has carried over 150,000 passengers since opening in 2009, it has operated at a cumulative loss of RMB 3 billion since opening.[24]

The electric power sector and renewable energy industries have also faced difficult financing situations—in both cases as a result of tight monetary policy combined with challenging sales price trends. In the case of solar energy, lower European demand and an oversupply of panels hurt pricing just at the time when the monetary tightening began. According to reports, the 13 largest Chinese solar companies have loans from state banks totaling over RMB 13 billion, most of which take the form of one-year loans that will be difficult to refinance.[25] Credit tightening has also hit conventional power producers when they are about to face more stringent emission regulations. Yet profits have suffered due to coal shortages and regulated power prices, in some cases leading to large economic losses. Given that the Big Five power producers now have debt-to-equity ratios over 80%, and the power industry as a whole has a debt-to-equity ratio of 76%, interest rates charged on loans have started to float upwards and financing is more difficult to secure.[26]

**The 13 largest Chinese solar companies have loans from state banks totaling over RMB 13 billion, most of which are one-year loans that will be difficult to refinance.**

Renewable energy projects also face new obstacles as a result of the tightened funding environment. Smaller wind and solar developers have difficulties obtaining financing on terms comparable with SOEs. Recently, some incentives offered by the central government have begun to work against renewable energy developers: the government has exempted renewable energy developers from some value-added taxes, which mainly feed into regional government accounts, making them reluctant to approve projects.

Given that policy has focused on real estate, the green building market has also seen a sharp reduction in funding available for efficiency projects. China's largest banks have shrunk their real estate loan portfolios as a proportion of total loans—real estate developers face a funding gap of over RMB 1 trillion for completing existing projects in

*20. Soh, Kevin and Aileen Wang, "Special report: China's debt pileup raises risk of hard landing," Reuters, October 10, 2011, www.reuters.com*

*21. Ibid.*

*22. Liu, Yan, "高铁产业链面临重建 融资陷入困境配套商将被洗牌" [High-speed rail industry chain is facing reconstruction funding into the plight supporting providers will be shuffling], HLJNEWS, August 12, 2011, www.hljnews.cn*

*23. Zhang, Ao, "铁路数千亿融资难解近渴高铁建设将进入缓慢期" [Hundreds of billions of railway financing intractable thirst high-speed rail construction will enter a slow period], Sohu, November 20, 2011, news.sohu.com*

*24. Chung, Jenny, "在建高铁需千亿元事故或使融资打折扣" [To build high-speed rail need hundreds of billions of dollars of accident or discounted financing], HC360, July 27, 2011, info.wujin.hc360.com*

*25. "银行收紧信贷中国光伏企业面临融资困境" [Banks Tightening Credit, Chinese PV companies facing financial difficulties], New Energy, November 22, 2011, www.newnergy.org.cn*

*26. "火电光伏风电：能源企业融资难题调查" [Thermal power photovoltaic-wind power: energy corporate finance problems survey], New Energy, July 14, 2011, www.newnergy.org.cn; "2011年1-6月份电力行业、1-7月份电力企业经济效益情况简要分析" [Brief Analysis on Power Industry (January-June 2001) and Power Company (January-July 2001)], China Electricity Council (CEC), August 18, 2011, www.cec.org.cn*

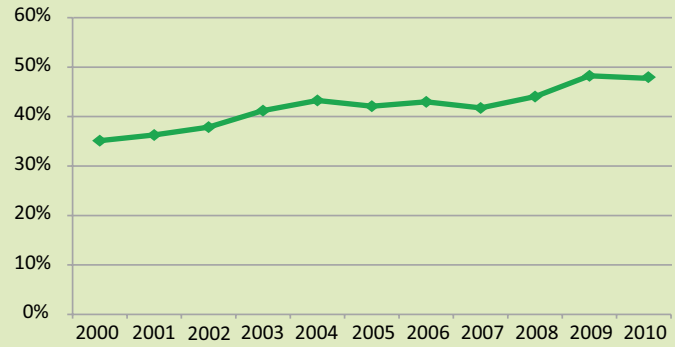
2012.[27] China's building loan market is also heavily reliant on short-term loans and lacks financing methods available elsewhere for energy efficiency projects. For example, most energy service companies (ESCOs) in China lack operational track records and are too small to obtain financing from banks, and there are few methods to translate government subsidies for energy efficiency projects into loans or project debt.

### China's long-term infrastructure spending growth will gradually slow

Market players are concerned that China's infrastructure boom may begin to slow—though the impact on greentech spending may be exaggerated. For the past two decades, China has pursued a strategy of rapidly building out its infrastructure, particularly energy and transportation infrastructure, to raise productivity and grow exports. After the 2009 financial crisis, China dedicated almost its entire economic stimulus package to investments, in contrast to the developed world.[28] And this trend in investment growth continues: China invested RMB 30 trillion in 2011, up from RMB 28 trillion in 2010, according to the National Bureau of Statistics. Urban fixed-asset investment rose 25% from a year earlier.[29]

As the Chinese government recognizes, this growth strategy has limits. Investment accounted for over 40% of China's GDP from 2004 to 2008, far higher than any other country, according to an IMF study that concluded that "experiences from Asian economies that had similar export-oriented growth suggest there are limits" to such growth models.[30] The government has started to plan for a more consumer-oriented economy.[31]

**China's Ratio of Gross Domestic Investment to GDP, percentage of GDP, 2000-2010**




*Note: 2011 ratio estimated from full year using data through November.*
*Source: World Bank, www.worldbank.org, accessed January 30, 2012*

Will the inevitable decline in investment as a share of GDP hit the energy and environmental sector? The answer is debatable for several reasons. First, although China's government and private debts are higher now versus 2009, China still has room for pro-growth stimulus, according to the IMF.[32] Second, China will need vast new energy infrastructure to meet its needs—and if current policy commitments are kept, a large amount of spending on cleaner energy and energy efficiency projects is inevitable.

*27. "明年开发商资金缺口过万亿上市房企或面临债务危机" [Developer's financing gap may be over 1 trillion, listed real estate company may face debt crisis], Guangzhou Daily, November 25, 2011, fdc.soufun.com*
*28. Wang, Xiuqiong, "After massive stimulus, a long way to go for China," Xinhua, March 12, 2009, news.xinhuanet.com*
*29. Moody, Andrew, "Dragon Dance," China Daily, January 20, 2012, usachinadaily.com.cn*
*30. Guo, Kai and Papa N'Diaye, "Is China's Export-Oriented Growth Sustainable?" International Monetary Fund (IMF), Washington, DC: August 2009*
*31. Roach, Stephen S., "China's Turning Point," Project Syndicate, January 24, 2011, www.project-syndicate.org*
*32. Rastello, Sandrine and Michael Heath, "Policy Scope Shields Asia From Global Risk: IMF," Bloomberg, January 31, 2012, www.bloomberg.com*

## Long-term macroeconomic challenges also loom

Three long-term macroeconomic forces will challenge China's growth: the aging of society, limits to labor force growth, and the efficiency of China's state-led economy. These forces are rapidly changing China's greentech industry as greentech-oriented manufacturing firms, such as solar companies, can no longer rely solely on low-cost labor to provide an advantage.

China's aging society has already begun to transform the country's economy. 178 million Chinese were over 60 in 2009, and the United Nations (U.N.) forecasts the figure will reach 437 million by 2050, when it would represent almost a third of the population.[33] After a 2.5% annual expansion since 1980, China's working-age population has reached a turning point. Whereas the working-age population grew by roughly 92 million in the last two decades, in the current decade it will grow by just one million.[34] Starting in 2013, the workforce will begin to contract rather than expand.[35]

Due in part to this demographic trend, rising labor costs are starting to end China's term as the low-cost manufacturing center of the world.[36] China now has the highest labor cost in emerging Asia when including benefits, according to one study.[37] Labor cost is now 25% of production cost in China,[38] and the majority of manufacturers in China report offering better amenities to retain skilled workers.[39] Some manufacturers have tried relocating to lower-cost regions of the interior, but studies suggest the cost advantage of these regions will disappear within three years.[40] Although manufacturing wages are still low compared to those of industrial countries, with minimum wages rising by 22% on average in China last year, more companies are looking for strategies to improve productivity and competitiveness, whether through automation or moving production elsewhere.[41]

The government has promoted rising wages for workers, despite high inflation, as a way to address income inequality while also nudging the economy away from low-end assembly toward higher-end manufacturing and technology. China currently ranks low in terms of automation.[42] For example, a typical 500 MW solar manufacturing plant employs 2,000 direct laborers, compared to 400 at a similar plant in the U.S.[43] Over 42% of manufacturers surveyed in 2011 by Caixin, a Beijing-based financial newspaper, are addressing rising labor costs by increasing investment in technology and machinery to reduce labor inputs.[44] The International Federation of Robotics forecasts that by 2014 China will be the largest purchaser of industrial robots.[45] These trends will have a major impact on clean energy manufacturing worldwide, such as in solar and wind.

**A typical 500 MW solar manufacturing plant employs 2,000 direct laborers, compared to 400 at a similar plant in the U.S.**

Mergers are another way to improve productivity. Surveys found that the energy sector was particularly likely to pursue efficiencies of scale through mergers and acquisitions, with 57% of companies in the field anticipating using mergers and acquisitions to address efficiency issues.[46] The government is keen to continue this trend, especially in the energy field. Consolidation can help integrate supply chains, drive out less-efficient players, and help achieve economies of scale and distribution. Manufacturing, such as for solar, autos and batteries, may be the most attractive area for consolidation.

*33. Balfour, Frederik and Alfred Cang, "China 'Demographic Tsumani' Begins," Bloomberg, January 5, 2012, www.bloomberg.com*
*34. Jackson, Richard, et al., "China's Long March to Retirement Reform," Center for Strategic and International Studies (CSIS), Washington, DC: 2009*
*35. Hamlin, Kevin, "Global Growth Slows to 3.9% as O'Neill Sees BRICs Diminished by Population," Bloomberg, January 3, 2012, www.bloomberg.com*
*36. Marsh, Peter, "China labor costs push jobs back to US," Financial Times, October 6, 2011, ft.com*
*37. Devonshire-Ellis, Chris, "China Now Has Third Highest Labor Costs in Emerging Asia," China Briefing, January 19, 2011, www.china-briefing.com*
*38. Ling, Huawei, "Liu Mingkang: Responding to the Challenges of 2012," Caixin Online, January 17, 2012, caixin.com*
*39. Zhang, Xuechun, "Caixin Survey: Manufacturers Work to Retain Workers," Caixin Online, August 12, 2011, caixin.com*
*40. Qu, Yunxu, "Closer Look: Foxconn's Escalation of Automation," Caixin Online, August 8, 2011, caixin.com*
*41. Rabinovitch, Simon, "China Labor Costs Soar as Wages Rise 22%," CNBC, October 25, 2011, www.cnbc.com*
*42. "China Enters The Danger Zone, SocGen Presents The Four Critical Themes," Zero Hedge, January 1, 2011, zerohedge.com, quoting research by Societe Generale Cross Asset Research*
*43. Goodrich, Alan, et al., "Solar PV Manufacturing Cost Analysis: U.S. Competitiveness in a Global Industry," National Renewable Energy Laboratory presentation, October 11, 2011*
*44. Qu, Yunxu, "Closer Look: Foxconn's Escalation of Automation," Caixin Online, August 8, 2011, caixin.com*
*45. "World Robotics 2011 Industrial Robots," International Federation of Robotics, 2011, www.ifr.org*
*46. Zhang, Xuechun, "Caixin Survey: Manufacturers Work to Retain Workers," Caixin Online, August 12, 2011, caixin.com*

### The energy sector faces inefficiencies

Encouraging industry consolidation in the energy field has clear policy benefits. For example, China's coal industry has thousands of small illegal mines that are difficult to monitor for safety, environmental quality and efficiency—in 2011 alone China shut down over a thousand illegal mines.[47] Larger companies are easier to monitor and regulate, and state-owned companies have incentives to cooperate with national policy objectives since their funding and upper-level personnel promotions depend on government support.

State-led growth can lead to inefficiencies, however. Though SOEs produce only between a fourth and a third of China's GDP, they receive over 75% of capital historically, and over 90% during 2008 and 2009.[48] The government has been eager to consolidate even efficient and successful private companies, such as in the auto market.[49] Private companies have to be wary of intruding into areas where SOEs are establishing a presence, including the wine market, where state-owned Great Wall dominates production. When a private company has successfully established a technology and beaten its international rivals, it can be pushed aside by local governments eager to capture the profits for the state.[50] When the government establishes industry consortiums to set standards and policies, it leans toward SOEs—for example, China excluded BYD, a private Chinese automobile manufacturer, from an alliance to promote electric car manufacturing.[51] In some cases of major infrastructure deals granted to the private sector in the rail sector, government agencies have turned to recently-formed companies with sweetheart connections rather than companies with established technology or relevant experience.[52]

**The U.S. controversy in 2011 following Solyndra's collapse illustrates that governments are not always good at picking winners.**

In February 2012, the World Bank and China's Development Research Center (DRC) jointly released a report describing a variety of issues regarding the role of SOEs in China's economy. The report noted that private companies complain that many sectors lack competition and the private sector cannot obtain loans from commercial banks, which give preference to the state sector. While the central government has advocated reforms to the state sector and pushed to gradually reduce monopolistic behavior, Ding Yufan, a DRC researcher, noted that SOEs have a vested interest in slowing such reforms and preventing meaningful change.[53]

As the 2011 U.S. controversy following Solyndra's collapse illustrated, governments are not always good at picking winners. Although most governments worldwide support a broad range of technologies, in China's case, the explicit promotion of SOEs in organizing and fulfilling policies related to government-designated strategic emerging industries (SEIs) will make its role in picking winners and losers particularly intense. In the past, SOEs have pursued a variety of tactics to fulfill government policies related to the environment, such as shutting electricity production to meet carbon emissions targets, or bidding below cost on wind farm developments to establish a presence. Other examples of local governments pursuing marquee projects on a vast scale have led to criticism of empty cities and bridges to nowhere.[54] On the other hand, China's ambitious targets and ability to move rapidly on energy and environmental policy have helped China become a market leader in greentech over the past decade.

### China's push to develop an innovation economy also faces obstacles

Can China's economy rapidly transform into a center of global innovation? China has made innovation a major area of focus during the 12th Five-Year Plan, and the 2010 plan on establishing SEIs noted that China needs to correct weaknesses in this area citing, "poor technology innovation, fewer core technologies, unsound policies

*47. "China shuts down 1289 illegal coal mines," China.org, August 26, 2011, china.org*
*48. Lee, John, "If Only China Were More Like Japan," Bloomberg Businessweek, August 31, 2010, www.businessweek.com*
*49. Forsythe, Michael, "China, Inc.," Bloomberg, October 13, 2010, www.bloomberg.com*
*50. Barboza, David, "An Entrepreneur's Rival in China—the State," New York Times, December 7, 2011, www.nytimes.com*
*51. Forsythe, Michael, "China, Inc.," Bloomberg, October 13, 2010, www.bloomberg.com*
*52. "'奢侈动车'背后的系列悲剧" [In 'Luxury High-Speed Train' Background, A Series of Tragedies], Caixin Online, February 21, 2012, caixin.com*
*53. "World Bank urges reforms in China," Global Times, February 24, 2012, www.globaltimes.com*
*54. Vuk, Vedran, "Regulation to Nowhere," Casey Daily Dispatch, September 1, 2010, www.caseyresearch.com*

and laws."[55]

Policies to promote innovation are certainly already showing results. China spent 1.5% of GDP on research and development (R&D) from 2000 to 2010, and the central government has planned to increase this figure to 2.5%. China ranks second as a producer of research publications and is in the top five globally for patents.[56] Chinese-born scientists educated and trained in foreign countries are returning to China.[57] Western high-tech firms are racing to establish R&D centers, and local governments are eager to cooperate by building up whole cities around science and research.[58] Yet despite this progress, China's R&D to a large extent still focuses on lower value R&D efforts, such as reengineering products.[59]

Along with the focus on state-led growth, intellectual property (IP) protection weaknesses may be hurting China's ability to promote domestic innovation. IP is not just an issue for foreign companies doing business in China, but for successful domestic players as well.[60] However, as China pursues exciting, high-technology infrastructure projects in high-speed rail, nuclear, water-treatment and renewable energy, China will likely develop world-leading research and technologies in each of these areas. China's government has led the push to ensure that it does by concluding high-profile deals enabling technology transfer.[61]

### Despite these challenges, China's greentech markets remain strong

In 2012, China's greentech markets will continue to face challenges in the areas of financing, global economic softness and concern about the potential for slowing infrastructure spending, yet there are many more reasons to be optimistic, as the next three sections will show. China's policies supporting the energy sector have only become more ambitious over the past year, and the need for such measures has also risen. Just as important, China's strength during the present period of global weakness continues to be an asset for the country's development, as the nation attracts talent, technologies and resources while at the same time using its own financial stability to acquire assets abroad.

**CGTI Perspective**

Although China appears likely to escape an economic hard-landing, many of the difficulties discussed in this chapter will continue to challenge individual greentech sectors over the next year. Renewable energy manufacturers will see difficult markets in Europe and the U.S. due to global macroeconomic problems. Small companies in the Renewable Energy and Green Buildings sectors will face challenges obtaining financing on attractive terms, in turn hurting the government's ability to achieve targets. Yet the government will continue to adapt policies to overcome these problems, proceeding with financial reforms in certain areas.

*55. "Decision on Accelerating the Cultivation and Development of Strategic Emerging Industry (SEI)," China State Council, October 10, 2010*
*56. Clarke, Charmaine, "China's Innovation Quotient," Forbes India, December 26, 2011, forbesindia.com*
*57. Wang, Guanqun, "More Chinese overseas students return home in 2010," Xinhua, March 11, 2011, news.xinhuanet.com*
*58. Dumont, Jean-Michel, "A business culture with Chinese characteristics," China Daily, February 3, 2012, www.chinadaily.com.cn*
*59. Steinfeld, Edward S., Playing Our Game: Why China's Rise Doesn't Threaten the West (U. S.: Oxford University Press, 2010)*
*60. Barboza, David, "An Entrepreneur's Rival in China—the State," New York Times, December 7, 2011, www.nytimes.com*
*61. Wang, Ying, "Westinghouse, China Extend AP1000 Reactor Agreement," Bloomberg, January 19, 2011, www.bloomberg.com; Wines, Michael, "China Takes a Loss to Get Ahead in the Business of Fresh Water," New York Times, October 25, 2011, www.nytimes.com; Shirouzu, Norihiko, "Train Makers Rail Against China's High-Speed Designs," The Wall Street Journal, November 17, 2010, online.wsj.com; the State Development & Investment Corporation (SDIC) built a desalination complex in Beijing at the request of the National Development and Reform Commission (NDRC) as a concept project; with the help of Japanese and European companies, China has adapted the technology to produce high-speed rail.*

# China's Strengthened Greentech Policies

China's ambitious energy and environmental policies will not only help overcome the challenging financing situation for infrastructure investment, but ensure China continues to lead the world in greentech. Based on targets in the 12th Five-Year Plan, China's energy mix will slowly shift from coal to other fuels. In the *China Greentech Report 2011*, the China Greentech Initiative (CGTI) outlined the 12th Five-Year Plan's greentech-related contents in detail. In the months since the Plan's release, targets for solar and wind were raised and funding improved. China has also increased targets for energy efficiency and embarked on new policies in the area of energy taxes and carbon trading. In other areas, such as biofuels, nuclear and rail, progress has faced setbacks or been uneven. Yet taken together, China is accelerating its pursuit of clean energy and environmental protection, and policy measures now underway will keep the nation at the forefront of energy and environmental business and investment for the years that come.

## Renewable targets have been raised, again

**China is the largest manufacturer of wind turbines and solar panels, and has more wind generation capacity installed than any other country.**

China has taken the world lead in a number of renewable energy technologies: China is now the largest manufacturer of wind turbines and solar panels, and has more wind generation capacity installed than any other country.[62] The central government continues to raise already ambitious targets across the renewable energy field, anticipating that clean energy will help solve environmental problems, diversify energy supply and help the nation establish new world markets for energy equipment manufactured in China.

In the area of **wind power**, China has raised its targets yet again, and now plans to have 100 GW of installed capacity by 2015 and 200 GW by 2020, up from 2011 capacity of 62 GW. Of the 100 GW planned for 2015, 5 GW will be located offshore, where China has only recently started development. While onshore resources will dominate through 2020, China's long-term wind policy roadmap calls for offshore and onshore wind installations to be weighted equally following 2020. In response to past problems with interconnection and low wind power capacity factors, China has adopted a power production target of 190 terawatt-hours (TWh) for 2015.[63] This will help resolve a major problem identified in the *China Greentech Report 2011*, namely installations of low-quality or poorly-connected wind power to meet announced capacity targets instead of accomplishing overall policy objectives, such as higher cleaner energy production.

For **solar energy** China's new targets are equally ambitious. The National Development and Reform Commission (NDRC) has increased its 2015 nationwide solar target to 15 GW total installed capacity, partly to offset potential softness in demand from Europe—China had just 2 GW of solar capacity at the end of 2011. The new target includes 10 GW for utility-scale solar photovoltaic (PV), 1 GW for concentrated solar power (CSP), and 4 GW for distributed PV. For 2020, the national target is for 50 GW of capacity including 25 GW of distributed PV.[64] The current distributed PV installed capacity is just 300 MW.

*62. Wu, Yanrui, "Green China? You'd better believe it," The Drum Opinion, April 15, 2011, www.abc.net.au*
*63. "国家能源局关于印发分布式接入风电项目开发建设指导意见的通知" [Notice on the Guidance of On-Grid Distributed Wind Energy Development], National Energy Agency (NEA), November 17, 2011*
*64. Li, Ran, "中国或将'十二五'太阳能发电装机目标再上调50%--报载" [China might increase 50% of the 12th Five Year Plan solar installation target], Reuters, November 16, 2011, cn.reuters.com*

China is also pushing forward in biomass power, calling for 13 GW of installed capacity by 2015, including 8 GW from agricultural and forest biomass, 2 GW from biogas, and 3 GW from municipal solid waste (MSW) incineration.[65] New targets also explicitly set out the percentages of crop residue that should be used for energy generation.

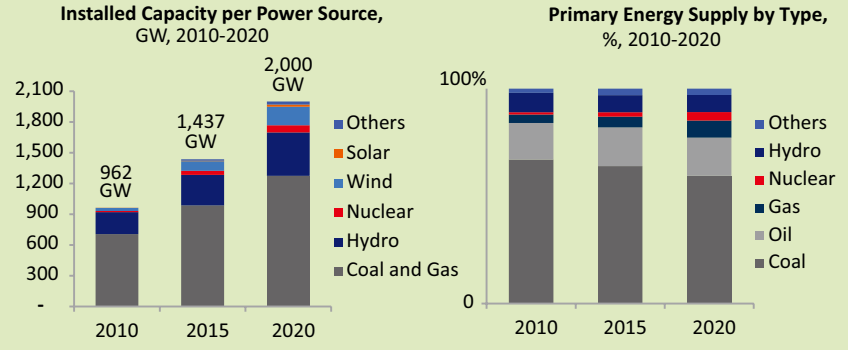
As important as these targets are, they would be insufficient to guarantee sustainable growth without supportive policies to support and fund the projects needed to fulfill them. In this area, 2011 has seen major progress, namely in improved interconnection, higher fees to reimburse grid companies for renewable energy costs, new feed-in tariffs to encourage capacity as opposed to earlier concession rounds, renewable energy portfolio standards to ensure efficient production,[66] tax credits for renewable energy producers,[67] and even low-priced land sales for renewable energy projects.

## China's overall electric generating fuel mix is shifting

Sustainable development is a central element of the 12th Five-Year Plan, which goes much further toward promoting low-carbon development than its predecessors. Changing a country's energy mix is a very ambitious endeavor given that most countries have a fairly fixed resource endowment and the economics and technology of energy production change slowly. For these reasons, the changes in store for China's energy mix are very notable.

China is expected to add 475 GW of new capacity of all fuel sources over the next five years, or the equivalent of 42% of the U.S.'s total installed capacity in 2009, versus 962 GW installed at the end of 2010.[68] While coal will remain the country's base energy source and will continue to rise strongly in absolute terms, its share of China's electric generating fuel mix is projected to diminish from 71% to 66% over the next five years.[69] China's target is for non-fossil energy—nuclear, hydro, biomass, wind and solar power—to rise from an 8% share of China's energy mix in 2011 to 11.5% by 2015 and 15% by 2020.[70]

### China's Power Generation and Energy Mix




*Sources: "Statistical Review of World Energy 2010," BP, www.bp.com, accessed on September 2, 2010; "World Energy Outlook 2010," Industrial Energy Agency, www.iea.org, accessed on August 11, 2009; "2009年度发电业务情况通报" [2009 Generation Business Communication], SERC, November 2010, www.serc.gov.cn*

**Coal power** generation holds a 71% share of the country's total installed electric generating capacity.[71] Even if coal's share declines to 66% by 2015 as forecast, this still implies the nation will need to install an additional 274 GW generating capacity

*65. "Shifts in China's biomass energy policy," Biomass Energy, January 30, 2012, www.biomass-energy.org*
*66. Lao, Jiadi and Seibei Wu, "中国可再生能源发电配额管理办法将出台" [Measures on Renewable Energy Portfolio to be released], New Energy, January 12, 2011, newenergy.in-en.com*
*67. "宁夏‘三免一低’扶持新能源" [Ningxia supports new energy with "three exempt and one lowered" policy], Ministry of Land and Resource (MLR), July 19, 2009, www.mlr.gov.cn*
*68. Ibid.*
*69. "2010 年度发电业务情况通报" [2010 Report on China's Power Industry], China State Electricity Regulation Commission (SERC), April 2011, www.serc.gov.cn*
*70. "Non-fossil fuels to take up 11.4% of China's energy use," Xinhua, March 4, 2011, www.chinadaily.com.cn*
*71. "2010 年度发电业务情况通报" [2010 Report on China's Power Industry], SERC, April 2011, www.serc.gov.cn*

between 2011 and 2015, which is the equivalent of almost the entire U.S. coal plant capacity. Companies with stronger revenue bases will invest in cleaner coal technologies, such as scrubbing or coal-to-gas. The 12th Five-Year Plan also contains a non-mandatory consumption cap at 4.1 billion tons of coal per year, or 41% higher than current consumption levels.[72]

**China is expected to add 475 GW of new capacity of all fuel sources over the next five years, or the equivalent of 42% of the U.S.'s total installed capacity in 2009.**

For **natural gas power**, development in China has been slow due to supply scarcity and poor infrastructure. Today, central-level regulators are promoting gas power generation to meet environmental and energy-efficiency targets under the 12th Five-Year Plan. Gas-based power generation emits very little sulfur dioxide ($SO_2$) and particulates compared to coal. Gas power plants can also cycle on and off relatively quickly and can be used during either peak hours or to compensate for intermittence of wind and solar resources.[73] As a result of policies promoting gas power generation and new gas pipelines, the share of gas power generation in gas consumption rose to 18% in 2010 and may reach 21% by 2015. China National Petroleum Corporation's (CNPC) power-related gas consumption forecast suggests that by 2015 China will have 73 GW of gas-fired power capacity, up from 32 GW currently.[74]

**Hydro power** capacity was 213 GW in 2010 and is targeted to exceed 400 GW by 2020.[75] While regulators slowed new dam project approval following the 18 GW Three Gorge Dam, China's new green targets have renewed the push to develop hydro power. New hydro mega-projects include a 12-dam, 59-GW project on Jinsha River in Tibet, Yunnan and Sichuan.[76] China is also pursuing hydro power from neighboring countries. China has pursued multiple dam projects in Myanmar to supply power to China's southwest. Although in September 2011, Myanmar's government cancelled a controversial dam project on the Irrawaddy River—the plant was to be built by China's State Power Investments—six other dams in Myanmar are moving forward.[77]

Japan's nuclear crisis, which began after the March 2011 magnitude 9.0 earthquake and subsequent deadly tsunami, put China's ambitious **nuclear power** development plan on temporary hold. Regulators froze new plant approvals just a day after the Fukishima incident and ordered safety checks to be performed on all of China's 14 operating reactors.[78] The National Nuclear Safety Administration (NNSA) and the National Energy Administration (NEA) are currently drafting new safety plans which will likely include a requirement to meet the higher safety standards of third-generation reactors.[79] Despite the crisis, preliminary work on China's first inland nuclear power project, the Taohuajiang Nuclear Power Plant, is in progress. In May 2011, China Guodian Power Development and China Guangdong Nuclear Power Group announced that they would build three nuclear plants in Northern Jilin province.[80] The country appears to be on track to achieving its 40 GW capacity target by 2015.[81] An early 2020 target of 80 GW has been lowered to 70 GW, but this still represents seven-fold growth from current capacity of 11 GW.[82]

*72. "发改委投千亿治理矿难 十二五或设煤炭产量上限" [The NDRC Invested RMB 100 billion on Coal Mining Accident, The 12th Five-Year Plan May Set Coal Production Upper Limit], Sina Finance, October 28, 2010; the estimate from Zhang Guobao, Deputy Director of NDRC and Director of NEA, is based on annual coal consumption growth at 0.2 billion tons.*

*73. Zhang, Jianfeng, "中国风电强国前景可期" [China, A Prospective Wind Power Leader], China Business Journal, November 7, 2011*

*74. Duan, Zhaofang, "China's Natural Gas Market Outlook," 4th CNPC/IEEJ Press Conference of Oil Market Research, December 10, 2010, eneken.ieej.or.jp; assumptions based on 50% thermal efficiency and 40% capacity factor.*

*75. Beitarie, Rachel, "Burst of New Dams in Southwest China Produces Power and Public Ire," Circle of Blue, March 22, 2011, www.circleofblue.org*

*76. Ibid; Jinsha River is a 2,300-kilometer section of the Yangtze River in Sichuan Province.*

*77. Fuller, Thomas, "Myanmar Backs Down, Suspending Dam Project," New York Times, September 30, 2011, www.nytimes.com*

*78. He, Li, "中国暂停审批核电项目" [China suspended all nuclear project approval], Financial Times, March 17, 2011, www.ftchinese.com*

*79. Watts, Jonathan, "WikiLeaks cables reveal fears over China's nuclear safety," The Guardian, August 26, 2011, www.guardian.co.uk*

*80. Liu, Yiyu, "China's nuclear power projects continue," China Daily, May 26, 2011, www.chinadaily.com.cn*

*81. Ibid.*

*82. Shao, Minghui, "7000万核电审批将重启12股今日井喷" [Approval for 70 GW Nuclear Power Restarted, and 12 Stocks Soared Today], China Nuclear Power Information Portal, May 24, 2011, www.cs.com.cn*

### China will improve energy transportation infrastructure

Transportation is another major element of China's monumental energy plans. 60% of China's coal is transported by train and occupies 50% of the country's rail haulage capacity. To partially relieve the need to transport coal by train, the central government is investing in its energy transportation infrastructure, investing in new gas pipelines and long-distance ultra-high voltage (UHV) power lines. By 2015, China will build 65,000 kilometers of new gas pipelines, adding to the 35,000 today, which will increase gas coverage of cities across China.[83] Long-distance pipelines, including the West-to-East, Sichuan-to-Shanghai, North-to-South and Ocean-to-Land projects will increase the market potential for distributed energy in cities and industrial zones.[84] China's current UHV line projects are the largest such investments underway worldwide. Nearly RMB 500 billion has been earmarked to extend the direct current (DC) and alternating current (AC) line network to 31,000 kilometers by 2015, from 11,580 kilometers today.[85] Investment in AC lines alone in the 12th Five-Year Plan is 12 times higher than the total amount spent on UHV under the previous Plan.[86]

**Increasing vehicle fuel efficiency and seeking alternative fuels are essential elements to China's energy policy.**

### China has ambitious targets for biofuels, automobile efficiency and new energy vehicles (NEVs)

Given that China now imports more than half its oil requirements, most of which are used in the transportation sector, increasing vehicle fuel efficiency and seeking alternative fuels are essential elements to national energy policy. On auto fuel efficiency, phase III of China's fuel economy standard is expected to be fully implemented by 2015—the standard calls for cutting the average vehicle carbon emissions by 30% by 2015.[87] In 2002, average fuel consumption in China was 9.1 liters per hundred kilometers (equivalent to 25 miles per gallon, or mpg); through the implementation of Phase I and II standards, average fuel consumption decreased to 8.1 liters per hundred kilometers (equivalent to 29 mpg). Phase III standards for new cars are 5.9 liters per hundred kilometers (39 mpg).[88]

In addition, China is making major progress on transportation air emissions. China IV (equivalent to Euro IV, implemented by the European Union in 2005) emission standard was initially implemented in Beijing and Shanghai and expanded nationwide in 2011. China V standards (equivalent to Euro V, implemented in the EU in 2009) are scheduled to be implemented in Beijing in 2012 and nationwide in 2016. In both cases, the rules tighten auto emission standards on carbon monoxide (CO), oxides of nitrogen ($NO_X$), volatile organic compounds (VOCs), and particulates.[89]

To encourage fuel efficiency and ensure the targets are met, China has a mixture of subsidies and taxes. For traditional internal-combustion engine (ICE) vehicles, the Ministry of Finance (MOF) will pay subsidies of RMB 3,000 per vehicle if the engine size is 1.6 liters or below and overall fuel efficiency is 20% better than current national standards. Plug-in hybrid and battery electric cars purchased between 2010 and 2012 are also eligible to receive subsidies.[90]

Biofuels is one area where China has ambitious targets, but these have not changed since 2010 and there is no clear path to realizing them. In 2011, China produced 1.8 million tons of fuel ethanol and 200,000 tons of biodiesel—insignificant compared

*83. "我国天然气管道规划长度2015年将达10万千米" [China's Planned Natural Gas Pipeline Will Reach 100,000 km by 2015], Sinopec News Network, January 22, 2010, www.sinopecnews.com.cn*

*84. "十一五"我国油气骨干管网初步建成 提升油气供应保障能力" [During the 11th Five-Year Plan, China Has Preliminarily Established Its Natural Gas Pipeline Network System and Improved the Supply Capacity], Xinhua, December 2010*

*85. "十二五特高压电网建设将提速 规划投资5000亿元" [Ultra-high voltage grid construction to speed up during 12th Five-Year Plan period, investment RMB 500 billion in Plan], China Government, January 8, 2011, www.gov.cn*

*86. "China Utilities: A Cleaner 12th Five-Year Plan," Bank of China, January 24, 2011, www.bocigroup.com*

*87. "'十二五'汽车碳强度厘定: 下降30%" [12th Five-Year Plan Auto Carbon Intensity Set to Fall 30%], 21st Century Reports, September 20, 2010, www.21cbh.com*

*88. "2012年中国汽车产业实施新政一览" [In 2012, China's Auto Industry Will Implement a New Round of Policies], People Net, February 15, 2012, people.com.cn*

*89. "China: On-Road Vehicles and Engines," DieselNet, www.dieselnet.com, accessed on February 14, 2012; Feng An, et al., Global Overview on Fuel Efficiency and Motor Vehicle Emission Standards: Policy Options and Perspectives for International Cooperation (New York: United Nations (U.N.) Department of Economic and Social Affairs, May 2011)*

*90. Hui, He and Anup Bandivadekar, A Review and Comparative Analysis of Fiscal Policies Associated with New Passenger Vehicle $CO_2$ Emissions (Washington, DC: International Council on Clean Transportation, 2011); Li, Shigong, "Top Story: Is China Ready for Environmental Tax?" Beijing Review, March 11, 2010, www.bjreview.com.cn*

to overall oil consumption of over 450 million tons.[91] Government targets for road transportation call for 20% alternative fuel use by 2020,[92] but with fossil fuel use expected to grow by 51% over that time, and no clear alternative fuel policy roadmap for increasing supply and infrastructure, it is unclear how alternative fuel consumption can rise 11-fold over that time period.[93]

China has designated the electric car sector as a SEI and set out to develop an extensive domestic manufacturing capability in transportation batteries and electric vehicles. However, hybrid vehicles have had less success in China than in other countries, partly due to high cost. In April 2011, the government submitted its Energy Saving and New Energy Vehicle Development Plan (2011-2020), which envisions 5 million NEVs by 2020 and RMB 100 billion in investment, to the State Council for approval.[94] Yet an earlier program, the Tens of Cities, Thousands of Vehicles program has failed to meet its targets set when it was launched in 2009.[95] As of November 2011, the program has deployed only 8,500 vehicles, mainly hybrid electric vehicle (HEV) buses.[96]

### High-speed rail expansion slowed in 2011

China continues to expand its high-speed passenger rail network to link major cities and relieve freight transportation bottlenecks. By the end of 2010, the country had 8,358 kilometers of high-speed rail in operation, making China the world leader in terms of operating distance.[97] If current development plans are realized, the network will have 16,000 kilometers of high-speed rail by the end of 2015.[98] However, after a series of corruption scandals at the Ministry of Railways, the government in April reduced operating speeds on the high-speed rail network.[99] In July 2011, two bullet trains collided near Wenzhou, in east China's Zhejiang province, killing 40 people and injuring almost 200 more. The tragic accident shocked the nation, prompting additional speed reductions and a slower pace of rail network expansion.

### Clean water and clean air have strict new targets

China's central government is increasingly prioritizing clean air and water over the past few years, and has broadened the scope of pollutants covered by national policy targets while also setting out goals for building out infrastructure to keep the air and water clean.

**China's central government is prioritizing clean air and water, and has broadened the scope of pollutants covered by national policy targets.**

In the water sector, the 12th Five-Year Plan targets 30% reduction in water use per unit of industrial production, similar to the target achieved over the prior Five-Year Plan, and a 60% reduction in water use intensity of GDP by 2020. The Plan limits water use volume to 620 billion cubic meters ($m^3$) in 2015 versus 590 billion $m^3$ in 2009, ensuring an increase in water use efficiency as well as reuse. China will add 40 billion $m^3$ of urban water supply capability, and continue building wastewater treatment plants after three years of astonishing growth when the number of treatment plants rose from 1,018 at year-end 2008 to a projected 5,200 at the end of 2012.[100] The 12th Five-Year Plan also includes a 10% water reuse target for provincial wastewater.

On water pollution, the Plan sets out an 8% reduction in chemical oxygen demand (COD), a 10% reduction in ammonia nitrate, and a 15% reduction in heavy metals—

*91. "GAIN Report, China, People's Republic of, Biofuels Annual Report 2011," U.S. Department of Agriculture, July 2011*
*92. "中国油品清洁化之路还将面临诸多挑战" [China's Clean Fuel Development is Facing Various Challenges], ESI, September 14, 2011, www.china-esi.com*
*93. "中国未来车用能源发展的思考" [Thought on China's Vehicle Used Alternative Fuels Development], Nevfocus, November 25, 2011, www.nevfocus.com*
*94. New energy vehicle (NEV) is defined by the Ministry of Industry and Information Technology (MIIT) as vehicles that use unconventional fuel as power source (or use conventional fuels, but use new drive system), integrated with advanced drive and control technologies to form new technology and new vehicle structure. MIIT is currently evaluating whether hybrid electric vehicles (HEVs) should be excluded from the definition as it is considered a mature technology.*
*95. "China to benefit from emerging Global Electric Vehicle demand, though challenges remain," World Bank, April 20, 2011, www.worldbank.org*
*96. China Greentech Initiative (CGTI) analysis*
*97. "统计局:中国铁路营业里程世界第二 高铁排榜首" [Bureau of Statistics: China's Rail World's Second Longest, High-Speed Rail Number One], Chinanews, March 4, 2011, www.news.163.com*
*98. Ibid.*
*99. Xin, Dingding, "Putting high-speed travel back on track," China Daily, December 13, 2011, www.chinadaily.com*
*100. "China's Thirst for Water," The Dow Chemical Company, April 2011, www.futurewecreate.com; Zhou, Yannian, et al., "Status and development for municipal wastewater reuse in China," Zhejiang University of Technology, June 16, 2011, ieeexplore.ieee.org; Menant, Magali, "Energy efficiency in China's wastewater sector," AHK, August 12, 2011, china.ahk.de*

prior Five-Year Plans did not include ammonia nitrate or heavy metals targets.[101] The Plan specifically targets an increase in the ratio of main rivers and lakes in Yangtze and Yellow river basins meeting quality standards to 60%.

Given the importance of clean water, it's important to note that this area of policy has had mixed success in the past. In particular, a focus on installation of wastewater treatment infrastructure in the past neglected operations—as a result, many cities and provinces made remarkable gains building treatment plant capacity that subsequently operated far below stated design capacity or failed to operate at all. Because of this, China's spending on this infrastructure achieved far less in terms of environmental benefits than it should have.

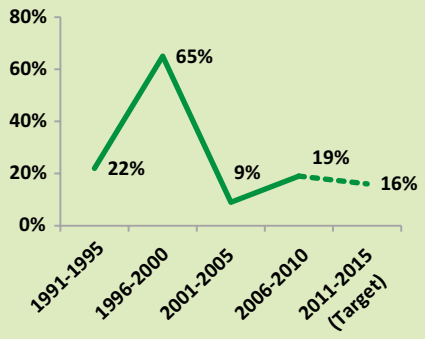
For air pollution, one of the most significant developments has been new emissions standards for power plants. In July 2009, the Ministry of Environmental Protection (MEP) released a draft Emission Standard of Air Pollutants for Thermal Power Plants, to replace a prior 2003 standard. In January 2011, a new draft was released even stricter than the first draft, calling for tighter limits in emissions of $NO_x$ and $SO_2$ in line with power plant emissions standards in the U.S. and Japan.[102] The standard introduces mercury emissions regulations for the first time as well. On July 29, 2011, MEP officially approved the new standards effective from January 1, 2012.[103]

## China will focus on energy efficiency and low carbon

China's 12th Five-Year Plan renews and improves on earlier efforts on energy efficiency and carbon emissions intensity. For the first time, China has agreed in principle to binding international carbon emissions targets for developing countries. The country has already announced pilot projects related to carbon taxes and carbon emissions credit trading. The government also plans to more closely align performance incentives for local government officials with energy and environmental goals.

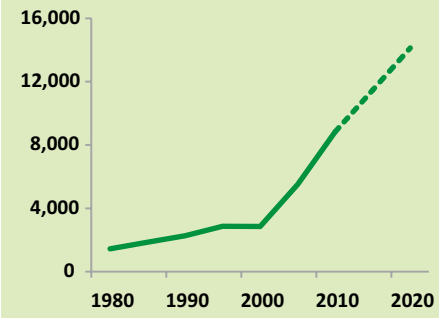
During the 11th Five-Year Plan period (from 2006 to 2010), China set an ambitious target of reducing energy intensity by 20%. The actual result fell just shy of this target, and was met partly through top-down enforcement actions, such as plant closures.[104] China's energy intensity target for 2015 is for a further reduction of approximately 16%.

**Energy Intensity in China, per unit GDP, 1991-2015**




*Source: Wu, Henry, "12th Five-Year Plan – A Healthy Push," Nomura Research, September 29, 2010*

**Carbon Emissions in China, million metric tons $CO_2$, 1980-2020**




*Note: CGTI analysis based on 45% carbon intensity reduction by 2050.*
*Source: "International Energy Statistics, Carbon Emissions," U.S. Energy Information Administration, www.eia.gov, accessed on February 14, 2012*

*101. Wen, Yumin, "水利部：'十二五'水利发展面临六项主要任务" [Ministry of Water Resources (MWR): Under 12th Five-Year Plan water infrastructure development faces 6 main tasks], China Energy Network, October 12, 2011, www.china.com.cn*
*102. "火电厂大气污染物排放标准" [Emission Standard of Air Pollutants for Thermal Power Plants], Ministry of Environmental Protection (MEP), July 29, 2011; "火电最新排污标准严过欧美 火电企业面临倒闭或造" [New emission standard stricter than EU and U.S., Coal-fired plants may fail and commit fraud], Energy Magazine, November 23, 2011; with the exception of plants in Guangxi, the standard for sulfur is 100 mg/m³ for new plants and 200 mg/m³ for existing plants, and for $NO_2$ it is 100 mg/m³ for all plants.*
*103. "火电厂大气污染物排放标准" [Emission Standard of Air Pollutants for Thermal Power Plants], MEP, July 29, 2011*
*104. "'十一五'期间我国能源强度下降19%" [China energy intensity reduced by 19% during 11th Five-Year Plan], People Net, November 15, 2011*

For building energy efficiency, the 12th Five-Year Year Plan calls for a 65% reduction in energy consumption versus existing building stock, emphasizing five aspects: shading, HVAC (heating, ventilation and air conditioning), building envelope, integrated renewable energy, and lighting.[105] Some policies are specific to China's five climate zones, such as Standards for Design of Residential Buildings in Hot Summer and Cold Winter Areas. To speed the implementation of these energy saving guidelines, the government might, sometime in the future, provide cash grants up to RMB 75/$m^2$ for building projects that attain 3-Star certification.[106] Local government standards can go further: Beijing has mandated that all new residential buildings achieve a 75% reduction in energy consumption versus existing building stock.

A year ago, China's carbon policy was a matter of intense debate in both government and private circles. At the November 2011 Durban, South Africa, climate change conference, negotiators from the world's largest carbon emitting countries, including China, the U.S. and India, agreed to negotiate legally binding emissions limits.[107] The conference also agreed to commence a new commitment period under the framework of the 1997 Kyoto Protocol on climate change—the new commitment period will run from January 1, 2013, to either the end of 2017 or 2020. Though the Durban conference ended without clear commitments to specific levels of emissions needed to prevent global temperature rising more than 2.5 degrees Celsius, the progress made at least allows for the potential of major new international cooperation on both carbon trading and prevention of catastrophic climate change through binding targets.[108]

**In 2011, China unilaterally declared a commitment to reduce carbon emissions intensity per unit GDP by 17% by 2020.**

For China, the focus in the near-term is domestic carbon policy. Early last year, China unilaterally declared a commitment to reduce carbon emissions intensity per unit GDP by 17% by 2020. Just prior to the Durban conference, China released several carbon policies. On October 29, 2011, the NDRC released plans for a carbon trading pilot program in five of China's large cities—Beijing, Tianjin, Shanghai, Chongqing and Shenzhen—and the two large industrial provinces Guangdong and Hubei.[109] And on December 11, 2011, the 12th Five-Year Plan on greenhouse gas emissions introduced measures to meet the 17% carbon emissions intensity target by 2015, including energy and carbon reduction targets for each province, making carbon reduction a key performance indicator (KPI) for evaluating local officials, and establishing carbon trading systems and low-carbon zones.[110] On January 13, 2012, the State Council announced several industries would have to publish greenhouse gas emissions reductions targets, including iron and steel, construction materials, electric power, coal, oil, chemical, dyeing, fabric, food, paper, transportation, rail and construction.[111] Subsequently, in late February, the 12th Five-Year Plan on Industry Energy Efficiency laid out energy savings targets for each industry.[112]

These developments are all fairly recent, and face challenges and uncertainties. Carbon trading is complex and involves emissions measurement, monitoring, standards, baselines and enforcement. As noted in the *China Greentech Report 2011*, China currently lacks these measures and it will take time to demonstrate they can be implemented effectively even at the pilot stage in large cities. In addition, enforcement of provincial energy and environmental targets has been difficult in the past.

*105. "关于发展节能省地型住宅和公共建筑的指导意见" [Guidance on Developing Energy Efficiency and Land Saving Residential and Public Buildings], Ministry of Housing and Urban-Rural Development (MOHURD), May 31, 2005, www.mohurd.gov.cn*

*106. "建筑工程绿色施工评价标准 CB/T50640-2010" [Green Construction Evaluation Standards], MOHURD, December 2, 2010, www.mohurd.gov.cn*

*107. "Durban Climate Conference," U.N., unfccc.int, accessed on February 14, 2012*

*108. James, Adam, et al., "There is more than one way to reduce global emissions," Center for American Progress, December 9, 2011, www.americanprogress.org*

*109. "国家发展改革委办公厅关于开展碳排放权交易试点工作的通知" [Notice on Implementing Carbon Trading Pilot Program], NDRC, October 29, 2011, www.ndrc.gov.cn*

*110. "'十二五' 控制温室气体排放工作方案" [12th Five-Year Plan Greenhouse Gas Emissions Working Document], State Council, January 13, 2012; "国务院关于加强环境保护重点工作的意见" [The views of State Council on strengthening the work of key environmental protection], NDRC, December 20, 2011, fgs.ndrc.gov.cn*

*111. Liang, Jialin, "内地七省市试点碳排放权交易 或征收区域性碳税" [Seven provinces in the Mainland China pilot carbon emissions trading and may impose a regional carbon tax], ifeng, January 16, 2012, news.ifeng.com*

*112. "工业和信息化部发布工业节能 '十二五' 规划" State Council, February 27, 2011, www.gov.cn*

### With some exceptions, ambitious policies are transforming China

Overall, the past year has seen major improvements in energy and environmental policy goals and targets, yet some have failed to meet expectations. Areas of policy weakness include electric cars, where existing programs failed to meet targets and the market is currently tiny; biofuels, where the government has not yet specified how it might meet its 20% alternative fuel use target for 2020; building energy efficiency, where prior targets for energy use were not met due to insufficient standards and lack of incentives; and clean water, where enforcement of existing water quality standards has lagged and many wastewater and sludge treatment plants suffer from poor operational records. In these and other cases, the explanations for missed targets can range from inadequate technology, poor enforcement, insufficient economic incentives, and simply overly ambitious and impractical initial targets. Yet despite these challenges, the overall policy situation is overwhelmingly positive for greentech markets.

**CGTI Perspective**

China has a record of setting ambitious greentech targets, and subsequently raising them as technology and markets evolve. This trend will continue over the next year. The most promising areas include renewables, where not only has the government raised capacity targets, but also included production and energy mix goals, and carbon emissions, where the government has launched emissions trading programs and specified that local officials must be evaluated based on meeting goals. For every sector, China's policy has evolved significantly in ways that will create and expand new markets.

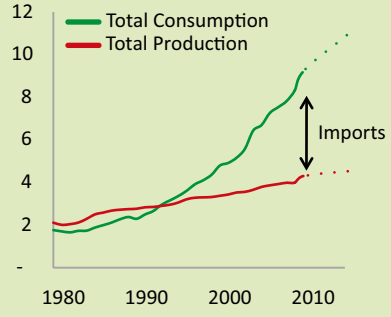
# Public Awareness of Urgent Environmental Problems Is Growing

One of the reasons China has moved so quickly on energy and environmental policy is that China's needs in both areas are urgent. In energy, China must now import over half of its oil, and the country is overly reliant on coal, which produces high emissions of carbon and other air and water pollutants. On the environment, feeding China's enormous population requires improved water and soil quality, while guaranteeing the health and safety of the rapidly growing urban population requires new efforts to clean the air. Another major impetus for policy is public awareness. The past year has witnessed a number of major pollution incidents and, on micro-blogging sites and elsewhere, the public is more engaged on this issue than ever.

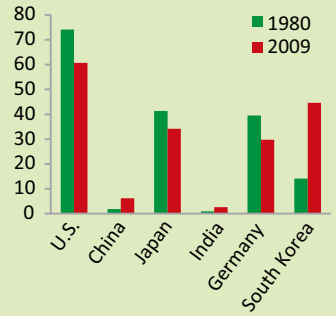
## As China imports more oil, energy security will remain an urgent priority

Despite China's ambitious fuel efficiency regulations for new vehicles, its oil consumption has grown more rapidly than the rest of the developing world in percentage terms. In 2009, China consumed 8 million barrels daily out of a total daily world production of 84 million barrels. In the same year, the U.S. consumed 19 million and the E.U. consumed 14 million barrels per day.[113] China's oil consumption doubled from 1998-2009 and is currently growing at 5-7% per year, whereas the developed world's consumption is stagnant, meaning consumption rates are converging.[114] Of even more concern to policymakers, since China's domestic oil production cannot keep pace, China must now import over 50% of its oil.[115] China has already become the world's second largest oil importing country after the U.S., and could pass the U.S. in the next three decades as the largest oil importer even if the U.S. remains the largest oil-consuming nation.[116]

**China's Oil Imports, millions of barrels per day, 1980 to 2015**




**Selected Countries' per Capita Oil Consumption, barrels per thousand people, 1980 and 2009**




*Source: "International Energy Statistics," U.S. Energy Information Administration, www.eia.gov, accessed on February 24, 2011*

*113. "International Energy Statistics," U.S. Energy Information Administration, www.eia.gov, accessed on February 24, 2011*
*114. Ibid.*
*115. "China Energy Data, Statistics, and Analysis," U.S. Energy Information Administration, November 2010, www.eia.gov*
*116. CGTI analysis*

### Industrialization and prosperity have stressed water and food supplies

China's food and water challenge has two elements: first, demand is rising in tandem with living standards; second, changing environmental conditions challenge China's water supply picture—these include melting Himalaya glaciers, rapidly falling water tables, droughts and pollution.

Food sufficiency and security is one of modern China's greatest achievements: thanks in part to careful management and technology innovation, China today feeds 22% of the world's people with just 7% of the world's arable land.[117] China has lifted 300 million people out of poverty and improved nutrition substantially. According to the World Food Program, a six-year-old boy in China today is 6 centimeters taller and 6 kilograms heavier than a boy of the same age in 1978 at the outset of the Reform and Opening period.[118]

**China feeds 22% of the world's people with just 7% of the world's arable land.**

Unfortunately, water poses a severe challenge to this achievement. The government estimates that 10% of arable land is polluted.[119] Fertilizer overuse has reduced productivity, polluted groundwater and released greenhouse gases. Nitrous oxide ($N_2O$), a fertilizer with an estimated global warming impact almost 300 times that of carbon dioxide ($CO_2$), accounted for almost 90% of the agriculture sector's greenhouse gas emissions.[120] Pollution also affects rivers. One-fourth of river water in the Yangtze and Yellow Rivers is too polluted for use in agriculture, and one-third of river water in the Huai and Liao Rivers is unsafe for any purpose.[121]

The water supply crisis is worsening. Water use in China grew 430% from 1949 to 2004. Agriculture as a share of water use has fallen from 97% to 65%; industry now uses 22% of water and domestic water uses the remaining 13%.[122] As China's diets move towards more consumption of meat, more water must go towards providing animal feed instead of directly for food grain; it takes 3,200 liters of water to produce one kilogram of beef.[123] Given trends towards urbanization and more diverse diets, demand for water will only grow.

China's per capita water supply is 2,100 $m^3$ per year, or 25% of the world average, but in Northern China the per capita supply is just 500 $m^3$. Rainfall in Northern China has decreased between 20-40 millimeters per decade on average since the 1950s.[124] In Northern China, the water crisis has affected rivers, other surface water and groundwater. Many rivers have reduced in volume and often run dry. The Yellow and Huaihe Rivers have seen run-off decline by 15%, and the Yellow River has run dry over 30 times since 1972, the first time in recorded history the river ran dry.[125] The percentage of villages in Northern China reporting reliable surface water supplies has fallen from 64% in the early 1990s to 39%.[126] Irrigation systems are inefficient, so only 45% of the water drawn reaches the crops.[127] Agencies devoted to water management are reportedly under-staffed and regulations poorly enforced.[128]

*117. Liu, H. and Deblitz, C., Determinants of Meat Consumption in China (Australia: Asian Agribusiness Research Center, 2007)*
*118. Watts, Jonathan, "More Wealth, More Meat. How China's Rise Spells Trouble," The Guardian, May 30, 2008, www.guardian.co.uk*
*119. Pan, Chenjun, "China Meat Demand to Soar In Coming Decade," China Daily, June 7, 2011, www.chinadaily.com*
*120. Wang, J., et al., Climate Change and China's Agricultural Sector: An Overview Of Impacts, Adaptation and Mitigation (Switzerland: International Centre for Trade and Sustainable Development, 2010)*
*121. "Water, Air Pollution In China Still Serious," China Daily, February 24, 2009, www.chinadaily.com*
*122. Wang, J., et al., Understanding the Water Crisis in Northern China. In China's Dilemma: Economic Growth, the Environment and Climate Change (Australia: ANU E Press, 2010)*
*123. "Water Footprint Calculator Methodology and Tips," National Geographic, www.nationalgeographic.com, accessed on February 23, 2011*
*124. Wang, J., et al., Climate Change and China's Agricultural Sector: An Overview Of Impacts, Adaptation and Mitigation (Switzerland: International Centre for Trade and Sustainable Development, 2010)*
*125. Ibid; "Yellow River," Facts And Details, factsanddetails.com, accessed on February 18, 2011*
*126. Wang, J., et al., Understanding the Water Crisis in Northern China. In China's Dilemma: Economic Growth, the Environment and Climate Change (Australia: ANU E Press, 2010)*
*127. Xie, Jian, Addressing China's Water Scarcity: Recommendations for Selected Water Resource Management Issues (Washington, DC: The World Bank, 2009)*
*128. Wang, J., et al., Understanding the Water Crisis in Northern China. In China's Dilemma: Economic Growth, the Environment and Climate Change (Australia: ANU E Press, 2010)*

Climate change is another challenge affecting agriculture and water. Climate change may enlarge China's deserts, particularly in west China, and in the worst-case scenario outlined by the Intergovernmental Panel on Climate Change (IPCC), may reduce rain-fed yields of rice, wheat and maize by 20-36%.[129] Climate change also threatens the Himalaya glaciers. In China, 23% of the population resides in regions where glacial melt is the main source of water during the dry season. Over 80% of glaciers in Western China have retreated in the last 50 years, losing 4.5% of surface area[130]—though recent satellite observations have suggested glacial retreat is slower than anticipated.[131]

China's food crisis is also connected to worldwide food shortages and price fluctuations. The U.N. Food and Agriculture Organization's (FAO) forecasts suggest that world food output will have to rise 70% by 2050 to feed an estimated population of 9 billion, many of whom will eat more meat. The FAO also reports food prices in 2011 rose to new highs due to high grain prices.[132] Now that China has become a major importer of such food staples as corn, it is newly vulnerable to such price swings. China imported 1.75 million tons of corn from the U.S. in 2011, and has sought to diversify supplies by signing new deals with Argentina.[133]

### Pollution has tremendous health and economic consequences

China's tremendous strides in building its greentech economy must go further still to address the human cost of pollution. A 2007 World Health Organization (WHO) study estimated diseases caused by indoor and outdoor air pollution kill 656,000 people in China every year, and polluted drinking water kills another 95,600.[134] A more recent academic study put the total figures higher, at 1.3 million deaths per year for air and water pollution.[135] By comparison, the 2008 earthquake in Sichuan killed an estimated 68,000 people, while the 1976 Tangshan earthquake killed approximately 250,000.[136]

**Diseases caused by indoor and outdoor air pollution kill 656,000 people in China every year, and polluted drinking water kills another 95,600.**

Pollution's human costs can also be considered in terms of impact on China's GDP. The Ministry of Environmental Protection (MEP) has estimated pollution reduces annual GDP by 3.1% in total, but more recent World Bank estimates placed health care costs alone at between 3.8% and 4.3% annually.[137] Certain industries, such as tourism and agriculture, bear a disproportionate burden of pollution. Air, water and soil pollution directly reduce the food production from China's limited arable land, while inefficient water and energy use can worsen droughts by reducing irrigation water supply downstream.

*129. Wang, J., et al., Climate Change And China's Agricultural Sector: An Overview Of Impacts, Adaptation and Mitigation (Switzerland: International Centre for Trade and Sustainable Development, 2010)*
*130. "The Internationl Panel on Climate Change's (IPCC) 2035 Prediction About Himalayan Glaciers," Skeptical Science, January 21, 2010, www.skepticalscience.com*
*131. Llanos, Miguel, "Himalayan ice melt estimates get a major downsizing," MSNBC, February 9, 2012, msnbc.msn.com*
*132. "Era of Falling Food Prices Seen at End," Bloomberg, February 6, 2012, www.bloomberg.com*
*133. Yap, Chuin-Wei, "As Xi Charms Iowa, China Hedges Corn Ties with U.S.," The Wall Street Journal, February 16, 2012, blogs.wsj.com*
*134. Platt, Kevin Holden, "Chinese Air Pollution Deadliest in World, Report Says," National Geographic, July 9, 2007, www.nationalgeographic.com*
*135. "Environment problems pose health risk for China: Lancet," The Independent, March 26, 2010, www.independent.co.uk*
*136. "2008 Sichuan earthquake," Wikipedia, en.wikipedia.org, accessed on February, 2011; "1976 Tangshan earthquake," Wikipedia, en.wikipedia.org, accessed on February 17, 2011*
*137. "China Is Set to Lose 2% of GDP Cleaning Up Decades of Pollution," Bloomberg, September 17, 2010, www.bloomberg.com; "Pollution controls used during China Olympics could save lives if continued, study concludes," ScienceDaily, February 11, 2011, www.sciencedaily.com; Cost of Pollution in China (Washington D.C.: The World Bank and MEP, 2007)*

## Public environmental awareness is rising

Public awareness of air pollution in China has increased markedly in recently years. Official Chinese media have reported extensively on the issue, and noted Chinese celebrities have made air pollution a cause célèbre, both in public and online using Sina Weibo, China's leading micro-blogging service. In the fall of 2011, CCTV aired a commentary by Bai Yansong—a celebrated CCTV anchor who led coverage of the 2008 Sichuan earthquake—calling for adoption of standards for PM2.5 (particulate matter smaller than 2.5 micrometers).[138] Over the Spring Festival holiday in 2012, when many Chinese families watch television together, the Shanghai-based Mr. Zhou Live Show, starring comedian Zhou Libo, contained a long and frank discussion of the conflict between official Beijing pollution statistics and the U.S. Embassy monitoring station.[139] Newly released public data on PM2.5 levels in various cities should improve awareness, and the issue is already affecting public policy. In early 2012, as Shanghai announced it would make public the readings from its 24 PM2.5 monitoring stations by mid-2012—the city installed its first such station 10 years ago. Shanghai Mayor Han Zheng said, "We must face it scientifically, monitor and release it as soon as possible, and release true and scientific data that accord with residents' feeling on the environment."[140]

**Noted Chinese celebrities have made air pollution a cause célèbre, both in public and online using Sina Weibo.**

Press reports of pollution incidents have been hard to miss over the last year. The most important incident was the major offshore oil spill in the Bohai Bay in July 2011, which contaminated thousands of square kilometers of water.[141] The spill was not publicly known for a month, leading to accusations printed in state media of a cover-up by state-owned oil company China National Offshore Oil Corporation (CNOOC).[142] ConocoPhillips, the operator of the oilfield in the Bohai case, also received heavy criticism.[143] Food quality also stayed in the news, as China suffered another milk scandal—carcinogenic feed was blamed.[144] In Guangxi, where the press reported on a major cadmium pollution incident affecting drinking water in the city of Hechi, scientific surveys showed that of 292 food products from Guangxi, 92% contained lead, 93% contained cadmium and 16% contained mercury. 41% had lead levels above safety standards, 20% had cadmium levels above standard, and 5% had mercury levels above standard.[145] In December 2011, state-run People's Daily reported that on two days of heavy smog in Beijing, local hospitals reported a 12% increase in respiratory and cardiovascular problems and a 17% increase in auto accidents.[146]

As press coverage has increased, personal awareness is rising too. A poll conducted by consulting firm Horizon-China found that 73% of respondents put the environment as a higher priority than economic development and 87% consider environmental concerns urgent. Among environmental concerns, family health and safety are the top issues. Respondents believe environmental protection is mainly the government's responsibility, and while 39% of respondents are satisfied with the government's performance, approval is only 33% among those aged 18 to 25 and just 23% among students.[147]

*138. "Pressure builds up for tighter air quality monitoring in Beijing," Xinhua, November 7, 2011, www.xinhuanet.com*
*139. "综艺：壹周立波秀2012年1月24日词说2011 大雾引致的空气质量问题" [Zhou Libo show on January 24, 2012: Air quality problems caused by fog in 2011], Sohu, January 24, 2011, tv.soho.com*
*140. "Shanghai to release PM2.5 data in June," People's Daily, February 17, 2012, peopledaily.com.cn*
*141. "中海油证实国内最大海上油田渗漏" [CNOOC confirmed the nation's largest offshore oil field leakage], Sina, July 2, 2011, www.sina.com.cn*
*142. "China needs zero tolerance for concealing major accidents," People's Daily, July 8, 2011, www.peopledaily.com*
*143. "Bohai oil spills ConocoPhillips' fault: authorities," Xinhua, November 11, 2011, english.xinhuanet.com*
*144. "蒙牛称牛奶致癌物超标问题饲料来源已查明" [Mengniu said excessive milk carcinogens' problem feed source has been identified], Sina, December 28, 2011, www.sina.com.cn*
*145. "研究显示：龙江污染源头河池近20%受检食品镉超标" [Studies have shown that nearly 20% of the cadmium in food exceeded standard in Hechi, the origin of Longjiang pollution], Caixin Online, February 3, 2011, www.caixin.com*
*146. "Expert: Beijing's PM2.5 air pollution getting worse," People's Daily, December 12, 2011, www.peopledaily.com*
*147. "2010中国公众环保指数发布 公众环保行为无突破" [2010 Chinese public environmental index released, no public environmental behavior breakthrough], Sina, October 12, 2010, www.sina.com.cn*

This increased awareness is reflected both in the media and on social networking sites. In January 2012, in the interior city of Lanzhou, parents went online to criticize the decision to hold an annual children's road race during an episode of heavy pollution.[148] In Dalian, after a major citizen protest attended by an estimated 12,000 people, local officials ordered a chemical factory closed in July 2011.[149] On the 1diaocha website, which allows users to start their own unscientific polls of fellow users, environmental polls are rising rapidly, from only four in 2006 to six in just the first few weeks of 2012; one of the most popular in early 2012 asked users whether they agreed with experts that a seven-legged turtle's mutations were not caused by environmental problems.[150]

All levels of government must bolster monitoring and enforcement, increase transparency, and ensure economic incentives and government targets do not encourage local officials to put short-term profits over human health. China's State Council recognized this when it prioritized three energy-efficient sectors (energy-saving technology, new energy vehicles, and new energy industries such as wind and solar) as SEIs in 2010: "To build an affluent society and realize sustainable development, we shall spare no efforts to … meet the increasing demands from the people for both material and culture and boost the growth of a resource-saving and environmentally-friendly society."[151]

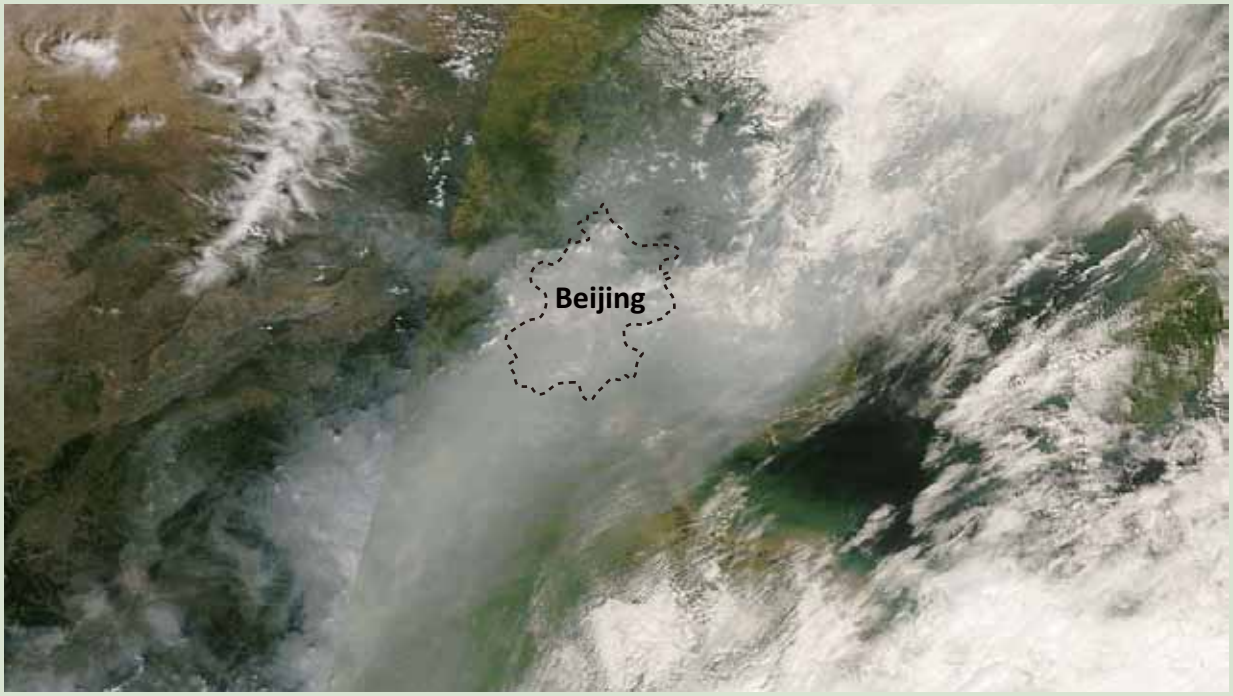
**CGTI Perspective**

Environmental awareness goes hand-in-hand with economic development: in the long run the two are not in conflict. On the contrary, ecological and environmental stewardship is critical to the well-being and prosperity of a country's society and economy. This trend will only grow more apparent in China over the coming year as issues related to the quality of food, air, soil and water continue to come to the fore, in turn leading to more policies to respond to such concerns and more opportunities for companies offering solutions.

*148. "空气中度污染组织环城跑：家长呼吁放过孩子" [Organization holding children's road race during heavy pollution: Parents criticizing the decision], Sina, January 4, 2012, www.sina.com.cn*
*149. "中国决定关闭大连化工厂" [China decided to close the Dalian Chemical Factory], China Entrepreneur Club, July 15, 2011, www.daonong.com*
*150. "市民逮到七条腿青蛙专家称与环境污染无关" [The public caught a seven-legged frog, experts say it has nothing to do with environmental pollution], Diaocha, October 15, 2011, www.1diaocha.com*
*151. "国务院关于加快培育和发展战略性新兴产业的决定" [State Council's Decision on Accelerating the Cultivation and Development of SEI], State Council, October 10, 2010*

## Separating Fact and Fiction - Air Pollution in Beijing:

Beijing suffers from some of the worst air pollution of major Chinese cities, with official annual average PM10 (particulate matter smaller than 10 micrograms (μg)) readings of 121 μg/m$^3$ for 2010—higher than Tianjin's reading of 101 and Shanghai's of 81.[1] This compares with 25 for Los Angeles, 23 for Tokyo, 52 for Mexico City and 64 for Seoul. Though domestic and international coverage of China's air pollution problems has increased, the issue is complex, and reports often mix truth and myth.




NASA Rapid Response, July 24, 2008

*Note: Above is a satellite photo of air pollution extending across a broad multi-province area in Northern China.*

### Pollution is getting worse because more and more people drive cars: False

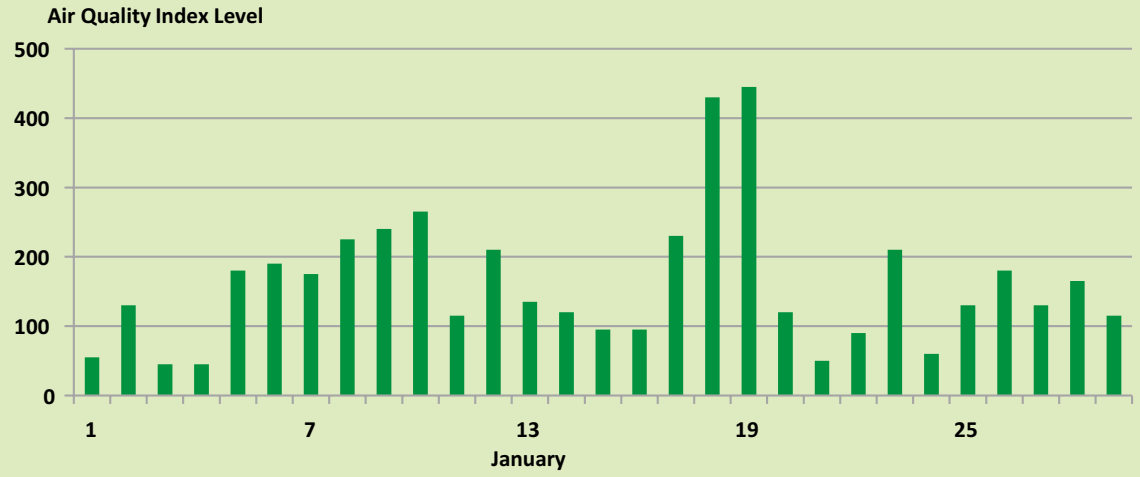
Air pollution comes from many sources, and the proportion from these varies by city, pollutant, season and year. Media reports often mention automobile exhaust as the main contributor to Beijing's air pollution.[2] For PM2.5 in Beijing, various studies have placed the contribution from vehicle exhaust at between 5-15%, with road dust and secondary emissions adding to this figure.[3] While vehicle ownership in Beijing has grown rapidly, rising from 1.5 million in 2000 to 4.8 million at the end of 2010,[4] one study of vehicle emissions estimates that pollution from cars and trucks declined from 1999 through 2009 due mainly to improved fuel and vehicle standards and vehicle-scrapping programs.[5] Stationary combustion sources account for almost 45%, with sources ranging from coking to industrial plants. Dust from sandstorms and agricultural burning can be a major contributor in some years and seasons.[6] Overall, a large fraction of PM2.5 can come from oxidation of other pollutants, complicating identification of the source.

### It's always polluted in Beijing: False

Several studies of Beijing's pollution show wide daily and hourly variation. For example, a graph of PM2.5 levels during January 2012 shows this variability, with several days rated moderately polluted or good by the U.S. Embassy monitor.

*1. "Database: Outdoor Air Pollution in Cities," World Health Organization (WHO), www.who.int/en, accessed on January 29, 2012*
*2. "Death-by-Air in Beijing Shows China's Heart Risk From Worsening Pollution," Bloomberg, December 16, 2011, www.bloomberg.com*
*3. Song, Yu, et al., "Source apportionment of PM2.5 in Beijing using principal component analysis/absolute principal component scores and UNMIX," Science of the Total Environment, 2006; Song, Yu, et al., "Source apportionment of PM2.5 in Beijing by positive matrix factorization," Atmospheric Environment, 2006; Wang, Q., et al, "Source apportionment of fine organic aerosols in Beijing," Atmospheric Chemistry and Physics, Issue 9, p. 8573–8585, 2009; Zhang, Yuanhang, et al., Urbanization, Energy, and Air Pollution in China: The Challenges Ahead—Proceedings of a Symposium (China: National Academies Press, 2004); Wang, Hailin, et al., "Long-term monitoring and source apportionment of PM2.5/PM10 in Beijing, China," Journal of Environmental Sciences, Issue 20, 2008; Zheng, Mei, et al., "Seasonal trends in PM2.5 source contributions in Beijing, China," Atmospheric Environment, Issue 39, 2005*
*4. "New cars in Beijing cut by two-thirds to battle traffic," BBC, December 24, 2010, www.bbc.co.uk*
*5. Wu, Ye, et al., "On-Road Vehicle Emission Control in Beijing: Past, Present, and Future," Environmental Science and Technology, Issue 45, 2011*
*6. Zheng, Mei, et al., "Seasonal trends in PM2.5 source contributions in Beijing, China," Atmospheric Environment, Issue 39, 2005*

**Beijing Air Quality Index (AQI) Average Daily PM2.5 Level, January 2012**




*Source: U.S. Embassy, using data compiled from www.lantiantian.com, accessed on January 30, 2012*

### Air pollution in Beijing depends on the wind: True

Winds from the north bring fresher air on average, whereas winds from the south import emissions from industrial areas of Hebei and Tianjin. Up to 40% of particulates come from outside the boundaries of the vast Beijing Municipality on days with winds from the south.[7] 72% of PM2.5 blowing in from outside comes from industrial and power plant sources. Haze levels can change dramatically in a matter of an hour or so when the wind shifts. Satellite photos confirm that air pollution often extends across a broad multi-province area centering to the south of Beijing.[8]

### There is a discrepancy between Chinese air monitoring and that of other countries: True

Beginning in the 1990s, U.S. and European environmental agencies began to respond to scientific findings that showed the severe health consequences of inhaling PM2.5 concentrations over even short periods.[9] In 1997, the U.S. Environmental Protection Agency (EPA) adopted a daily and annual PM2.5 standard.[10] This standard is also used at an air quality monitor at the U.S. Embassy in Eastern Beijing. Chinese government air quality announcements are widely available, but until recently all were based on PM10 levels. Often the contrast between the tone of public announcements in China with the observed PM2.5 level can be dramatic. For example, in early December 2011, the Beijing airport delayed dozens of flights due to heavy smog as the U.S. Embassy reported air quality index (AQI) levels at or near 500, rated as "hazardous for the entire population," but Chinese PM10 levels continued to suggest the air was "lightly polluted."[11] Reports for Beijing are based on daily average readings from monitoring stations located throughout the Beijing area, including stations in rural areas.[12] In mid-December 2011, the Beijing Municipal Environmental Protection Bureau (EPB) noted the city had achieved its 2011 target of 274 Blue Sky Days "ahead of schedule," with 22 more Blue Sky Days than 2010.[13] Using the same particulate matter readings under different standards would have yielded substantially different results: whereas from January through October 2011 Beijing rated 77% of days as Blue Sky Days, under Hong Kong standards 80% of days would have rated as high pollution, and under European Union standards 82% of days would have rated as high or very high pollution.[14]

*7. Wang, T., et al., "Air quality during the 2008 Beijing Olympics: secondary pollutants and regional impact," Atmospheric Chemistry and Physics, Issue 10, 2010; Wang, Litao, et al., "A Modeling Study of Coarse Particulate Matter Pollution in Beijing: Regional Source Contributions and Control Implications for the 2008 Summer Olympics," Journal of the Air and Waste Management Association, Issue 58, August 2008*

*8. "NASA Earth Data, FAS China4 Subset - Aqua 1km True Color 2008/206 (07/24)," NASA, earthdata.nasa.gov, accessed on January 29, 2012*

*9. Pope III, C. Arden and William Dockery, "Health Effects of Fine Particulate Air Pollution: Lines that Connect," Journal of the Air and Waste Management Association, Issue 56, 2006*

*10. Esworthy, Robert, "Particulate Matter (PM2.5): Implementation of the 1997 National Ambient Air Quality Standards (NAAQS)," Congressional Research Service, August 24, 2010*

*11. "12月6日全国重点城市空气质量日报 北京轻微污染" [Daily air quality of China's major cities on December 6: Beijing minor contamination], Xinhua, December 6, 2011, www.xinhua.com; "北京市环保局：12月5日空气质量为轻度污染" [Beijing Municipal Environmental Protection Bureau (EPB): air quality on December 5 is light pollution], ifeng, December 5, 2011, www.ifeng.com; "大雾造成首都机场157架次航班不正常" [The fog caused 157 flights in Beijing Capital International Airport delay], STCN, December 5, 2011, www.stcn.com; "12月4日北京大雾PM2.5浓度超极限值" [Fog PM2.5 in Beijing on December 4 exceeds limits], STCN, December 5, 2011, www.stcn.com*

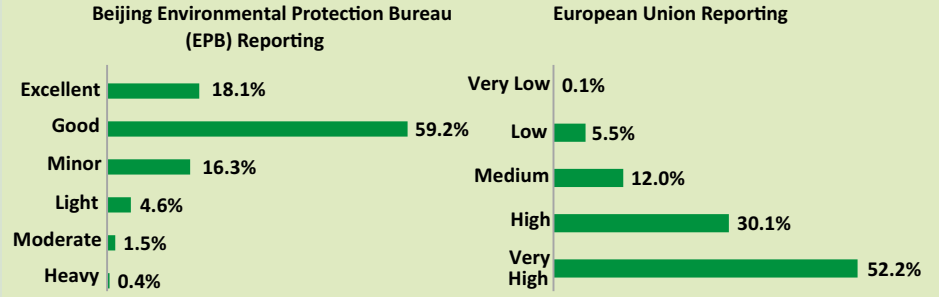
*12. Andrews, Steven Q., "Inconsistencies in air quality metrics: 'Blue Sky' days and PM10 concentrations in Beijing," Environmental Research Letters, Issue 3, 2008*

*13. "Beijing reaches annual 'blue sky days' target," China Daily, December 18, 2011, www.chinadaily.com*

*14. Andrews, Steven, "Beijing's hazardous blue sky," chinadialog, December 5, 2011, www.chinadialogue.net*

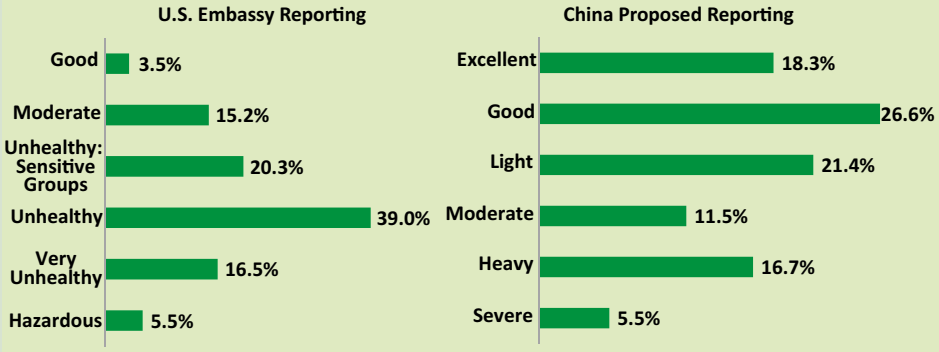
In 2011, the Chinese government suggested public data on PM2.5 would have to wait until 2016, but in late 2011, the Beijing government announced it would have hourly, location-specific PM2.5 monitoring in place within a year, with some experimental data available by Chinese New Year in January 2012.[15] On Chinese New Year's eve, Beijing officials reported that fireworks had caused PM2.5 levels to spike to 1,593 μg/m$^3$ over the course of a few hours, far beyond the U.S. EPI AQI uppermost value of 500 μg/m$^3$.[16] Nonetheless, even under the newly released standards on PM2.5, Beijing may average "excellent" or "good" on around 45% of days, whereas using U.S. AQI figures pollution would rate as "good" or "moderate" pollution on just 20% of days.[17]

**How Do Beijing's PM10 Pollution Reports Compare?**




*Note: Comparison of actual Beijing PM10 average daily pollution levels from January 2010 to October 2011, as classified under Beijing EPB's reporting methods versus European Union reporting methods, in both cases based on public data from Beijing EPB PM10 monitoring stations.*
*Source: Andrews, Steven, "Beijing's hazardous blue sky," chinadialog, December 5, 2011, www.chinadialogue.net*

**In The Future, How Will Beijing's PM2.5 Pollution Reports Compare?**




*Note: Comparison of actual Beijing PM2.5 average daily pollution levels from January 2010 to October 2011, as classified under Beijing EPB's proposed reporting methods versus U.S. EPA reporting methods, in both cases based on public data from the U.S. Embassy in Beijing.*
*Source: Andrews, Steven, "Beijing's hazardous blue sky," chinadialog, December 5, 2011, www.chinadialogue.net*

## Pollution in Beijing is getting worse: Disputed

In January 2012, CCTV reported that Beijing has experienced a decade of progress reducing average PM2.5 concentrations, flashing a graphic showing levels have fallen from 100-110 μg/m$^3$ in 2000 to 80-90 in 2005 and 70-80 in 2010.[18] Bloggers were quick to point out differences between this data and academic studies available from other Chinese sources showing no obvious trend.[19] In November 2011, a Xinhua story reported on a Chinese Academy of Sciences (CAS) study that found while PM10 concentrations have fallen 2% to 3% annually since 2000, PM2.5 concentrations have risen 3% to 4% annually.[20] In contrast, oxides of sulfur ($SO_x$) and oxides of nitrogen ($NO_x$), emissions targeted under the 11th Five-Year Plan did show marked improvement. In 2008, yet another study showed that previous trend data on particulate emissions had been affected by the addition of rural stations, along with selective data modification—without the changes, annual average PM10 concentrations would have shown little or no change.[21] Du Shaozhong, deputy director of Beijing's EPB, responded to the 2008 study by noting: "Over the past 10 years, through our enormous hard work, Beijing's air pollution has visibly improved... This is an indisputable fact."[22]

*15. "PM2.5: a gauge easy to monitor but hard to control," Xinhua, January 10, 2011, www.xinhuanet.com*
*16. "New Year fireworks spree leaves Beijing's air smothering for hours," Xinhua, January 24, 2012, www.xinhuanet.com*
*17. Andrews, Steven, "Beijing's hazardous blue sky," chinadialog, December 5, 2011, www.chinadialogue.net*
*18. "Beijing releases PM2.5 monitoring data," CNTV, January 8, 2012, www.china.org.cn*
*19. "Beijing claims PM2.5 reductions," Livefrombeijing, January 16, 2012, www.livefrombeijing.com*
*20. "Expert: Beijing's PM2.5 air pollution getting worse," People's Daily, December 12, 2011, www.peopledaily.com*
*21. Andrews, Steven Q., "Inconsistencies in air quality metrics: 'Blue Sky' days and PM10 concentrations in Beijing," Environmental Research Letters, Issue 3, 2008*
*22. Yardley, Jim, "Consultant Questions Beijing's Claim of Cleaner Air," New York Times, January 10, 2008, www.nytimes.com*

Jim Gourley

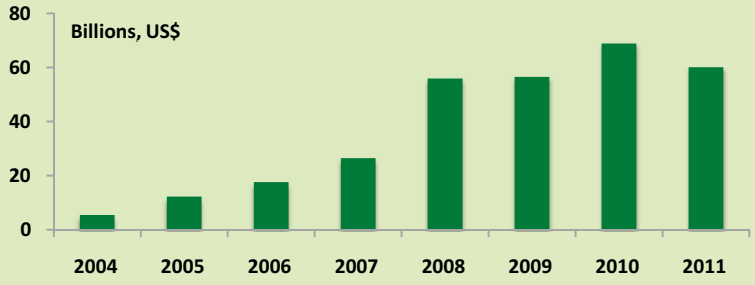
# To Secure Its Energy Future, China Is Expanding Abroad

Given the scale and rapid growth of China's energy needs, China's leaders recognized early on that the stability, security and sustainability of energy supply would depend on active policies to support the domestic energy industry. Now that China has achieved world-leading results in areas such as renewable energy and high-speed rail, the government and companies seek to go abroad both to capitalize on the country's successes while continuing to secure resources and technologies. 2011 saw a continuation of an earlier trend where the energy sector dominated outbound investments, with companies going abroad for energy deals in the areas of oil and renewable energy. The deals in 2011 also highlighted a new push for investing in basic infrastructure, such as European water and power grid utilities, to achieve asset diversification and financial returns. As the developed world copes with economic challenges, China will continue to deploy its capital, labor and technology abroad, deepening international collaboration and cooperation while also occasionally capturing unflattering press attention.

## China's outbound investment trend continues

Mainland China's non-financial outbound foreign investment grew to US$ 60.1 billion in 2011, representing growth of just 1.8% versus 2010. This represented 1,392 overseas projects in 132 countries. This figure has grown from just US$ 5.4 billion in 2004 and US$ 26.5 billion in 2007.[152] The outstanding value of Mainland China's outbound investment stock was US$ 322 billion at the end of the year.[153] These figures are likely underestimated because many small and medium enterprises in China do not register their investments.[154] According to the Ministry of Commerce (MOFCOM), China's outbound direct investments will grow by 30% annually and will exceed foreign

**China's Annual Outbound Direct Investment (ODI), US$ billion, 2004-2010**




*Sources: "Statistics," Ministry of Commerce (MOFCOM), accessed on January 13, 2012; "China's non-financial ODI totals 60.07 bln USD in 2011," People's Daily, January 19, 2012, peopledaily.com.cn*

*152. "2010 Statistical Bulletin of China's Outward Foreign Direct Investment (FDI)," Ministry of Commerce (MOFCOM), 2010, hzs.mofcom.gov.cn, accessed on February 14, 2012*
*153. Zhou, Xin and Nick Edwards, "China 2011 FDI stutters to record US$ 116 billion," Reuters, January 17, 2012, www.reuters.com*
*154. Mlachila, Montfort and Misa Takebe, "FDI from BRICs to LICs: Emerging Growth Driver?" IMF, July 2011*

direct investment (FDI) into China within three years. The U.S. Asia Society estimates that by 2020 China's worldwide overseas assets may reach US$ 2 trillion.[155] Similarly, the Vale Columbia Center on Sustainable International Investment at Columbia University estimates China will strike US$ 1-2 trillion in outbound direct investment (ODI) deals over the coming decade.[156]

However, with all the headlines about China buying the world—echoing earlier worries about the U.S. doing the same in Europe in the 1960s or Japan acquiring U.S. assets in the 1980s—it's important to recognize that China's foreign investment stock is a tiny proportion of total foreign-owned assets worldwide. At the end of 2010, China's investment stock accounted for just 1.2% of such assets worldwide, comparable to the ODI assets of Denmark, and less than one-twentieth those of the U.S.[157] China's investments in the U.S. are tinier still: just 0.25% of outbound investment stock, less than those of Brazil or Russia.[158]

**China accounts for 8% of global trade, and outbound investments will possibly accelerate in light of the European debt crisis.**

Still, since China accounts for 8% of global trade, the trend toward outbound investments will continue—and possibly accelerate in light of the European debt crisis. In Portugal, Chinese state-owned companies have recently acquired stakes in both the national power utility, Eletricidad de Portugal (EDP), and the grid owner, Redes Energéticas Nacionais (REN), in the wave of privatizations required by international lenders. The State Grid News, the official publication of China's State Grid, said the privatization of state-owned European assets has "created entry opportunities" for China.[159] As one influential government official noted about the economic crisis, "This is the opportunity that occurs only once in a thousand years."[160] Other press reports noted, however, that countries like Spain or Greece may be less receptive.[161]

### The effort to go abroad has both policy and commercial motives

China's push into foreign investment began with a quest for resources, and is broadening to include other motivations and strategies, such as seeking new markets, new technologies and even lower-cost labor.[162] Foreign investment has also been actively supported by government policy, especially since 2004 when the National Development and Reform Commission (NDRC) and the China Export-Import Bank announced policies to support outbound investments in four strategic areas: natural resources, promotion of export of domestic technologies, research and development (R&D), and mergers and acquisitions (M&A) to enhance domestic competitiveness.[163] In March 2011, the NDRC eased limits on outbound investment by Chinese companies, eliminating approval requirements for resources-related outbound investments under US$ 300 million and non-resource investments below US$ 100 million.[164] In May 2011, MOFCOM announced new policy supports for outbound investments, including low-cost loans and subsidies for items, such as legal services, mineral exploration, project feasibility studies, translation services, trademark filings, and personnel insurance coverage and worker training.[165]

*155. Zhou, Yan, "Energy firms increase the pace of overseas M&A," China Daily, December 6, 2011, www.chinadaily.com*
*156. Edwards, Nick, "Analysis: China's US$ 300 billion fund a wake-up call to U.S.," Reuters, December 14, 2011, www.reuters.com*
*157. Rosen, Daniel H. and Thilo Hanemann, "An American Open Door: Maximizing the Benefits of Chinese Foreign Direct Investment," Asia Society, July 2011*
*158. Hanemann, Thilo, "It's Official: Chinese FDI in the U.S. Is Soaring," Rhodium Group, August 25, 2011, www.rhgroup.net*
*159. Kang Lim, Benjamin and David Stanway, "China power giants flex muscles abroad," Reuters, February 9, 2012, www.reuters.com*
*160. Edwards, Nick, "Analysis: China's US$ 300 billion fund a wake-up call to U.S.," Reuters, December 14, 2011, www.reuters.com*
*161. "Deal Profile: China Three Gorges Buys EDP Stake for US$ 3.51 Billion," The Wall Street Journal, December 23, 2011; Subler, Jason, "EDP deal highlights China's desire for physical assets," Reuters, December 23, 2011, www.reuters.com*
*162. Rosen, Daniel H. and Thilo Hanemann, "An American Open Door: Maximizing the Benefits of Chinese Foreign Direct Investment," Asia Society, July 2011*
*163. Salidjanova, Nargiza, "Going Out: An Overview of China's Outward Foreign Direct Investment," U.S.-China Economic & Security Review Commission, March 31, 2011, www.uscc.gov*
*164. "China's NDRC to Ease Limits on Outbound Investment, Daily Reports," Bloomberg, March 2, 2011, www.bloomberg.com*
*165. "财政部 商务部关于做好2011年对外经济技术合作专项资金申报工作的通知" [Ministry of Finance (MOF) and MOFCOM published the Notice About Special Funds Declaration on 2011 External Economic and Technical Cooperation], MOFCOM, May 9, 2011*

These policies have had an impact. A 2010 survey by the China Council for the Promotion of International Trade showed that company motivations for overseas investments were driven by the central government's policy incentives for going abroad, followed by availability of low-cost capital and the desire to reduce local labor costs given that Chinese labor costs have grown substantially, as noted earlier.[166] Even so, many observers have noted that Chinese companies do not invest abroad just because the government says so: an International Monetary Fund (IMF) study found that overseas investments from China were similar to those from other countries.[167]

China's outbound investment trend has provoked a mixed response. China's ODI has many international benefits, especially in a period of world economic distress when many countries lack capital. China has expressed an interest in helping major U.S. cities refurbish aging road and subway infrastructure.[168] And U.S. trade missions now routinely emphasize investment opportunities as well as American products—such as a recent visit by the mayor of Milwaukee to Ningbo, which sought to highlight opportunities to invest in Wisconsin's food and beverage industry.[169]

In China's case, the country's size, its focus on acquiring natural resources and technologies, and its pervasive government involvement in its economy have raised particular concerns.[170] This past year, press reports have focused on Chinese state-owned banks using lending to ensure domestic firms gain access to lucrative markets or technologies. For example, in the energy sector, a Reliance Power order for US$ 10 billion worth of Shanghai Electric power equipment was financed by Chinese banks. As Vidhan Goyal, a professor of finance at the Hong Kong University of Science and Technology, noted in a Reuters report, "If it helps China, the banks will lend."[171]

Such criticism will undoubtedly continue as China steps up efforts to diversify away from pure resource-acquisition deals. For example, when China Three Gorges acquired a stake in the Portuguese utility EDP, press reports noted, "to win such deals, [China] is able to harness a formidable advantage that few other countries or companies possess—alliances between its state-owned industrial firms and state-owned banks, with the backing of the government."[172]

**In 2011, press reports focused on Chinese state-owned banks using lending to ensure domestic firms gain access to lucrative markets or technologies.**

### China's outbound investments have diversified globally

In the past few years, Chinese investment flows have diversified away from the developing world. Initially, Latin America accounted for the bulk of Chinese foreign investment, but this is no longer the case. "China's investments in Europe and Africa were particularly strong in 2011," according to Shen Danyang, the spokesman of MOFCOM.[173] The U.S., the European Union and Latin America will be the focus for Chinese investment in the next few years, according to Zheng Chao, a commercial counselor at MOFCOM, speaking in May 2011.[174] Industrialized countries are the major destinations for M&A deals in terms of transaction volume.[175]

*166. "Survey on Current Conditions and Intention of Outbound Investment by Chinese Enterprises," China Council for the Promotion of International Trade, April 2010*
*167. Mlachila, Montfort and Misa Takebe, "FDI from BRICs to LICs: Emerging Growth Driver?" IMF, July 2011; Rosen, Daniel H. and Thilo Hanemann, "China's Changing Outbound Foreign Direct Investment Profile: Drivers and Policy Implications," Peterson Institute for International Economics, p. B09-14, June 2009*
*168. "China wants to invest in U.S. roads and subways," Associated Press, December 2, 2011, www.cleveland.com*
*169. Sandler, Larry, "Milwaukee mayor set for second trade mission to China," Milwaukee Journal Sentinel, December 3, 2011, www.jsonline.com*
*170. Rosen, Daniel H. and Thilo Hanemann, "China's Changing Outbound Foreign Direct Investment Profile: Drivers and Policy Implications," Peterson Institute for International Economics, p. B09-14, June 2009*
*171. Ibid.*
*172. "Deal Profile: China Three Gorges Buys EDP Stake for US$ 3.51 Billion," The Wall Street Journal, December 23, 2011; Subler, Jason, "EDP deal highlights China's desire for physical assets," Reuters, December 23, 2011, www.reuters.com*
*173. Zhou, Xin and Nick Edwards, "China 2011 FDI stutters to record US$ 116 billion," Reuters, January 17, 2012, www.reuters.com*
*174. Zhou, Yan, "Energy firms increase the pace of overseas M&A," China Daily, December 6, 2011, www.chinadaily.com*
*175. Ibid.*

## Energy still dominates

Although the trend has started to shift, energy still dominates China's outbound investment field. During the first nine months of 2011, energy, chemicals and materials accounted for more than 50% percent of China's outbound M&A deals.[176] As before, oil and gas remain major focus areas: China Petroleum and Chemical Corporation (Sinopec), China National Petroleum Corporation (CNPC) and China National Offshore Oil Corporation (CNOOC) are the top three holders of overseas investment assets, according to MOFCOM statistics.[177] For Chinese energy companies, unconventional natural gas resources in Canada and Australia as well as liquefied natural gas (LNG) resources in Australia are the major targets for deals, according to CNPC's research unit.[178]

**During the first nine months of 2011, energy, chemicals and materials accounted for more than 50% percent of China's outbound M&As.**

Natural resource transactions also tend to be large, as a sampling of oil and gas deals announced in the past year shows:

- PetroChina agreed to acquire a stake in two U.K. refineries owned by Ineos, a U.K. chemical producer, for an undisclosed sum. According to the Financial Times, the deal gives PetroChina refining expertise and access to Europe's refining markets (January 2011).[179]
- Sinopec signed a preliminary deal for 20 years of LNG supplies with Australia Pacific LNG, in which Sinopec will acquire 15% of a Queensland, Australia, coal seam project owned by U.S. integrated oil company ConocoPhillips and Australia's Origin Energy (February 2011).[180]
- CNOOC agreed to acquire Opti Canada Inc. for US$ 2.1 billion in cash and debt to increase its oil-sands reserves (July 2011).[181]
- Sinopec bought a stake in U.S. integrated oil company Chevron's deepwater Indonesian project for US$ 680 million (October 2011).[182]
- Sinopec acquired Canada's Daylight for US$ 2.1 billion to gain access to Canadian shale-gas assets (October 2011).[183]
- Sinopec announced a US$ 3.5 billion deal to acquire a 30% stake Portuguese energy company Galp Energia SA's Brazilian unit (November 2011). The deal mirrored Sinopec's 2010 deal with Spanish oil company Repsol YPF SA to acquire Respol's Brazilian unit for US$ 7.1 billion.[184]
- Sinopec invested US$ 2.2 billion in U.S. oil and gas producer Devon (January 2012). The focus of the deal is on producing gas from shale deposits across the U.S., including in Colorado, Alabama, Mississippi, Ohio and Michigan.[185]

In addition to these large deals, China's oil and gas firms suffered two major acquisition-related setbacks in 2011: PetroChina's planned US$ 5.5 billion joint-venture with Canada's Encana to develop shale gas assets in the Cut Bank Ridge collapsed after the two sides failed to come to terms.[186] And in November 2011, CNOOC terminated negotiations to acquire a US$ 7.1 billion stake in the Argentine crude producer Pan American Energy, held by BP PLC.[187]

*176. Zhou, Yan, "Energy firms increase the pace of overseas M&A," China Daily, December 6, 2011, www.chinadaily.com*
*177. "2010 Statistical Bulletin of China's Outward Foreign Direct Investment," MOFCOM, 2010, hzs.mofcom.gov.cn, accessed on February 14, 2012*
*178. Zhou, Yan, "Energy firms increase the pace of overseas M&A," China Daily, December 6, 2011, www.chinadaily.com*
*179. Pfeifer, Sylvia and James Blitz, "PetroChina takes stake in UK refinery," Financial Times, January 10, 2011, www.ft.com*
*180. Bai, Jim and Rebekah Kebede, "Sinopec, Australia Pacific in 20-yr LNG deal," Reuters, February 25, 2011, www.reuters.com*
*181. "CNOOC Agrees to Buy Opti Canada for US$ 2.1 Billion to Expand Oil-Sand Assets," Bloomberg, July 20, 2011, www.bloomberg.com*
*182. Driver, Anna, "Sinopec, Devon in US$ 2.2 billion shale deal," Reuters, January 3, 2012, www.reuters.com*
*183. "Sinopec Buys Canada's Daylight for US$ 2.1 Billion to Gain Shale-Gas Assets," Bloomberg, October 11, 2011, www.bloomberg.com*
*184. Zhou, Yan, "Energy firms increase the pace of overseas M&A," China Daily, December 6, 2011, www.chinadaily.com*
*185. Driver, Anna, "Sinopec, Devon in US$ 2.2 billion shale deal," Reuters, January 3, 2012, www.reuters.com*
*186. Nicholson, Chris V., "Encana's Natural Gas Deal with PetroChina Collapses," New York Times, June 21, 2011, www.nytimes.com*
*187. Zhou, Yan, "Energy firms increase the pace of overseas M&A," China Daily, December 6, 2011, www.chinadaily.com*

### Renewable energy is a new hot area

Though renewable energy deals announced over the last year are smaller than those in oil and gas, they cover a broad range, including acquiring manufacturing capacity abroad, partnerships and joint ventures (JVs) for technologies, and international renewable energy plant development on both small and large scales:

- Sinovel Wind announced it would partner with Greek power producer PPC to develop renewable energy projects, potentially involving development of a 200-300 MW wind farm and an offshore wind park (April 2011).[188]
- Suntech Power Holdings Co. said it hired more workers and is expanding its manufacturing plant in Arizona to produce 50 MW of panels annually (March 2011).[189]
- Goldwind announced in 2011 cooperation deals with Timken, a bearings manufacturer, LM Windpower for blades, Broadwind Towers for tower components and Switch for megawatt-class permanent magnet generators and full-power converters.[190]
- China Longyuan Power Group Co. purchased a stake in a 100 MW wind farm being built by Canadian power company Farm Owned Power (Melancthon) Ltd. (July 2011).[191]
- ENN Mojave Energy, a division of Chinese ENN Group, announced plans to build a 720 MW solar farm and adjacent thin-film manufacturing facility in Nevada (July 2011).[192]
- Sany Electric announced the completion of a 10 MW wind plant in the Texas Panhandle, which will supply power to U.S. utility Xcel Energy (August 2011).[193]
- Xinjiang Goldwind Science and Technology Co. announced it will build a US$ 200 million wind farm in Illinois (September 2011).[194]
- China Datang Corporation Renewable Power and Baoding Tianwei Baobian Electric jointly acquired a 100 MW wind farm in New South Wales, Australia, with local partner, CBD Energy (September 2011). A JV established by the three companies, called AusChina, will spend A$ 3 billion to construct renewable plants in the region.[195]
- Guohua announced it would pay US$ 89 million for stakes in two wind farms with a total of 140 MW of capacity in Tasmania, Australia (December 2011).[196]
- LDK Solar announced plans to purchase Germany's Sunways AG for Euro 24 million to acquire inverter technology and an improved sales distribution network in the German solar market (January 2012).[197]
- Flexible thin-film solar PV manufacturer Ascent Solar Technologies announced China's TFG Radiant Group would acquire an additional 21% equity stake for US$ 4 million (January 2012).[198]

*188. "Greece's PPC, China's Sinovel sign wind power deal," Reuters, April 13, 2011, www.reuters.com*
*189. "Suntech adds a third shift at Arizona solar plant," Bloomberg Businessweek, May 17, 2011, www.businessweek.com*
*190. "Leading Chinese wind turbine maker signs deals in U.S. to explore overseas market," Xinhua, May 24, 2011, www.news.xinhuanet.com*
*191. "China's largest wind power developer marches into Canadian market," Xinhua, July 14, 2011, www.xinhuanet.com*
*192. "ENN Mojave Energy planning to build 720 MW solar system and manufacturing plant in Nevada," Energy Efficiency News, July 7, 2011, www.energyefficiencynews.com*
*193. "China's Sany Electric completes first US wind project," Wind Power Monthly, August 4, 2011, www.windpowermonthly.com/home*
*194. "China's Goldwind Signs $200 Million Wind Farm Contract In US," Fox Business, September 18, 2011, www.foxbusiness.com*
*195. "Datang Renewable Jointly Acquires Australian Wind Farm," e-wind, September 23, 2011, www.evwind.es*
*196. "Guohua pays US$ 88.6m for stakes in Hydro Tasmania wind farms," The Australian, December 22, 2011, www.theaustralian.com.au*
*197. Nicola, Stefan, "LDK Solar Enters German Market," Bloomberg, January 2, 2012, www.bloomberg.com*
*198. "China's Solar PV Players Ramp Up Overseas Investments," Cleantechnica, January 5, 2012, cleantechnica.com*

### China is interested in basic infrastructure for profits and diversification

Though the list and sizes of Chinese deals in renewables, oil and gas is impressive, some major deals in the area of basic infrastructure have captured more attention over the past year, partly because the deals suggest the trend of things to come.

- China Three Gorges announced it would pay Euro 2.7 billion for the Portuguese government's stake in its national utility EDP (December 2011). To win the stake, China Three Gorges out-bid German utility E.On and Brazil's Eletrobras by offering a 53% premium to the listed share price, and by negotiating access to Chinese financing for the Portuguese national utility.[199]
- China Investment Corporation (CIC) bought a 9% stake in the U.K.'s Thames Water Utilities for an undisclosed sum, which analysts estimated would be at least GBP 500 million (January 2012).[200]
- China's State Grid Corp. announced it would spend Euro 387 million to acquire 25% of Portugal's power grid operator, REN (February 2012).[201]

These deals have created excitement partly because they appear to be a clear indication that Chinese energy companies are not just looking abroad for resources and technology. Instead, these assets will allow Chinese state-owned companies—including both energy firms and banks—to deploy resources in ways that diversify their businesses and create more stable returns over time. And while technology is not an explicit area of these three deals, they do offer the potential for greater international collaboration in areas such as the smart grid or vehicle charging, as Chinese and European policies continue to promote sustainability.

**International partnerships will allow Chinese state-owned companies to deploy resources in ways that diversify their businesses and create more stable returns over time.**

### Challenges for companies going abroad

As China's state-owned and private companies go abroad looking for assets or establishing business activities, past experience yields a number of lessons that will help them succeed. An IBM survey of Chinese companies going global showed that companies face a number of challenges, most importantly: (1) lack of human resources, especially qualified management that can work well with the Chinese parent company, (2) difficulty building global brands, (3) difficulties designing and managing a global business model, and (4) business process challenges. For most energy companies, building a qualified management team and overcoming basic global business process challenges are likely to be the most universal. For technology and manufacturing firms, maintaining a technology and cost edge by continuous improvement is an additional challenge. For all four of these areas, companies are likely to need additional investments to ensure training and adjustment to global operations. For human resources, especially recruiting talented management, acquisitions can be a more effective model for Chinese companies compared to training a team in China or recruiting global professionals—such as overseas Chinese—in the host country.[202]

*199. "Deal Profile: China Three Gorges Buys EDP Stake for US$ 3.51 Billion," The Wall Street Journal, December 23, 2011, asia.wsj.com/home-page; Subler, Jason, "EDP deal highlights China's desire for physical assets," Reuters, December 23, 2011, www.reuters.com*

*200. Gosden, Emily, "Santander sells Thames Water stake to China," Telegraph, January 20, 2012, www.telegraph.co.uk*

*201. Kang Lim, Benjamin and David Stanway, "China power giants flex muscles abroad," Reuters, February 9, 2012, www.reuters.com*

*202. Beebe, Alan, et al., "Going Global," IBM Business Services (Somers, NY: IBM Corp., 2006)*

The IBM study's findings were broadly similar to a discussion CGTI held in January 2012 with senior Chinese and international executives looking to partner, invest or expand internationally. Business leaders identified top challenges as ensuring technologies and solutions offered by Chinese firms will match the needs of new markets, understanding and complying with regulations in multiple countries, and navigating overseas public perceptions about Chinese companies.[203] Overcoming these challenges can be difficult, and most Chinese companies are in the early stages of going abroad, but the rewards to diversification and growth are apparent.



**CGTI Perspective**

China's outbound investment trend has been apparent for several years, but in reality, this trend is only at its initial stages. Over the next year, not only will investment flows continue to rise, but the trend towards diversification into infrastructure and new markets will also increase. These trends will increase opportunities for business services, international investment and international greentech cooperation.

*203. CGTI analysis*

# Market Opportunities

Chelsea Eakin

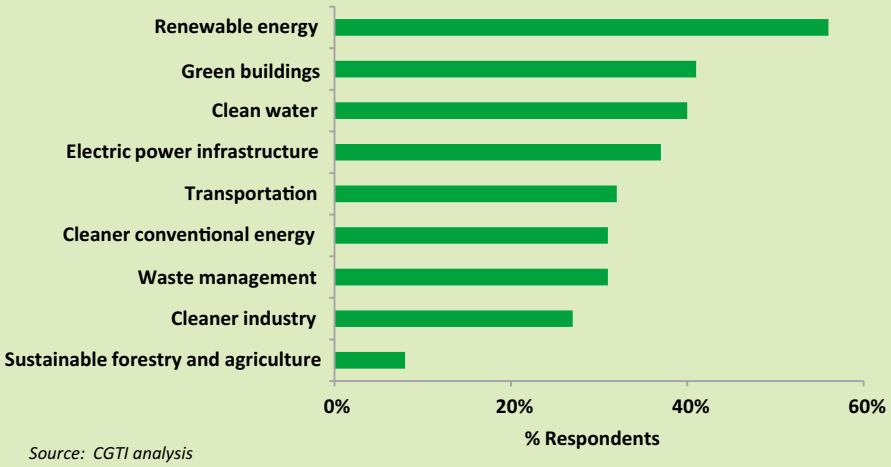
Given the rapid changes underway in China's greentech sectors, market opportunities can change quickly. In last year's Report, CGTI identified renewable energy, cleaner transportation (particularly high-speed rail) and clean water as the most appealing subsectors from the overall perspective of government policy, openness and solution attractiveness. With the exception of high-speed rail, where growth and investment slowed after a major accident in mid-2011, these assessments were confirmed by trends visible in 2011.

## CGTI survey results confirm importance of policy

In mid-2011, CGTI conducted an extensive greentech investment climate survey of 133 Partners and other members of the CGTI community—including investors, technology solution providers, technology buyers and other market participants. Respondents were mainly business unit executives or other top-level managers—and a full 14% were company CEOs. By region, most responses came from Mainland China (36%), the U.S. (30%) and Europe (24%), with other regions accounting for the remaining 10%.

Overall, survey participants were very positive about greentech markets, with over 75% either optimistic or very optimistic about the near-term future. Survey participants favored the renewable energy, green building and clean water segments of the market, and cited offshore wind and solar as the most attractive renewable fields.

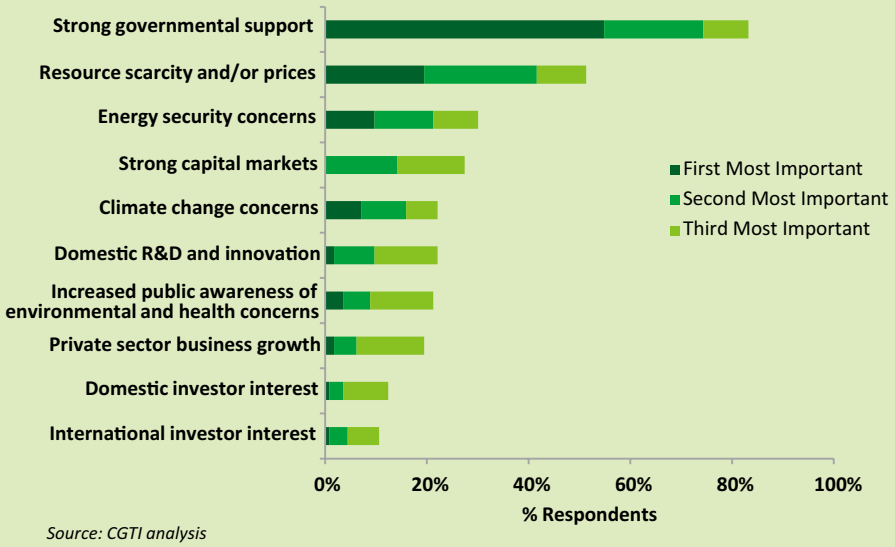
**Which Areas Will Offer the Highest Investment Returns Over the Next Three Years?**




*Source: CGTI analysis*

The survey's more important result, however, was participants' views on the nature of China's greentech markets. Respondents overwhelmingly agreed that government support is the main factor driving greentech investment, and that obstacles related to government programs were the main impediments. Resource scarcity, resource prices and energy security concerns were also major factors driving investment in greentech markets.

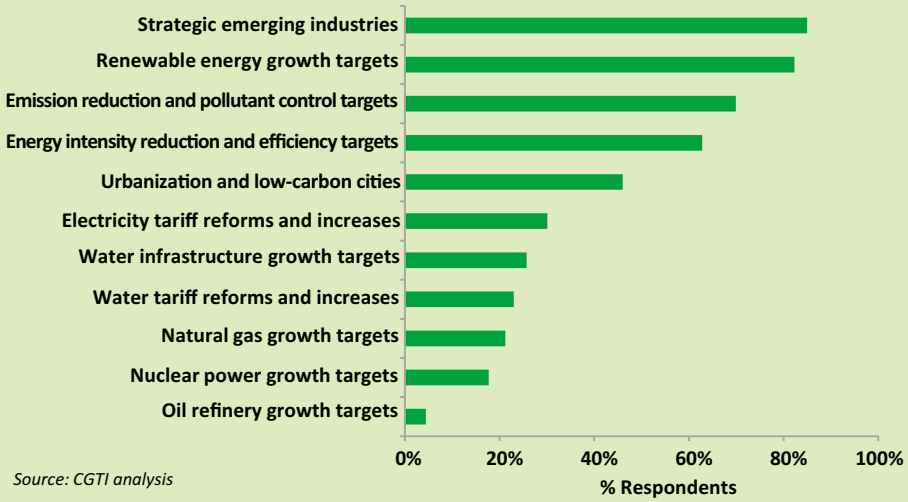
**Most Important Factors for Greentech Investments in China Over the Next Two Years**




*Source: CGTI analysis*

Among policies respondents considered important, the most critical were industrial policies related to strategic emerging industries (SEIs), followed by targets in renewable energy, emissions and carbon intensity. Policies on water, nuclear and oil were viewed as less important to respondents. As for the reason why respondents view investing or doing business in China's greentech markets as attractive, the main motivation is the high levels of investment in the field, as opposed to the large market or prospects for good profit margins.

**What Elements of Government Policy Are Most Important?**




*Source: CGTI analysis*

This result confirms CGTI's past emphasis on policy developments as central to accelerating greentech markets in each field—and it also shows the potential risk of the greentech field, since macro-economic challenges that affect spending in the area will have a relatively outsized effect on progress. Indeed, the importance of high investment levels to business interest in greentech underlines the potential for volatility in this field.

## Top Market Opportunities for 2012

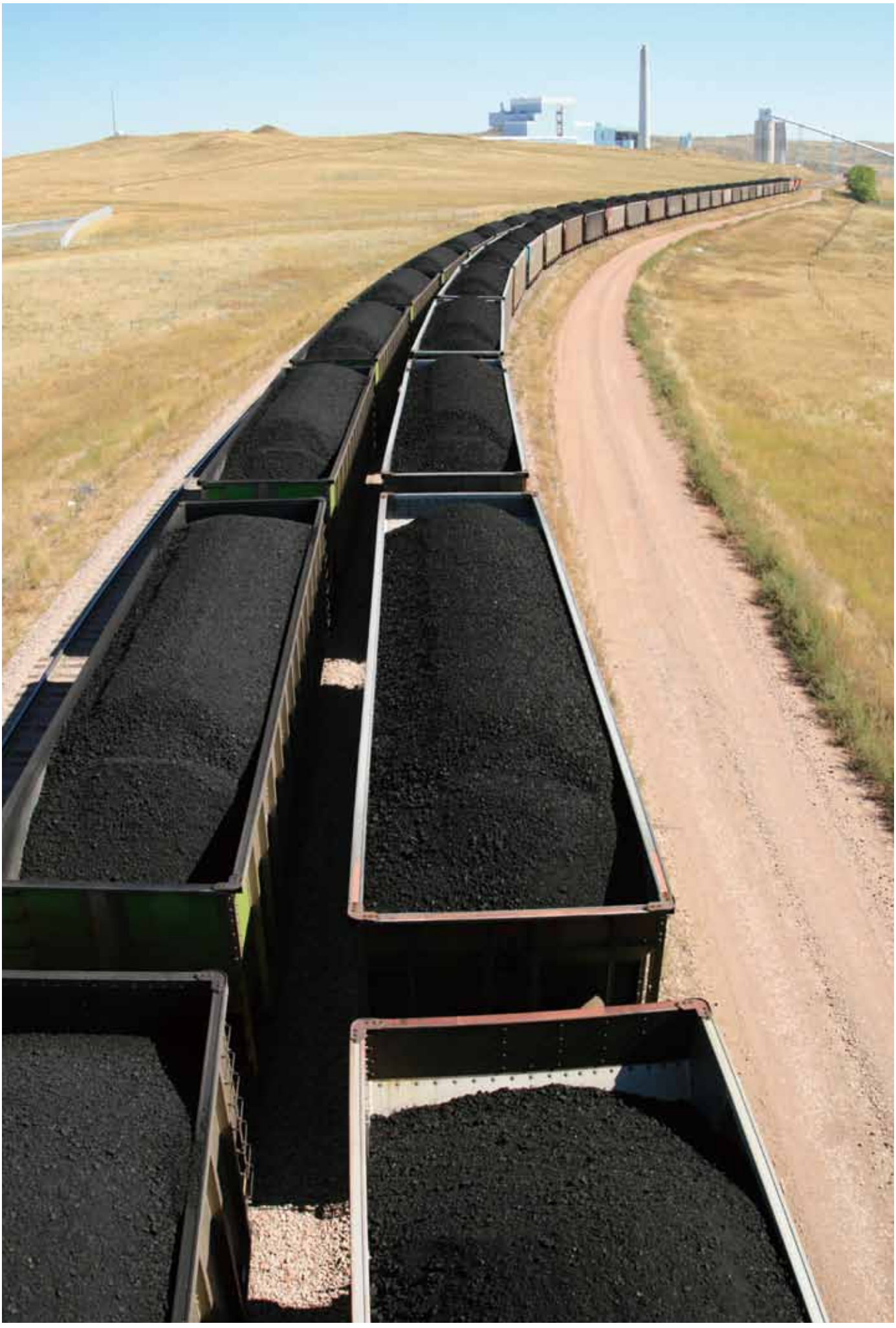
This year, CGTI has taken a different overall approach to identifying market opportunities, looking more at individual technologies instead of evaluating sector attractiveness. This report, in the sector chapters that follow, briefly summarizes a small subset of the most important opportunities identified in the 2011 Partner Program, and they cover a broad range:

- **Cleaner Conventional Energy:** Natural gas infrastructure, distributed gas power, power plant mercury monitoring and control, coal-bed methane, and advanced nuclear power.
- **Renewable Energy:** Moving photovoltaic module production overseas, retrofitting wind turbines for higher output, and biogas production.
- **Electric Power Infrastructure:** Intermittent power management, distributed energy management, energy storage, charging infrastructure, and grid communication networks.
- **Green Buildings:** Green building design, building energy retrofits, green building material supply, integrated energy efficiency solutions, and green building energy management.
- **Cleaner Transportation:** Advanced drivetrains, battery raw material supply, and commercial vehicle emission control systems.
- **Clean Water:** Wastewater and sludge treatment, water-use efficiency equipment, and water-quality monitoring technologies.

Given the speed at which greentech markets are evolving, 2012 will undoubtedly be another period of surprises and setbacks. Yet it seems clear that despite challenges, China's greentech market is healthy and developing rapidly, propelled by government policy and urgent needs.

**Despite challenges, China's greentech market is healthy and developing rapidly, propelled by government policy and urgent needs.**


GROUP



# Cleaner Conventional Energy

**The sheer size of conventional energy in China's energy mix, combined with a strong government commitment to cleaner and low-carbon initiatives, make conventional energy a top priority with many opportunities and challenges.**

Cleaner Conventional Energy continues to receive strong policy attention, particularly in China's 12th Five-Year Plan. Ambitious emission and energy intensity targets set by the central government will promote cleaner and more diversified energy production and use. On the energy production side, China's nuclear and gas sectors will experience strong growth while the government continues to restructure the coal mining industry, implementing efficiencies and cleaner processes. The National Energy Administration (NEA) expects the share of natural gas in China's energy mix to rise from just 4% in 2010 to 8% in 2015 and 10% in 2020.[1] While China's State Council temporarily

## Cleaner Conventional Energy Sector Definition

CGTI defines **Cleaner Conventional Energy** as energy derived from non-renewable fossil fuels (such as coal, oil and natural gas) and nuclear power in ways that minimize their negative impact on the natural environment.

**Cleaner coal** describes the cleaner use of coal with methods that reduce its negative impact on the environment. Cleaner coal technologies typically address atmospheric pollution from burning coal, and include such solutions as coal screening and scrubbing, gasification, flue gas desulfurization, carbon capture and sequestration, and coal blending.

**Cleaner oil** refers to technologies that help reduce wastewater, gas and residue emissions, as well as increase energy utilization. Cleaner oil technologies can be applied to oil exploration and extraction oil transportation, and refining.

**Cleaner gas** refers to technologies to extract and use natural gas, a cleaner burning fuel compared to coal and oil. Cleaner gas technologies facilitate the improved usage of coal-bed and coal-mine methane (CBM/CMM), reduction of greenhouse gases through the use of low concentration methane, and the support of natural gas combined cycle (NGCC) processes.

**Nuclear power** uses nuclear fission reactions to produce steam which then generates electricity. Nuclear power reduces carbon emissions and decreases dependence on fossil fuels.

*Director Piper Stover* (蓝沛文) *and Senior Analyst Junda Lin* (林骏达) *led the writing of this chapter with support from contributing writers Senior Analyst Julien Bédin* (朱立安) *and Director of Research Analytics Anders Hove* (侯安德) *based on 2011 strategic research conducted by Analysts Lini Fu* (付莉霓) *and Jackie Wang* (王静).

*1. "十二五期间天然气占能源消费结构比重倍增至8%--能源局" [Share of Natural Gas in China's Energy Mix Expected to Double to 8% under the 12th Five-Year Plan: National Energy Administration (NEA)], Reuters, June 21, 2010, www.reuters.com*

suspended nuclear project approval after Japan's nuclear crisis, China will proceed with nuclear energy targets using new generation technologies and higher standards. Stricter emission standards will come into effect for coal plants, and the government will introduce carbon trading pilot programs. Gas power, especially distributed gas energy, should experience rapid growth with strong government policy support. China will also continue energy pricing reforms, especially for natural gas.

This chapter begins by providing an overview of Cleaner Conventional Energy sector developments since the publication of the *China Greentech Report 2011*. It then summarizes three Opportunity Assessments developed by the China Greentech Initiative (CGTI) in collaboration with our Partner companies and organizations throughout 2011:

- Unconventional Gas
- Gas Power Generation
- Coal Conversion



CGTI's Partner companies and organizations prioritized each of these Opportunity Assessments as critical to the growth of China's Cleaner Conventional Energy sector over the next two to three years. The summaries represent high-level findings of CGTI's detailed research and analysis. The chapter concludes with an outlook on additional opportunities and issues in the Cleaner Conventional Energy sector that CGTI plans to explore during 2012.

## Market Update

### China experienced power shortages in 2011

China suffered its most severe power shortfall since 2004 in 2011, and the situation is expected to continue in 2012. The China Electricity Council (CEC) estimated a 30 GW capacity shortage during summer 2011 and has warned of another 30-40 GW shortfall again during 2012. 24 provinces experienced shortages, with Jiangsu, Henan, Jiangxi and Anhui among the worst hit. Rising coal fuel prices led to a temporary shutdown of coal-fired plants combined and hydro output dropped. Increasing electricity demand were blamed for the power shortages. Hydro output decreased by 3.5% due to the lack of rainfall during the summer. Electricity consumption in 2011 rose by 11% while GDP grew by 9.2%. Industrial electricity consumption—including light and heavy industry—grew by 11.9% in 2011, representing a 76% growth in power demand and accounting for 75% of China's total electricity consumption.[2]

China's rigid power pricing system prevents power plants from passing increased costs to end users, while inflation concerns have slowed government price adjustments—this has limited the incentive for coal-fired power plants to keep operating, and led to more frequent plant outages. Coal prices rose by 150% while the feed-in tariff (FiT) has increased only by 32% since 2004.[3] Interest rate increases have raised costs for power plant owners, which have an average 74% debt-to-equity ratio. Between January and July 2011, China's Top Five power groups accumulated RMB 18 billion in losses for coal-fired power plants.[4]

**Coal prices rose by 150% while the feed-in tariff has increased only by 32% since 2004.**

To address the power shortage, the government has taken short- and long-term measures. In November 2011, the National Development and Reform Commission (NDRC) adopted an interim policy to cap coal prices and increase the FiT. The government set an RMB 800/ton cap for fuel coal in major ports, while coal-fired plants received an average FiT increase of RMB 0.026/kilowatt hour (kWh).[5] While such policies may help reduce power plant losses temporarily, they do not address fundamental issues and may even create

*2. "国家能源局发布2011年全社会用电量" [NEA Released Data on 2011 Electricity Consumption], China Electricity Council (CEC), January 14, 2012, www.cec.org.cn*

*3. "3000万千瓦缺口 求解结构性缺电" [30 GW Power Gap, Need to Resolve Structure Shortage], 21 Business News, May 6, 2011, www.21cbh.com*

*4. "2011年1-6月份电力行业、1-7月份电力企业经济效益情况简要分析" [Brief Analysis on Power Industry (January - June 2001) and Power Company (January – July 2001)], CEC, August 18, 2011, www.cec.org.cn*

*5. "关于对电煤实施临时价格干预和加强电煤价格调控的公告" [Interim Price Control on Coal and Tightening Price Management], National Development and Reform Commission (NDRC), November 29, 2011*

other problems. For example, coal-fired power plants have at times reduced output or been forced to use low-quality coal, in turn hurting plant operations.

In addition to interim policies, government may consider other measures. Grid reform will also help reduce transmission and distribution costs, while introducing a tiered electricity price for consumers will help manage demand. A more flexible pricing system will help pass the fuel cost increases to end users; better regulation of the coal transportation system will reduce coal prices. However, such changes require political commitment and are likely to be gradual.

### Strict new power plant emission standards raise enforcement concerns

Coal-fired power plants are China's largest source of industrial solid waste and air pollutants. Oxides of sulfur ($SO_x$) and oxides of nitrogen ($NO_x$) from the exhaust flue gas produced by the plants have contributed to acid rain and smog in China's cities and affected public health. After decades of inaction, the country began to address air pollution with a 10% reduction target for sulfur dioxide ($SO_2$) emissions during the 11th Five-Year Plan, a target that China exceeded—reducing emissions 14% by 2010.[6] The 11th Five-Year Plan had no $NO_x$ reduction target, however. The 12th Five-Year Plan has introduced a 10% reduction target for $NO_x$ emissions and targeted a further 8% reduction in $SO_2$ emissions.[7] In July 2011, the Ministry of Environmental Protection (MEP) approved new emission standards for thermal power plant air pollutants with the new standards effective on January 1, 2012.[8]

**The 12th Five-Year Plan has introduced a 10% reduction target for $NO_x$ emissions and targeted a further 8% reduction in $SO_2$ emissions.**

Enforcement of standards will be essential to meet the new targets. To comply, most plants will require retrofits to install flue gas treatment equipment. This will stretch power company budgets, given their high debt loads and rising coal costs.[9] CEC, the largest power industry association, has publicly challenged the new standards, warning implementation will lead to either plant bankruptcy or fraud.[10] The industry considers the interim RMB 0.008/kWh denitrification (de-$NO_x$) tariff subsidy insufficient to encourage adoption.[11]

As a result of the standards, de-$NO_x$ equipment and service producers should expect increased demand for treatment products and solutions. Selective catalytic reduction (SCR) is likely to become the immediate solution, as it offers higher denitrification rates, followed by a growing demand for catalyst and catalyst waste treatment (such as catalyst regeneration), solutions not yet available in China. In regions where standards are less strict than those in first-tier cities, selective non-catalytic reduction (SNCR) plus low-$NO_x$ burners (LNB) can be an alternative to SCR, as the cost is much lower. Power groups may consider build-operate-transfer (BOT) business models for de-$NO_x$ facilities, which present opportunities for service companies with BOT experience managing desulfurization (de-$SO_x$) projects. Though in-house service companies within the power group have won many engineering, procurement and construction (EPC) and retrofit contracts, smaller foreign companies with the right technology, business models and flexibility—such as LP Amina—are finding opportunities.[12] A combined de-$NO_x$ and de-$SO_x$ solution may also be an attractive technology since it requires less space and reduces costs. The new emission standards will also push coal-fired plants to switch to higher-quality coal or consider using cleaner power generation technology, such as integrated gasification combined cycle (IGCC) and natural gas combined cycle (NGCC).

*6. "十二五"主要污染物减排任务仍相当艰巨" [Zhou Shengxian: It's still challenging to meet 12th Five-Year Plan target on major pollutants], Xinhua, December 21, 2010, www.xinhuanet.com*

*7. "国民经济和社会发展第十二个五年规划纲要" [The 12th Five-Year Plan on Economic and Social Development], State Council, March 16, 2011*

*8. "火电厂大气污染物排放标准" [Emission Standard of Air Pollutants for Thermal Power Plants], Ministry of Environmental Protection (MEP), July 29, 2011*

*9. "2011年1-6月份电力行业、1-7月份电力企业经济效益情况简要分析" [Brief Analysis of the Power Industry (January – June 2001) and Power Companies (January – July 2001)], CEC, August 18, 2011, www.cec.org.cn*

*10. "火电最新排污标准严过欧美 火电企业面临倒闭或造假" [New emission standard stricter then EU and U.S., Coal-fired plants may fail or cause cheating], Energy Magazine, November 23, 2011, www.cec.org.cn*

*11. China Greentech Initiative (CGTI) interviews*

*12. Spegele, Brain, "China Fuels Energy Innovation," The Wall Street Journal, December 6, 2011, www.wsj.com*

## Unconventional gas exploration is underway

China is moving forward quickly to expand its unconventional gas supply. The 12th Five-Year Plan on shale gas development includes targets of 6.5 billion cubic meters ($m^3$) of unconventional gas production by 2015 and 80 billion $m^3$ by 2020.[13] China's Ministry of Land and Resources (MLR) held the first auction for four shale gas blocks in Guizhou and Chongqing in June 2011. The auction attracted interest from state-owned oil and gas companies PetroChina, China Petroleum and Chemical Corporation (Sinopec), China National Offshore Oil Corporation (CNOOC), Yanchang Oil, China United Coal-Bed Methane Corporation (CUCBM) and Henan Coal Seam Gas. While foreign companies are not allowed to participate in the first round of bidding, they can be involved by partnering with Chinese developers. MLR signed contracts with Sinopec and Henan Coal Seam Gas in July 2011 for the exploration rights to two shale gas blocks and announced that domestic private companies could apply for the next round, which is expected to take place in 2012.[14] In 2009, China signed a shale gas resource initiative with the U.S. government, hoping to gain from the U.S. experience in developing unconventional gas.[15] Despite increasing interest from the industry, exploration in China has been slow given a lack of technology plus the government's concerns about high capital costs and water pollution. Closer U.S.-China cooperation on shale gas development is critical to drive the Chinese market since U.S. companies are the leaders in this field.

**The 12th Five-Year Plan on shale gas development includes targets of 6.5 billion $m^3$ of unconventional gas production by 2015 and 80 billion $m^3$ by 2020.**

China's three domestic oil companies have started to invest in foreign exploration companies and shale gas projects to gain technology and operational know-how. For example, in February 2011, CNOOC paid US$ 570 million to acquire a one-third stake in Chesapeake's Niobrara shale project in the U.S., the second deal after a US$ 1.1 billion investment in Chesapeake's Eagle Ford project in November 2010.[16] The outbound investment will help CNOOC access fracturing (also called fracking) technology in preparation for exploration in China.[17] Meanwhile, exploration of shale gas offers opportunities for private sector involvement in China's tightly-controlled gas sector, as government encourages investment and innovation. Xinjiang Guanghui and Honghua Group, two Chinese private companies, are reportedly interested in the second round of block bidding.[18]

## Coal-bed methane (CBM) is finally at the commercialization stage

On December 2011, the NDRC approved the Overall Development Plan for the first commercial CBM project. The project, located in Shanxi province, will be jointly-developed by CUCBM and Asian American Gas; the plan is for capacity to reach 500 million $m^3$ by 2013.[19] In addition, the 12th Five-Year Plan on CBM and coal-mine methane (CMM) industry development sets a 16 billion $m^3$ target for CBM production and calls for development of two main CBM industry clusters. To meet production targets, National Energy Administration (NEA) is considering increasing the FiT for CBM-fired power plants.[20] All of these developments suggest China's CBM industry will enter large-scale commercial production after 15 years of pilot development—in turn attracting investment interest from oil giants, such as PetroChina, local coal groups and equity investors. In January 2011, Henan Coal Seam Gas and CITIC Group also set up a RMB 4.8 billion fund, the first industry fund for CBM development in China.[21]

*13. "页岩气十二五发展规划提出产量达65亿立方米" [Shale Gas 12th Five-Year Plan Set 6.5 bcm Production Target], China Land and Resources News, October 14, 2011, www.mlr.gov.cn*
*14. "部页岩气探矿权出让招标项目评标结果公示" [Results of the Shale Gas Exploration Right Bidding], Ministry of Land and Resources (MLR), July 7, 2011, www.mlr.gov.cn; "首次页岩气招标结果公布" [First Shale Gas Bidding Results Published], China Energy News, July 11, 2011*
*15. "U.S.-China Clean Energy Announcements," U.S. Department of Energy (DOE), November 17, 2009, www.whitehouse.gov*
*16. "China National Offshore Oil Corporation (CNOOC) pays US$ 570m to buy into US oil shale operation," China Daily, February 1, 2011, www.chinadaily.com*
*17. McMahon, Dinny and Yung Chester, "China Bids in Fracking," The Wall Street Journal, December 16, 2011, www.wsj.com*
*18. "宏华借力地方国资挺进页岩气 探矿权问题待解" [Honghua teaming up with local government to explore shale gas, mining right issue yet to be resolved], 21st Century News, June 24, 2011, www.21cbh.com*
*19. "The Overall Development Plan (ODP) of Panzhuang Coal-Bed Methane Project Approved by NDRC," Asian American Gas, December 19, 2011, www.asianamericangas.com*
*20. "煤层气（煤矿瓦斯）开发利用 '十二五' 规划" [12th Five-Year Plan on CBM/CMM Development], NDRC, December 26, 2011*
*21. "CITIC, Henan firm set up China's first new-energy industry fund on CBM," Xinhua, January 13, 2011, www.xinhuanet.com*

China started to explore CBM resources in 1996 with the establishment of CUCBM to improve mine safety. The industry experienced rapid growth during the 11th Five-Year Plan period due to government incentives, new technology—particularly horizontal drilling—and rising gas prices. The government's motivation to develop CBM has shifted from mine safety to exploiting coal-bed gas reserves and reducing greenhouse gas emissions. By 2010, annual CBM production reached 1.5 billion $m^3$, compared to less than 0.1 billion $m^3$ in 2006.[22] This was far less than anticipated by the 5 billion $m^3$ target set in the 11th Five-Year Plan. The shortfall was mainly due to mining rights conflicts, a monopoly market structure and limited access to gas pipeline infrastructure.[23]

## China will promote more distributed natural gas power generation

China's distributed gas energy sector has developed slowly, with only a dozen projects installed in Beijing and Shanghai, most of which are operating off-grid.[24] The industry faces numerous challenges, including gas supply, grid connection, higher costs and low tariffs.[25] City gas operators—not power groups—are developing most the projects to date, with no energy service company (ESCO) involvement. In October 2011, the NDRC, the Ministry of Finance (MOF), the Ministry of Housing and Urban-Rural Development (MOHURD) and the NEA jointly released the long-awaited Guidance on Developing Distributed Energy Using Natural Gas. The document sets a target for 1,000 gas-fired distributed energy projects and calls for plans to develop 10 distributed energy demonstration regions by 2015. The government plans to install 50 GW capacity of distributed energy by 2020, spurring the domestic equipment industry as part of this process. Priority will go to buildings and industries in regions with high energy demand as well as industrial eco-parks.[26] The plan also calls for financial incentives for distributed gas energy projects, including low-cost loans, tax breaks and favorable gas prices. Government agencies will also work to better coordinate and address grid connection issues.

Government plans are attracting interest from leading foreign small gas turbine manufactures as well as domestic power developers. For example, Huadian Group, one of China's Big Five power groups, has included distributed gas energy in the company's core development strategy, setting a 1 GW target by 2013 for its distributed gas power portfolio.[27] In August 2011, GE announced a US$ 100 million joint venture with Huadian to develop distributed energy combined heating and power projects in China.[28] Since domestic companies do not have advanced gas turbine technology, foreign companies have an opportunity to provide technology, though government intends to improve domestic manufacturing capacity, with a goal of 90% domestic equipment supply when installed capacity reaches 10 GW.[29]

**The government targets 1,000 gas-fired distributed energy projects and 10 distributed energy demonstration regions by 2015.**

## Nuclear approvals will resume with new safety standards

The March 2011 catastrophe at Japan's Fukushima Daiichi nuclear plant has had a profound effect on nuclear power development in Germany, China and other countries. On March 16, 2011, China's State Council suspended all new project approvals and started safety checks on operating and construction projects. These checks were completed in October 2011. Four pre-approved reactor designs were also delayed from commencing construction. The suspension of new project approvals and construction delays will challenge the government's 2015 and 2020 energy intensity and emission reduction targets—partly as a result, the government has increased renewable energy

*22. "China oil and gas distiller coal-bed methane (CBM) on the cusp," Macquarie Equities Research, June 29, 2010*
*23. CGTI interview*
*24. "天然气分布式能源可望快速发展" [Natural Gas Distributed Energy will experience rapid growth], People Net, July 28, 2010, people.com.cn*
*25. CGTI interview*
*26. "关于发展天然气分布式能源的指导意见" [Guidance on Developing Distributed Energy Using Nature Gas], NDRC, Ministry of Finance (MOF), Ministry of Housing and Urban-Rural Development (MOHURD) and NEA, October 9, 2011*
*27. "分布式能源是华电集团调整电源结构的重点" [Distributed energy, the key factor for China Huadian Corporation to progress power structure adjustment], CICC, September 2010*
*28. "GE Announces $100 Million Joint Venture in China to Grow Aeroderivative Gas Turbine Sector," GE, August 23, 2011, www.genewcenter.com*
*29. "关于发展天然气分布式能源的指导意见" [Guidance on Developing Distributed Energy Using Nature Gas], NDRC, MOF, MOHURD and NEA, October 9, 2011*

targets and encouraged energy conservation.

Nevertheless, the government has reiterated its long-term commitment to nuclear power and likely will resume project approvals in 2012 with an emphasis on third-generation technology—which includes more passive safety design features and improved fuel technology—and higher safety standards. China considers nuclear power essential to meeting stringent carbon emission reductions and increasing environmental protection. Zhang Guobao, former head of NEA, has publicly stated China will not abandon nuclear power, deeming it critical for meeting China's 15% non-fossil fuel energy mix target by 2020.[30] China's Nuclear Safety Plan is in the approval process and NEA is drafting a Mid- and Long-Term Plan on Nuclear Power. In 2012, the government will likely confirm its commitment to 40 GW of nuclear capacity by 2015 and 75 GW by 2020. But even then, nuclear power will still only account for less than 5% of total installed capacity. China will also accelerate the adoption of third generation technology, especially the AP-1000 developed by Westinghouse, not only for safety reasons, but also because China plans to export nuclear equipment with the CAP-1400 model derived from the AP-1000. Meanwhile, the Chinese government is working to improve other areas of nuclear oversight, including emergency response systems, public awareness, education of nuclear professionals, safety standards and monitoring.[31]



## Market Opportunities

Development in the Cleaner Conventional Energy sector during 2012 has fostered market opportunities in areas including gas infrastructure, distributed gas power, coal-bed methane (CBM), mercury monitoring and nuclear power. Given the size of the conventional energy sector in China, and the urgency of reducing its emissions, these market opportunities are significant.

### *Gas infrastructure*

Expansion of gas transmission and distribution networks increases opportunities for pipeline construction, liquefied natural gas (LNG) and liquefied petroleum gas (LPG). China's plans to increase its gas share of the energy mix from 4% to 8% during the 12th Five-Year Plan will require the country to dramatically expand and upgrade its gas transmission and distribution networks. China Petroleum and Chemical Corporation (Sinopec) and PetroChina will likely build more regional- and cross-border pipelines, and bottlenecks in pipeline transportation will encourage demand for gas compression and liquefaction solutions in areas like Shanxi and Inner Mongolia. Pipeline manufacturers like Shengli and Zhujiang Pipeline and city gas operators, such as ENN and China Gas, will profit from rising demand.

**China plans to increase the gas share of the energy mix from 4% to 8% during the 12th Five-Year Plan.**

### *Distributed gas power*

China's promotion of gas-fired distributed power will create business opportunities across the entire value chain, particularly for gas turbine manufacturers and energy service companies (ESCOs). Foreign micro- and small-turbine manufacturers, such as GE and United Technologies, can work with large power groups or city gas operators to install more combined cooling, heating and power (CCHP) systems in large buildings. ESCOs can provide energy efficiency solutions using gas turbines for large commercial buildings and develop integrated solutions that combine different clean technologies, such gas-fired CCHP, renewable energy and energy storage.

*30. "张国宝:中国不可能放弃核电" [Zhang Guobao: China Will Not Give Up Nuclear Power], China Economic Weekly, October 11, 2011*

*31. Tu, Kevin Jianjun, et al., "China's Energy Sector after Fukushima Daiichi," Carnegie Endowment, May 19, 2011, www.carnegieendowment.org*

### *Coal-bed methane (CBM)*

The commercialization of the CBM industry will foster opportunities related to methane exploration, production and use. With growing investment interest from domestic and foreign oil groups, merger and acquisition (M&A) activity will increase both in domestic and international markets. China National Offshore Oil Corporation (CNOOC) acquired 50% of China United Coal-Bed Methane (CUCBM) equity in 2011 to enter China's CBM market; CNOOC has also considered investing in Australian CBM blocks. Additionally, many opportunities exist for providers of specific technologies, including horizontal drilling, methane purification, gas turbines with fuel flexibility, and alternative ways to utilize low-concentration methane.

**The push for safer nuclear power provides incentives to develop alternative nuclear generation technology.**

### *Mercury monitoring and control for coal-fired power plants*

Coal-fired power plants are the largest source of mercury emissions in China. From 2012, the Ministry of Environmental Protection (MEP) will implement mercury emission standards for coal-fired power plants. Most power plants that have already installed conventional air pollution controls for dust and sulfur dioxide ($SO_2$) will easily meet the new standards. Existing and new power plants will be required to report mercury emissions, creating demand for continuous emission monitors. Service providers, such as system designers, engineering, procurement and construction (EPC) companies, and equipment manufacturers, will also benefit.

### *Advanced nuclear*

The 2011 Fukushima nuclear incident has pushed the Chinese government to accelerate the adoption of third-generation nuclear plant technology and introduce higher nuclear safety standards. Market opportunities will arise for equipment and service providers throughout the value chain with higher quality standards and proven technology. Government will also strengthen its capacity for nuclear monitoring and management, and international service providers may be involved. The push for safer nuclear power provides incentives to develop alternative nuclear generation technology, such as modular nuclear plants or fourth-generation nuclear plant technologies, including breeder reactors, gas-cooled reactors, or thorium reactors. In 2011, the Ministry of Science and Technology (MOST), the Commission on Science, Technology, and Industry for National Defense (COSTIND), the China National Nuclear Corporation (CNNC) and the China Institute of Atomic Energy (CIAE) co-led a pilot project of a prototype fast breeder plant in Beijing, adopting sodium-cooled fast reactor technology with a future capacity up to 40 GW in 2015. The Shidao pilot project, a partnership between Huaneng, China Nuclear Engineering Corporation (CNEC) and Tsinghua Holdings, is a 200 MW plant with future capacity of 1 GW. Opportunities may grow for related technology equipment providers, such as Shandong Nuclear Power Equipment Manufacturing Company.

# Unconventional Gas

## Opportunity Assessment Summary

**Unconventional gas, including coal-bed methane (CBM), coal-mine methane (CMM) and shale gas, could become a major contributor to China's energy mix, given the large potential supply and environmental benefits.**

Although natural gas is an economically-viable and practical bridge to a low-carbon economy, China's domestic conventional gas production is stretched to the limit. Fortunately, China has vast undeveloped unconventional gas resources, primarily CBM and shale gas. If the industry can overcome major pricing, regulatory, distribution and water challenges, China could increasingly rely on unconventional gas production to meet its booming domestic demand.



### Unconventional gas could help ease China's domestic gas supply shortfall

China's natural gas shortage reached 10 billion $m^3$ in 2010, up from 4 billion $m^3$ in 2009.[32] The shortage is estimated to grow nine-fold to 90 billion $m^3$ in 2015, or 25% of expected domestic consumption.[33] Pipeline imports from Kazakhstan, Turkmenistan and Russia, along with costly imports of liquefied natural gas (LNG) from Qatar, Indonesia and Australia could fill the gap. The main trend causing the shortage is rising urban gas consumption as gas distribution infrastructure expands. Whereas in 2003 only 60 cities had gas distribution networks, 270 cities had such networks by 2010.[34] City gas demand represented 34% of China's total gas consumption in 2008, up from 18% in 2000.[35] Gas demand from the power industry also increased over the last 10 years, reaching a 12% share, up from just 4% in 2000.[36] Despite starting from a much lower base, the transportation sector is expected to increase its reliance on natural gas as an alternative fuel. In 2010, there were 550,000 compressed natural gas (CNG) vehicles on the roads, and over the next 10 years CNG/LNG fueling is expected to expand from 1,400 stations to 12,000 stations.[37]

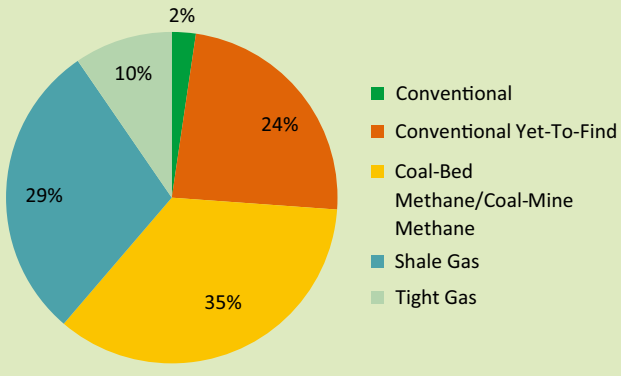
China has vast unconventional gas reserves that can help to address the country's gas supply shortage. At 37 trillion $m^3$ (equivalent to 1,306 trillion cubic feet), China is estimated to have the world's third-largest CMM and CBM gas resources after Russia (113 trillion $m^3$) and Canada (74 trillion $m^3$). China's resources are larger than those of the U.S. (21 trillion $m^3$), where unconventional gas production has expanded eight-fold in the past decade and now accounts for over 14% of total U.S. production.[38] China's CBM and CMM resources are located in prime coal basins: 60% of the total is in Qinshui (Shanxi), Ordos (Inner Mongolia) and Junggar (Xinjiang), of which 7.4 trillion $m^3$ are considered recoverable.[39] Estimates of China's total shale gas resources range widely, and exploration is at an early stage. According to some projections, shale gas could represent 10-14 times China's proven conventional gas reserves, but well characteristics and productivity vary across gas plays, explaining the uncertainty in national shale gas resource estimates.[40]

**At 37 trillion $m^3$, China is estimated to have the world's third-largest CMM and CBM gas resources after Russia (113 trillion $m^3$) and Canada (74 trillion $m^3$).**

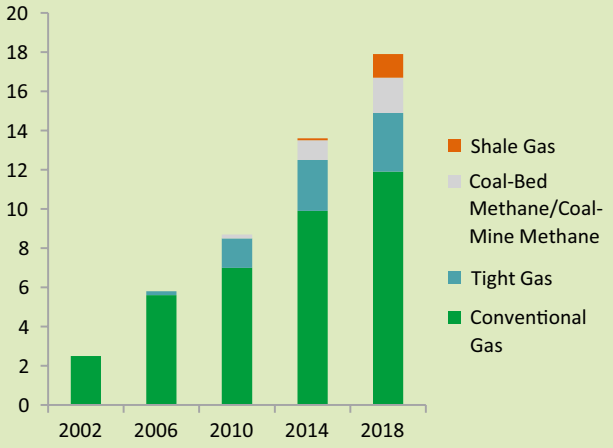
Overall, expectations of rising consumption paired with constrained conventional resources, and vast unconventional resources suggest a bright future for CBM/CMM and shale gas, provided challenges can be overcome.

*32. "China's 2010 Natural Gas Shortage To Exceed 10 bcm," China Mining Association, June 21, 2010, www.chinamining.org*
*33. "天然气产业十二五规划目标明确消费量年增25%" [12th Five-Year Plan for natural gas industry set clear targets: Consumption to grow 25% annually], Shanghai Securities Journal, January 21, 2011*
*34. "Natural Gas in China: Market Evolution and Strategy," International Energy Agency (IEA), June 2009*
*35. Duan, Zhaofang, "China's Natural Gas Market Outlook," 4th China National Petroleum Corporation (CNPC)/Institute of Energy Economics, Japan (IEEJ) Press Conference of Oil Market Research, Research Institute of Economics and Technology (RIET), December 10, 2010*
*36. "China's Natural Gas Market Outlook," CNPC, December 10, 2010*
*37. "小型LNG产业链在中国天然气供应格局中的地位" [The Role of the Mini Liquefied Natural Gas (LNG) in the Natural Gas Supply of China], Xinjiang Guanghui Petroleum, 2010*
*38. "Annual Energy Outlook 2011," (Washington, DC: U.S. Energy Information Administration (EIA), 2011)*
*39. "CBM in China," Standard Chartered Equity Research, November 30, 2010*
*40. "Annual Energy Outlook 2011," (Washington, DC: U.S. EIA, 2011); CGTI interviews*

**China Gas Resources By Type, 3,687 tcf, 2010**




**China Domestic Gas Production, bcf per day, 2002-2018**




*Note: tcf: trillion cubic feet; bcf: billion cubic feet*
*Sources: China Statistical Yearbook 2010 (Beijing: National Bureau of Statistics, 2010); Wood Mackenzie; CGTI analysis*



## Challenges hinder unconventional gas development in the near-term

China did not meet its 11th Five-Year Plan (2005-2010) targets for unconventional gas CBM and CMM due in part to the country's limited commercial experience. Of 10 CBM pipeline projects scheduled for completion by 2010, only two were finished on time.[41] For CMM, the industry met the government methane drainage target—a major element of mine safety—but by 2010 just 37% of methane extracted was used, hardly changed from five years earlier.[42] China has many small mines that make collection of gas into pipeline networks a challenge, and mine operators still have limited technology and know-how to process low-methane-concentration mine gas.[43]

CBM and CMM administrative frameworks are not yet fully developed, which has resulted in unclear division of responsibilities after the 1998 abolition of the Ministry of Coal Industry. Mineral rights are another hurdle for CBM development: CBM rights are licensed to national oil and gas companies, whereas local governments license mining rights to local mining groups. In 2007, 86 out of the 98 Ministry of Land and Resources (MLR) licenses for CBM overlapped with local mining rights; overlaps covered 12,534 $km^2$, mostly in Shanxi.[44] In December 2010, Vice-Premier Zhang Dejiang indicated that although 8,200 $km^2$ of overlapping mining rights have been resolved, the issue is still an industry bottleneck, an assessment shared by industry players.[45]

Unconventional gas resources also have higher extraction costs than China's conventional resources, leading the government to implement preferential policies to encourage the sector. Tariffs of RMB 0.2/$m^3$ support CMM gas production, and RMB 0.25/kWh feed-in-tariffs support CBM- and CMM-fired power.[46] In coal-rich Shanxi, an additional RMB 0.05/$m^3$ tariff is provided and end user prices for CBM gas are set below pipeline gas and LNG.[47] Other policies include exemption from corporate tax for the first two years of production and a reduction of 50% for the following three

*41. CGTI interviews*
*42. "煤层气产业扶持政策亟待明晰" [Clear supportive regulation is needed for the CBM/CMM Industry], China Energy News, November 8, 2010*
*43. Ibid.*
*44. Chen, Xianda, "我国煤层气勘探开发政策解析,全国瓦斯防治工作会议" [Analysis of China's policy for developing CBM—National Work Meeting on Coal Methane Prevention], MLR, September 3, 2009*
*45. "煤层气产业扶持政策亟待明晰" [Clear supportive regulation is needed for the CBM/CMM Industry], China Energy News, November 8, 2010*
*46. Ibid.*
*47. "山西省物价局关于临时调整山西天然气股份有限公司天然气销售价格的通知" [Notice on Adjusting the Gas Price for Shanxi Gas Company], Shanxi Pricing Bureau, June 20, 2010*

years, plus exemption from mining rights fees, royalty fees and value-added tax (VAT).[48] Finally, unlike conventional gas, retail prices for CMM and CBM are not regulated. These incentives, however, have not been enough to overcome pricing challenges. As one executive from a CGTI Partner company noted, "Coal companies don't expect to make money from methane. They just want to get rid of it. Methane is a meaningless business compared to coal profits." Given the higher price, grid companies are reluctant to purchase CBM- and CMM-fired power due to the instability of CBM/CMM gas supplies and the small size of their power plants.[49]

Shale gas will face similar pricing problems given that gas resources are located far from population centers and will require extensive storage, gathering and transmission networks. Estimated shale gas wellhead prices range from RMB 1.3-2/$m^3$, higher than in the U.S., but similar to the most expensive domestic conventional sources.[50] MLR is considering exploration subsidies of RMB 0.23-0.3/$m^3$ and other incentives, such as tax breaks.[51]



Shale gas exploration uses hydraulic fracturing technology, which was first developed in the U.S. in the late 1940s and is being considered for five shale gas basins in China. Fracturing technology, however, uses high water volumes (with estimates ranging from 11 to 26 million liters per well, sometimes several times in a well's life), and requires wastewater treatment, safe disposal or reuse.[52] Four out of the five most promising shale gas basins are in regions with severe water scarcity. Hydraulic fracturing also poses risks to local water supplies due to the highly toxic nature of chemicals added in fracking fluids. Despite these issues, on March 28, 2011, National Development and Reform Commission (NDRC) announced the National Energy Administration (NEA) was drafting a shale gas development plan, including policies, pilot development areas and technology research.[53]

### Attractive CBM, CMM and shale gas opportunities

The CBM market is a highly-concentrated industry, reflecting China's historic reliance on large state-owned firms to lead development of new energy resources. China United Coal-Bed Methane (CUCBM), PetroChina and Sinopec have the largest CBM capacities based on their involvement in coal-heavy Shanxi province.[54] In 2009, PetroChina had around 600 million $m^3$ of capacity, Jinmei over 500 million $m^3$ and CUCBM 300 million $m^3$, leaving the remaining 1,050 million $m^3$ to other smaller companies.[55] CUCBM, PetroChina and Sinopec own virtually all rights in Shanxi, while Jinmei Group has only recently been granted CBM development rights.[56] All three are expected to lead the next phase of CBM development, partly by bringing in technology through international partnerships.

**Four out of China's five most promising shale gas basins are in regions with severe water scarcity.**

In December 2010, PetroChina, Sinopec and Henan Coal Seam Gas were granted rights to form foreign partnerships, ending CUCBM's monopoly. However, no Shanxi coal companies gained partnership rights, perhaps due to resistance from CUCBM and PetroChina. PetroChina now has 24 self-operated blocks and 11 production sharing contracts (PSCs), plus two cooperation projects with BP and Shell in China, and a JV with Shell in Australia.[57] CUCBM has received capital injections from China National Offshore Oil Corporation (CNOOC), which is also investing in Australian and U.S. shale gas projects.[58]

*48. "CBM in China," Standard Chartered Equity Research, November 30, 2010*
*49. CGTI interviews and analysis*
*50. "Advances in unconventional gas," Halliburton, 2007*
*51. "决策层决意在'十二五'期间力推页岩气科技攻关" [Decision-makers set to promote shale gas exploration technology under the 12th Five-Year Plan], China Energy News, March 28, 2011*
*52. "Water Treatment Technologies for Global Unconventional Gas Plays," U.S. – China Industry Oil and Gas Forum: Fort Worth, Texas, September 16, 2010*
*53. "China energy authority drafting shale gas development plan: NDRC," Reuters, March 28, 2011, www.reuters.com*
*54. "China oil and gas distiller CBM on the cusp," Macquarie Equities Research, June 29, 2010*
*55. Ibid.*
*56. "晋煤集团首获煤层气采矿许可，气权矿权之争或解决" [Jinmei Group to obtain CBM mining right, conflict between gas and mining rights may be resolved], China Energy News, June 2, 2010*
*57. "China oil and gas distiller CBM on the cusp," Macquarie Equities Research, June 29, 2010*
*58. Bansal, Paritosh and Farah Master, "Chesapeake, CNOOC strike second shale deal for US$ 1.3 billion," Reuters, January 30, 2011, www.reuters.com*

**China's unconventional gas market is at a crossroads, both for relatively developed CBM/CMM and early-stage efforts in shale gas.**

Currently, small foreign E&P companies are the main PSC operators. ConocoPhillips, Chevron and Texaco were PSC holders in the first wave of development but pulled out mainly due to technological challenges.[59] Small foreign E&P players took over blocks relinquished by major companies and developed the blocks through better technology and expertise.[60] Overall, foreign companies provided about 70% of the funding for early exploration.[61]

### The need for shale gas technology leads to international cooperation

China's energy giants are going abroad via acquisitions to acquire technology and to gain foreign expertise. The government is also signing high-profile agreements with U.S. companies. Shale gas extraction is much more complex than for conventional sources due to its extensive reservoir modeling requirements, trial-and-error-based approach, horizontal drilling and hydraulic fracturing processes. This translates into large, long-term investments in exploration and production campaigns. For example, US$ 2 billion investment per year may be needed for a single shale gas project over a five-year period.[62]

The U.S.-China Shale Gas Resource Initiative, signed in November 2009 between Presidents Barack Obama and Hu Jintao, is intended to help reduce greenhouse gas emissions, promote energy security and create opportunities for U.S. firms to work in China's shale gas sector.[63] In terms of practical results, the agreement may allow China more access to U.S. experience when assessing its shale gas resource potential and promoting the sustainable development of the sector. The two countries will conduct joint technical studies to accelerate shale gas resource development in China. The agreement will also promote investment in the Chinese gas sector through forums, study tours and workshops.

China's unconventional gas market is at a crossroads, both for relatively more developed CBM/CMM and early-stage efforts in shale gas. The major challenges—namely mining rights for coal versus CBM, concerns surrounding shale gas extraction, and the extent of international partner contributions of unconventional gas technology and know-how at acceptable costs—need attention to smooth the path to a 10% natural gas share in China's energy mix by 2020.



*59. CGTI analysis*
*60. Ibid.*
*61. Ibid.*
*62. "Management of Risk and Uncertainty," Schlumberger Business Consulting, November 10-11, 2010*
*63. "U.S.-China Clean Energy Announcements," U.S. DOE, November 17, 2009, www.whitehouse.gov*

# Gas Power Generation

## Opportunity Assessment Summary

**Natural gas is a bridge fuel towards an economy fully powered by clean renewable energies. China is developing its gas power generation to meet near- to medium-term environmental protection targets while growing its renewable energy sector. Unresolved challenges remain, such as supply shortages, insufficient infrastructure and unattractive gas price economics.**

China is working to develop the country's natural gas sector to achieve pressing goals, including carbon intensity targets, reductions in other air pollutants and improved energy security through a more diverse fuel mix. Despite large investments in the sector, China's domestic gas production has not kept up with consumption, and its reliance on imports has increased while its distribution infrastructure has remained underdeveloped. China has prioritized residential consumption for cooking and heating over gas power generation, inhibiting the growth of gas power generation. Yet China has begun promoting distributed gas power as a local and cleaner energy source that can be developed in tandem with renewable energy technology and infrastructure. Government targets for the next five years call for a 6 GW increase in utility-scale gas power capacity (representing an annual growth rate of 2.9%), and smaller-scale distributed gas power could rapidly expand if challenges can be resolved.

**Government targets for the next five years call for a 6 GW increase in utility-scale gas power capacity, which represents an annual growth rate of 2.9%.**



### China's transition towards a lower-carbon economy will shift the country's power generation portfolio towards higher-efficiency and lower-emission sources, especially gas power

Gas is the cleanest of the three fossil fuels: gas-based power generation typically emits less carbon dioxide ($CO_2$), sulfur dioxide ($SO_2$) and particulate matter (PM) compared to coal. Flexibility is another benefit of gas power generation: gas power plants can cycle on and off relatively quickly and can be used during either peak hours or to compensate for intermittence of other power sources, such as wind. This is particularly relevant for provinces, such as Inner Mongolia and Xinjiang, which now source a fifth of their power from wind farms.[64] Natural gas is also well-adapted to distributed energy settings in populated urban centers. As a result, government policy is emphasizing gas power, though the economics remain challenging.

### Restrictive and unclear regulations hinder gas power

Overall, regulation on gas power has been slow due to limited supply and a recent regulatory focus on residential use. Under China's August 2007 Natural Gas Utilization Policy, the government prioritized natural gas use in the residential, public infrastructure, transportation and Combined Heat and Power/Combined Cooling, Heat and Power sectors (CHP/CCHP). The policy also prohibited gas-to-methanol plants and large gas power plants in cities with rich coal resources.

The National Development and Reform (NDRC) and its affiliate, the National Energy Administration (NEA), lead China's gas power policy, but there is no clear institutional coordination for natural gas distributed energy. Various Ministries are involved in policy drafting and local-level oversight. The Ministry of Environmental Protection (MEP) sets and monitors emission standards. The Ministry of Housing and Urban-Rural Development (MOHURD) sets technical standards for gas-fired CCHP projects. The State Electricity Regulatory Commission (SERC) regulates the power market. Technology development is driven by the Ministry of Science and Technology (MOST). As a leading turbine manufacturer notes, "Relevant government agencies and industry stakeholders should really work more closely to develop a cohesive plan, to better align incentives."[65]

*64. Zhang, Jianfeng, "China, A Prospective Wind Power Leader," China Business Journal, November 12, 2011*
*65. CGTI Interview*

NDRC has included natural gas distributed energy expansion in its agenda since 2009. During the 2010 National Energy Working Meeting, NEA released the Guidance on Developing Distributed Energy Using Natural Gas (Call for Comments). In October, NDRC published its Opinions on the Development of Gas Distributed Energy, outlining major policy measures to be taken to develop gas distributed energy in China.[66] The targets include 1,000 gas-fired distributed energy demonstration projects by 2015, and 50 GW of distributed energy generation installations in 10 demonstration regions by 2020. With only 25 such projects in Shanghai (one of the demonstration regions) so far, the target of 1,000 projects looks unrealistic, though it illustrates a strong government commitment.

### Interest in gas power is growing

China's gas power generation has been rising along with investments. The share of gas power generation in gas consumption rose to 18% in 2010 and may reach 21% by 2015, as the relative share percentage of industrial consumption declines. Long-distance pipelines, including the West-to-East, Sichuan-to-Shanghai, North-to-South and Ocean-to-Land projects have changed the gas consumption mix, and will increase the market potential for distributed energy by cities and power plants.[67] Official projections for installed capacity in 2015 by China's National Petroleum Corporation (CNPC) reach nearly 30 GW, however extrapolation from CNPC's power-related gas consumption forecast puts the capacity closer to 73 GW.[68]



Gas power only accounts for a small share of China's power mix, but recent years have seen increasing investment from oil companies, such as the China National Offshore Oil Corporation (CNOOC), which should help drive market development. Only nine of China's top 30 power groups have gas power plants, representing 7.7% of capacity.[69] While CGTI interviews suggest that the majority of power groups are still taking a cautious approach, the entry of gas companies will help reduce fuel prices, secure long-term gas supply contracts and spur investment in gas power plants near major liquefied natural gas (LNG) ports and pipelines.[70]

### High gas prices drive down the economics of gas-fired power generation projects

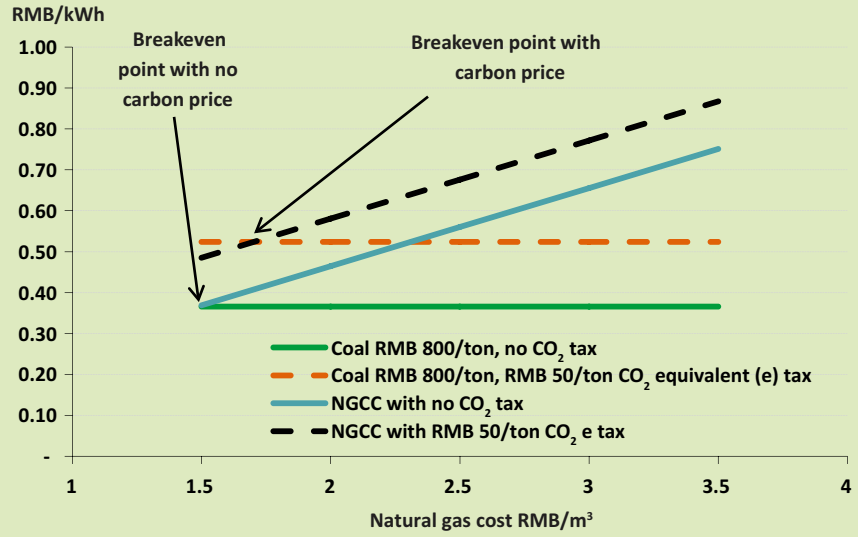
The economics of most natural gas power projects are not favorable due to fuel prices. In many cases, coal is seen a lower-cost alternative to gas for power generation projects. Gas prices in China can be as high as RMB 85 to RMB 90 per million British thermal units (Btu), but the cost of this gas varies greatly across sources. As a rule, transportation costs represent a large portion of end prices, so resources furthest from demand centers are seen as most costly. The cost of extracting gas in different locations also differs. Among sources of imported gas, pipeline gas from Russia is potentially the most expensive, while Central Asian and Middle East sources are more affordable.[71]

**Only nine of China's top 30 power groups have gas power plants, representing only 7.7% of capacity.**

A sensitivity analysis shows that gas prices in China are too high to make natural gas combined cycle plants (NGCC) competitive versus coal-fired plants. Without a carbon tax, gas prices would have to fall to RMB 1.5/$m^3$ for natural gas to be competitive with coal priced at RMB 800/ton. With a hypothetical carbon tax of RMB 50/ton, gas prices would still have to fall to below RMB 2/$m^3$ for gas to break even with coal.[72] Since gas prices are currently higher than RMB 2/$m^3$, the cost of electricity for gas power is roughly RMB 0.1 higher than coal-fired plants at the current coal price.

*66. "Opinions on the Development of Gas Distributed Energy," NDRC, October 9, 2011*
*67. "China Has Preliminarily Established Its Natural Gas Pipeline Network System and Improved the Supply Capacity," Xinhua, December 2010, www.xinhuanet.com*
*68. Duan, Zhaofang, "China's Natural Gas Market Outlook," 4th CNPC/IEEJ Press Conference of Oil Market Research, RIET, December 10, 2010; assumptions based on 50% thermal efficiency and 40% capacity factor.*
*69. "2008年30家大型发电企业调查数据统计一览表" [Survey of 30 Large-size Power Group in China in 2008], SERC, 2008; "重点企业将被强制上报碳数据" [Major Enterprise Will Be Required to Submit Carbon Emission Data], Economic Information Daily, May 27, 2011*
*70. CGTI interviews*
*71. Davis, Alex, "Reshaping Russia and China's energy alliance," Risk.net, February 11, 2011*
*72. CGTI analysis*

**Electricity Cost of Natural Gas Combined Cycle vs. Coal Power, RMB/kWh**




*Source: CGTI analysis*



## Gas power development still faces huge infrastructure challenges

Despite infrastructure investments, gas power generation development is still constrained by a lack of storage, processing and distribution facilities. Distributed energy projects face additional challenges with grid connection issues. Over the past 13 years, China has built 36,000 kilometers of gas pipelines and three LNG terminals.[73] The gigantic East-West 1 and East-West 2 projects will transport 42 billion $m^3$ of gas per year from domestic fields in Xinjiang, as well as foreign gas, to Eastern China demand centers. The Guangdong Dapeng pipeline will transport 13.8 billion $m^3$ per year of gas to Shenzhen and Guangzhou.[74] New LNG terminals in Shanghai, Yangshan and Chongming will allow for storage and distribution of gas supply secured via long-term contracts with Australia and Malaysia.[75]

Overall, gas power generation has good long-term prospects for larger-scale development in China. Given the environmental protection and energy diversification goals of the 12th Five-Year Plan, China's heavy reliance on coal and the challenges in scaling up intermittent renewable power generation, natural gas should be a near- to medium-term solution to the nation's energy challenges. Gas-fired power plants offer many advantages, such as low-capital requirements, technology maturity, scalability and flexibility for peak-shaving purposes. For gas power generation to take off in the next decade, China will need to resolve major bottlenecks, namely natural gas supply shortages, insufficient distribution infrastructure and high fuel costs. In the meantime, China is greatly expanding distribution infrastructure, while increasingly relying on imported pipeline gas and LNG to meet its fast-growing needs.

*73. Gu, Anzhong, et al., "The Development of LNG in China," May 17, 2011*
*74. "Guangdong Dapeng LNG Terminal Receives the 1st Shipment of LNG," BP China, May 26, 2006*
*75. "The 12th Five-Year Plan Sees Natural Gas Consumption Reach 9-10 bcm: Shanghai's 12th Five-Year Plan on Energy Development," ICIS Energy, December 19, 2011*

# Coal Conversion

## Opportunity Assessment Summary

**The government's promotion of coal conversion means opportunity for coal producers and equipment suppliers, especially for coal-to-chemicals and water treatment technologies.**

For years, China's central government has promoted coal conversion technologies for energy security given the country's abundant coal resources. Yet given concerns about water use, carbon emissions and the economic attractiveness of certain coal conversion technologies, a disconnect has emerged between the central government's caution with coal conversion versus the local government's efforts to promote the technology for local jobs and tax revenue. Because water represents the major market and policy impediment to coal conversion, research by CGTI suggests that water efficiency, wastewater treatment and water recycling technologies would represent a major market if government enforcement improves and issues related to intellectual property (IP) are resolved. Based on current conversion technologies and market prices for various fuels and chemicals, a CGTI sensitivity analysis suggests coal-to-chemicals offers the most attractive economics among coal conversion techniques.



### Central government policies on coal conversion have grown cautious

**China cautiously promotes coal conversion to enhance energy security, promote innovation, and improve resource use.**

China's abundant coal resources and rising imports of oil and chemical products have led the central and local governments to cautiously promote coal conversion to enhance energy security, promote domestic innovation and local employment, and improve resource use.

Beginning in 2000, the central government stepped up its efforts to acquire and develop coal conversion technology. In July 2000, the National Key Industry, Products and Technology Catalog exempted coal-to-gas (CTG) and coal-to-liquids (CTL) technologies from tariffs and import value-added taxes (VATs), and in 2001, the National 863 Plan initiated several CTL technology research projects.[76] In 2004, the Key Advanced Technology Industry Development Priority Guide emphasized equipment related to CTG, coal-to-chemicals and polygeneration.[77]

In 2006, the central government drafted—but never released—a Mid- to Long-Term Development Plan on the Coal Conversion Industry. The plan would have set annual coal conversion capacity targets in 2020 of up to 30 million tons of CTL, 66 million tons of coal-to-methanol (CTM), and 20 million tons of coal-to-dimethyl ether (DME).[78] In 2007, the 11th Five-Year Plan (2006-2010) promoted domestic technology for a million ton direct-CTL demonstration plant and two indirect CTL plants, and introduced foreign technology for a 3 million ton indirect CTL commercial demonstration project.[79] The 12th Five-Year Plan followed up on these developments by promoting research and development (R&D) and application of coal conversion, including coal-based polygeneration.[80]

For several reasons, the central government has pursued a more cautious approach to coal conversion over recent years. Coal conversion requires high capital investment, and China is still gaining experience and developing domestic technology. Overcapacity is another reason for slowing development: in the case of CTM, 50% of capacity is currently idle.[81] Rising coal price has reduced the economical return for coal conversion projects. When the government started coal conversion trials a decade ago, coal prices were just a fraction of those today. Nowadays, high coal prices have profoundly

*76. "当前国家重点鼓励发展的产业，产品和技术目录(2000年修订)" [National Key Industry, Products and Technology Catalog (2000)], NDRC, July 2000*
*77. "当前优先发展的高技术产业化重点领域指南(2004年度)" [Key Advanced Technology Industry Development Priority Guide (2004)], NDRC, Ministry of Science and Technology (MOST), and Ministry of Commerce (MOFCOM), April 2004*
*78. "煤化工产业中长期发展规划(初稿)" [Mid to Long-Term Development Plan on Coal Conversion Industry (Draft)], NDRC, October 2006*
*79. "煤炭工业发展'十一五'规划" [The 11th Five-Year Plan for Coal Industry], NDRC, January 2007*
*80. "中华人民共和国国民经济和社会发展第十二个五年规划纲要" [PRC 12th Five-Year Plan for National Economic and Social Development], National People's Congress, March 2011*
*81. "煤制甲醇上下游产能皆过剩" [Overcapacity Exists Upstream and Downstream of coal-to-methanol (CTM) Industry], CHEM99, May 3, 2011, www.coalchem.chem99.com*

changed the economics of the initiatives. Many projects have been forced to shut down as owners have failed to secure low-priced coal supplies. Large companies like Shenhua have managed to continue operations at a loss mainly due to access to large coal reserves. Most importantly, as will be discussed further below, coal conversion entails high water consumption and wastewater production.

### Provinces with abundant coal reserves have set high coal conversion targets

Notwithstanding the cautious attitude in Beijing, provincial governments have published plans for large-scale coal conversion projects and high provincial coal conversion targets. Regions with abundant coal have led the way, including Xinjiang, Ningxia, Shaanxi, Shanxi, Inner Mongolia, Guizhou and Yunnan. Some provinces have made coal conversion a condition for obtaining mining rights. The purpose of such policies at the provincial level is to diversify local economies by converting coal locally instead of exporting it for power production. High capital costs mean higher investment, more jobs and more local technology development.



Because local governments are eager to develop multi-billion RMB coal conversion projects to boost local GDP growth, they have adopted coal conversion targets that are not only much higher than those of the central government, but potentially unrealistic as well. In the case of CTL, where the central government has limited investments due to high cost, high water use and high emissions, the 2015 national target calls for 10 million tons of annual capacity, compared to combined provincial targets of 37.2 million tons. For CTG, the national 2015 annual capacity target is 30 billion $m^3$, compared to combined provincial targets of 147 billion $m^3$. Because of the importance of water in the context of obtaining national project approval, the national targets may be more realistic.

### Water scarcity in coal-heavy regions will limit coal conversion

Both the central and regional governments continue to promote coal conversion for domestic resource use, energy security, economic development and diversification. Other national policy themes are also vitally important to China's future, but at times seeing how such themes are compatible with aggressively promoting coal conversion can be difficult.

In the area of water consumption, national policies prohibit using residential and agricultural water for coal conversion, restrict CTG and CTL projects in regions with water scarcity, and prohibit coal conversion in regions where water consumption has reached quotas. On environmental protection, policies prohibit coal conversion in regions where industrial impact exceeds environmental tolerance, and require the rejection of projects that fail to meet environmental standards on emissions and wastewater treatment. Finally, on location selection, policies limit coal conversion in regions that import coal, while promoting coal conversion in regions with sufficient water and coal resources.

As these policies suggest, water is the main impediment to developing coal conversion in China. Coal conversion projects require a large amount of water for daily production. For example, typical CTM processes require 15 tons of water for each ton of methanol, coal-to-DME requires 20 tons of water for each ton of DME, and CTL requires 10 tons of water per ton of CTL.[82] A look at one of China's premier policies, the Energy Golden Triangle, illustrates the dilemma of coal conversion development and water scarcity. China's top four coal-rich provinces are Shanxi, Shaanxi, Inner Mongolia and Xinjiang.[83] National Energy Administration (NEA) has drafted plans for an Energy Golden Triangle to extend from Ningdong, Gansu, to Yulin, Shaanxi, and to Erdos, Inner Mongolia.[84] The region now accounts for 24% of national coal production, and under the plan would account for 30% by 2020, including the following major coal conversion elements: 15 million tons of CTL capacity, 40 billion $m^3$ of CTG capacity, and 2.5 million

**Water is the main impediment to developing coal conversion in China.**

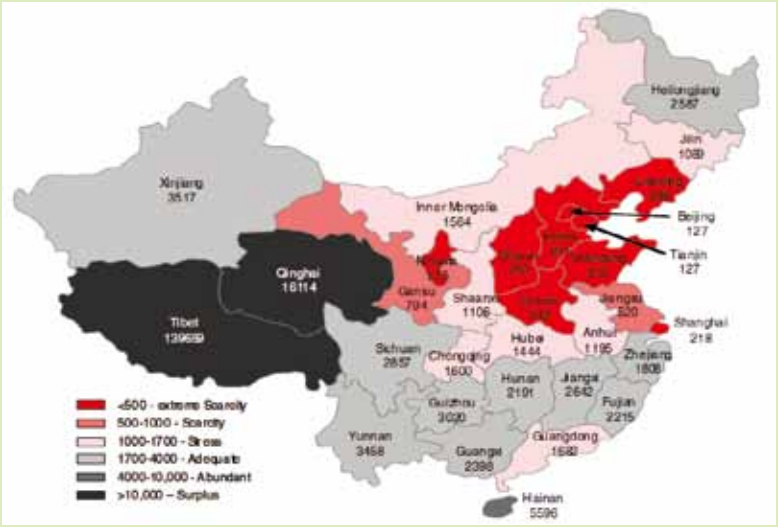
*82. Yang, Tao, 化工投资迅速重启，煤化工蓄势待发 [Investment on Chemical Industry Booming, Coal Conversion Industry Ready to Go] (Shanghai: CITIC, 2011)*

*83. "中国各省市煤炭储量情况" [Statistics of Coal Reserves in China], Journal of State Coal, June 5, 2008, www.statecoal.cn*

*84. "西部能源金三角开发规划上报国务院" [Development Plan of Energy Golden Triangle Area Submitted to State Council], 21CBH, October 11, 2011, www.21cbh.com*

tons of coal-to-olefin (CTO) capacity.[85] All four provinces included in the Energy Golden Triangle, Gansu, Ningxia, Inner Mongolia and Shaanxi, suffer from water scarcity or stress.

**Water Stress Levels in China, average $m^3$ per capita, 2010**




*Source: China Statistical Yearbook 2011 (Beijing: National Bureau of Statistics, 2011)*

### Future carbon prices could increase coal conversion cost

Carbon emissions present further problems for future coal conversion projects. While current projects have not been planned with carbon prices in mind, any future carbon policies could have deep and permanent effects on coal conversion economics. This is particularly evident given that carbon emitted by coal-derived chemicals, methane or diesel fuel might be substantially higher than their non-coal-based market equivalents. This could be particularly challenging for CTG, in light of the current large-scale plans in Xinjiang and the need for CTG to compete over the long-term with the price of domestic shale gas.

The next five years will help clarify how China's central and regional governments intend to resolve the critical dilemma regarding carbon emissions and water conservation needs in north China on one hand, versus efforts to develop coal conversion technologies for high-value domestic coal production on the other. Water treatment technologies and low-water use coal conversion technologies could help, but in many cases these advanced technologies are only available from foreign solution providers, which might require additional intellectual property protections and higher capital costs.[86]

### The coal conversion market appears to be at a turning point

Domestic supply gaps in oil, natural gas, ethylene and glycol will worsen, driving further development of coal conversion. Yet it appears some technologies have a clear advantage over others. Over a dozen large CTG projects are underway in west China to feed the West-to-East natural gas pipeline, whereas CTL has slowed due to concerns on costs and emissions. CTO is making progress, with one plant completed. Methanol-to-olefin (MTO) conversion requires further R&D.

Among coal conversion technologies, polygeneration has taken the lead in terms of the number of proposed and planned projects. Two projects have been completed in Shandong and Shanghai and a further eight are under construction in Xinjiang, Gansu, Qinghai, Ningxia, Guizhou, Shanxi, Anhui, and Inner Mongolia. An additional nine projects have been proposed. Given polygeneration's capability of producing a variety

*85. "能源‘金三角’崛起西部未来成龙头" [Emergence of Energy Golden Triangle, Lead in Future Western China], China Oil News, October 13, 2011, www.oilnews.com.cn*
*86. CGTI interview*

of derivative products, some believe it offers the best path for future coal conversion development.[87]

By number of projects, CTG is second in position after polygeneration with 12 projects under construction in Xinjiang (7 projects), Inner Mongolia (4 projects) and Liaoning (1 project). A further nine projects have been proposed, four of which are in Xinjiang. Xinjiang thus accounts for over half of all CTG projects and is poised to become a major base for CTG conversion.[88] The economics of CTG in Xinjiang are driven by the construction of the new West-to-East natural gas pipeline and the cost of exporting coal from the region via rail.

CTO projects, which are based on first transforming coal into methanol, and then methanol into olefin, are few in number so far, with only one plant in operation, two under construction, and two further plants proposed. Shenhua Group is the only Chinese company with domestic MTO technology, and operates the only plant located in Inner Mongolia, producing 600,000 tons of olefin annually, which is converted in turn into polypropylene and polyethylene. The plant cost RMB 17 billion and began commercial operations in January 2011 after several years of trial operations.[89] Representatives from several CGTI Partner companies expressed the view at a Working Session that improved domestic MTO technology is the key to accelerating this market.



Currently China has four CTL plants in operation: two in Inner Mongolia and two in Shanxi. A further eight plants are proposed or under construction, but the central government has taken a slow approach on CTL development in light of a number of problems in the industry. According to reports from CGTI Partner companies, several CTL plants have operated at a loss despite elevated world oil prices because of low conversion efficiency and inability to obtain sufficient coal of the quality needed to operate economically.[90] This seems reasonable given that coal quality issues have challenged conventional power producers in recent years. In addition, the water and carbon issues surrounding coal-derived liquid fuels for transportation will pose a dilemma for policymakers who might otherwise see CTL as a solution to oil imports.

**Xinjiang accounts for over half of all CTG projects and is poised to become a major base for CTG conversion.**

### Economic analysis of coal conversion shows CTM offers the most attractive economics

CGTI's study of coal conversion analyzed the economics of various technologies given current fuel and chemical prices, in addition to capital costs and conversion factors from publicly available project data. The analysis found that CTM would offer the most attractive economics, and CTL would be economical at today's oil prices. These results may differ from actual experience in China given a favorable coal conversion ratio and need for access to high quality coal. Notably, the analysis did not include the economic impact of environmental externalities related to water use or carbon emissions.

*87. Cai, Ningsheng, "Development of Coal Gasification & Polygeneration in China," IEA-MOST Workshop on Fossil Fuel Technologies, June 11, 2010*
*88. "新疆维吾尔自治区国民经济和社会发展十二五规划纲要" [The 12th Five-Year Plan on National Economic and Society Development in Xinjiang Uygur Autonomous Region], People's Government of Xinjiang Uygur Autonomous Region, January 18, 2011*
*89. "神华包头煤制烯烃示范项目运行情况及主要工艺" [Operation Status and Major Technologies Applied in Shenhua Baotou Coal-To-Olefin (CTO) Project], Shenhua (Baotou) Charcoal Chemical Industry Co., Ltd., www.shenhuagroup.com.cn, accessed on October 18, 2011*
*90. CGTI interview*

**China is set to make coal conversion a significant, large-scale commercial element in its energy development plans.**

### Coal conversion will be a critical component of China's energy portfolio

Overall, the coal conversion industry is at a turning point. For the first time, a major coal producing country is set to make coal conversion a significant, large-scale commercial element in its energy development plans. Yet the most aggressive provincial plans for coal conversion carry severe environmental risks that appear to conflict with national plans for the industry, as well as important national objectives for water use and environmental protection. For this reason, there are many areas where stakeholders can work together to ensure coal conversion can go forward in a way that reduces such policy conflict. Ideally, this can be accomplished through better enforcement of existing policies and regulations combined with cost-effective deployment of water-saving and wastewater treatment technologies.

## The Path Ahead

This chapter provides an update on China's Cleaner Conventional Energy sector and three Opportunity Assessments prioritized by CGTI's Partner companies and organizations in 2011. As the sector evolves, participants in the China Greentech Partner Program will continue to collaborate on additional opportunities. Topics may include coal mining industry consolidation, the nuclear power market after Fukushima, gas distribution networks, and energy pricing reform. CGTI will also continue to track the overall development of China's Cleaner Conventional Energy sector.



*Anders Hove*

# Renewable Energy

**2011 was a year of dramatic change for renewable energy, as China prepares for a period of more sustainable and diverse growth, especially for solar and wind.**

In 2011, the central government set out ambitious plans for China's renewable energy growth by raising 2015 installation targets, doubling the renewable energy surcharge rate, issuing standards to mitigate grid connection problems for wind and solar power, and introducing specific carbon reduction policies. In the solar sector, as European and U.S. market demand for Chinese modules shifted, overcapacity problems increased, squeezing profits for Chinese module makers and forcing consolidation on the global industry leading to bankruptcies of several prominent U.S.-based firms, such as Evergreen and Solyndra. To absorb excess production, the Chinese government stimulated the domestic market by raising 12th Five-Year Plan targets and increasing the feed-in tariff (FiT) for solar power, resulting in an estimated 2.5-3 GW of installation in 2011.[1] In the wind sector, about 18 GW of capacity was installed during 2011, a 40% increase over 2010,[2] but a slower pace is expected in the future as the government tightens wind farm approvals and introduces new standards for grid connection. Biomass power generation experienced rapid growth in 2011 due to favorable policies, including a new FiT.

This chapter begins by providing an overview of Renewable Energy sector developments since the publication of the *China Greentech Report 2011*. It then summarizes three Opportunity Assessments developed by the China Greentech Initiative (CGTI) in collaboration with Partner companies and organizations throughout 2011:

- China's Solar Photovoltaic (PV) Value Chain
- China's Waste-to-Energy (WtE) Markets
- Financing Utility-Scale Wind and Solar Power Projects in China

CGTI's Partner companies and organizations prioritized each of these Opportunity Assessments as critical to the growth of China's Renewable Energy sector within the next two to three years. These summaries represent high-level findings of the detailed proprietary research and analysis developed in collaboration with and for organizations participating in the China Greentech Partner Program. The chapter concludes with an outlook on additional opportunities and issues in the Renewable Energy sector that CGTI will explore in 2012.

**Renewable Energy Sector Definition**

CGTI defines **Renewable Energy** as energy produced from naturally replenishing sources, such as sunlight, wind, waves, underground heat, surface water flows and biomass. Of these, CGTI focuses on the markets and technology for wind power, solar energy and bioenergy.

*Analyst Jing Wang* (王静) *led the writing of this chapter with support from contributing writers Director of Research Analytics Anders Hove* (侯安德) *and Director Piper Stover* (蓝沛文) *based on 2011 strategic research conducted by Senior Analyst Junda Lin* (林骏达) *and Analyst Yaoqi Zhu* (朱瑶琪).

*1. Osborne, Mark, "NPD Solarbuzz: China leads solar PV demand in Asia Pacific region with 2.9GW installed in 2011," PV-Tech, January 26, 2012, www.pv-tech.cn*

*2. "Release of global wind statistics: Wind Energy Powers Ahead Despite Economic Turmoil," Global Wind Energy Council, February 7, 2012, www.gwec.net*

# Market Update

## Government targets strong growth for renewable energy

All of these figures show China's attempt to diversify its renewable energy sources after slowing nuclear development in 2011; China remains committed to producing 11.4% of total energy from non-fossil fuels by 2015. China's target for total domestic solar installations by 2015 has been raised several times. Initially, the 12th Five-Year Plan targeted 5 GW of installed capacity by 2015, but the government has since raised this to 15 GW, including 4 GW for rooftop photovoltaic (PV) and 1 GW of concentrated solar power (CSP).[3] The current 2020 target is 50 GW, with 25 GW for rooftop PV.[4] The industry assumes that the increased targets will help struggling domestic manufactures better face the challenging overseas market.[5] While the 2020 rooftop PV target represents an 83-fold increase versus the 2010 installation level of 300 MW, implementation will be difficult. This is particularly evident given that current feed-in tariff (FiT) levels and high capital costs will require significant decreases in the cost of solar energy per Watt over the time period.[6]

**China remains committed to producing 11.4% of total energy from non-fossil fuels by 2015.**

China's wind installation target is also ambitious: 100 GW is planned by 2015, including 5 GW for offshore wind, generating 190 TWh of power annually.[7] Future development will focus both on distributed wind energy and on large wind power bases—there are eight bases planned in seven provinces for a combined 70 GW capacity by 2020.



Aside from wind and solar, government is also focusing on biomass with a 2015 target for 13 GW of total installed capacity, including 8 GW from agricultural and forestry (ag/forestry) biomass, 2 GW from biogas and 3 GW from municipal solid waste (MSW) incineration.[8] The utilization rate of total produced crop straw for biomass energy production is targeted to increase from 70% in 2010 to 75% in 2015 and 80% in 2020.[9] For hydro, China will target 325 GW of capacity, with 284 GW from conventional hydro and 41 GW from pumped hydro storage.[10]

## Increased renewable surcharge compensates grid owners

To fund ambitious 12th Five-Year Plan targets, the government increased the renewable energy surcharge rate, partly addressing the problem of insufficient funding for renewable energy. In 2010, an incremental RMB 9.6 billion was collected through a renewable energy surcharge of RMB 0.004/kWh on all electricity sales; however, the incremental cost to grid companies of renewable energy tariffs versus coal thermal power reached RMB 11.0 billion, resulting in a RMB 1.4 billion shortfall.[11] The shortfall implies that grid companies will have less incentive to purchase electricity generated from renewable energy sources, especially if the FiT to suppliers is high relative to the price to users. To address the problem, the Ministry of Finance (MOF), the National Development and Reform Commission (NDRC) and the National Energy Administration (NEA) released the Interim Measures on Development Funds for Renewable Energy Collection and Management document, increasing the surcharge rate to RMB 0.008/

*3. "中国或将‘十二五’太阳能发电装机目标再上调50%--报载" [China may raise solar power installation target by 50% during 12th Five-Year Plan], Reuters, November 16, 2011, cn.reuters.com*

*4. Li, Yinlian, "五年扩十倍 屋顶发电规划‘命悬’补贴" [Chinese solar power installation expands 10 times during five years, rooftop mounted PV program relies much on subsidy], China Business, September 9, 2011, www.cb.com.cn*

*5. "中国或将‘十二五’太阳能发电装机目标再上调50%--报载" [China may raise solar power installation target by 50% during 12th Five-Year Plan], Reuters, November 16, 2011, cn.reuters.com*

*6. Li, Yinlian, "五年扩十倍 屋顶发电规划‘命悬’补贴" [Chinese solar power installation expands 10 times during 5 years, rooftop mounted PV program relies much on subsidy], China Business, September 9, 2011, www.cb.com.cn*

*7. "国际合作推动中国可再生能源规模化发展" [International cooperation promoted the large scale development of Chinese renewable energy], National Energy Administration (NEA), November 17, 2011, www.nea.gov.cn*

*8. Yang, Jing, "China has the target of total installed capacity of 13 GW in Biomass before 2015," Dow Jones Newswires (Shanghai), August 1, 2011, www.dowjones.com*

*9. Feng, Ya and Huayan Ding, "发改委：2013年秸秆综合利用率达到75%" [National Development and Reform Commission (NDRC): The overall utilization rate of straw will reach 75% by 2013], China National Radio, January 5, 2012, www.cnr.cn*

*10. Wei, Shaofeng, "电力工业‘十二五’规划研究报告" [Introduction on Power Industry 12th Five-Year Plan], China Electricity Council (CEC), March 26, 2011*

*11. "2010年度电价执行及电费结算情况通报" [Report on electricity price and balance in 2010], State Electricity Regulatory Commission (SERC), September 28, 2011, www.gov.cn*

kWh, effective January 1, 2012. Revenue collected will compensate grid companies for the higher renewable FiT.[12] Though the new surcharge represents progress, it may only address the shortfall issue for two to three years under the current development pace—by 2015, the cumulative shortfall may reach RMB 15 billion.[13] The issue is further complicated by inflation concerns and the potential introduction of carbon taxes, which if well designed could negate the need for a renewable surcharge.

### New grid connection standards announced for wind and solar

Grid connections are one of the biggest constraints on solar and wind market development; therefore, the government has issued a number of standards to solve this problem. For example, new national and industrial standards have been approved for grid connection of wind power.[14] Another three standards on low-voltage ride-through (LVRT), dispatch and operations management, which are critical components of a stable and safe grid connection, are to be published shortly.[15] Fourteen national standards and 10 industrial standards for solar energy have been issued for topics, such as grid connection technologies, inverters and power compensation protocols, to regulate the uniformity of components and practices for connecting to the power grid.[16]

### Global solar downturn has accelerated, encouraging industry restructuring

Historically, China's solar industry has been export-oriented: in 2011, more than 90% of total module production was exported, with 60-70% of exports shipped to the European market.[17] However, European countries with large solar demand, such as Germany, Spain and Italy, have planned to reduce preferential FiTs as a result of the financial crisis and falling module costs.[18] Due to weaker demand from these countries, Chinese module makers are exploring other markets, such as the U.S. and Portugal.



**In 2011, more than 90% of China's total module production was exported, with 60-70% of exports shipped to the European market.**

The U.S. is the largest potential non-European solar market for Chinese manufacturers and has shown rapid growth through favorable policies.[19] However, in late 2011, seven U.S. PV module makers, led by SolarWorld, filed an anti-dumping complaint with the U.S. government against Chinese firms that called for 100% countervailing duties.[20] The U.S. Department of Commerce and the U.S. International Trade Commission (ITC) are both pursuing processes related to the investigations, with a series of rulings expected over the spring and summer of 2012.[21] In March 2012, the U.S. Department of Commerce announced it would impose tariffs ranging from 3% to 5% on imported solar modules.[22] In response to the anti-dumping case, Chinese manufacturers and the government have issued protests, threatening a reciprocal trade dispute. Demonstrating growing international integration of the global solar supply chain and a U.S. solar industry divide over the trade dispute, 132 U.S. companies have joined a coalition to oppose

*12. "可再生能源发展基金征收使用管理暂行办法" [Release of Interim Measures of Development Fund for Renewable Energy Collection and Management], Ministry of Finance (MOF), NDRC and NEA, November 29, 2011*
*13. China Greentech Initiative (CGTI) analysis*
*14. "《风电场接入电力系统技术规定》批准发布" [Technical Guidelines on Wind Power Grid-connected Plant has been approved to release], CEC and China Electric Power Research Institute (CEPRI), July 16, 2011; "大型风电场并网设计技术规范" [Technical Guidelines for Large Wind Power Grid-connected Plant], NEA, January 12, 2012, www.gwpcm.com*
*15. "风电机组低电压穿越能力测试规程" [Test Protocol on Low Voltage Ride-Through Capacity for Wind Power Sets], CEC, January 6, 2012, dls.cec.org.cn; "风电调度运行管理规范" [Wind Power Dispatch and Operation Management Regulations], CEC, March 21, 2011*
*16. "中电联推进光伏并网发电标准化管理" [CEC promotes standard management on solar power grid connection], Xinhua, February 3, 2012, news.xinhuanet.com*
*17. "市场对外依存度高产能过剩 光伏业谋求突围" [Domestic PV market highly relies on foreign markets, the Chinese PV industry strives for a breakout], China Economic News, February 7, 2012, www.cet.com.cn*
*18. "Global market outlook for photovoltaics until 2015," European Photovoltaic Industry Association (EPIA), May 2011, www.epia.org; Osborne, Mark, "Italy has a new FiT," PV-Tech, May 6, 2011, www.pv-tech.org*
*19. "Solar Policies," Solar Energy Industries Association (SEIA), www.seia.org, accessed on February 9, 2011*
*20. Bradsher, Keith, "U.S. Solar Panel Makers Say China Violated Trade Rules," New York Times, October 19, 2011, www.nytimes.com*
*21. "U.S. Department of Commerce finds massive surge of Chinese solar imports, triggering 90-day retroactivity if it finds duties are warranted," Coalition for American Solar Manufacturing, January 30, 2012, www.americansolarmanufacturing.org; "Update on US-China Trade Dispute," SERC Trade, www.serctrade.com, accessed on February 24, 2012*
*22. Bradsher, Keith and Matthew L. Wald, "A Measured Rebuttal to China Over Solar Panels," New York Times, March 20, 2012, www.nytimes.com*

the U.S. anti-dumping case.[23] The dispute has led to uncertainty in the marketplace, leading some Chinese module makers to shift from export-oriented business models to establishing manufacturing bases in target markets and building partnerships with foreign companies to avoid trade friction.

On the manufacturing side, in 2011, major Chinese module makers expanded capacity to reduce cost through improved economies of scale. Suntech Power grew annual production capacity by 33% to 2.4 GW, while Trina Solar expanded by 90% to 1.9 GW.[24] This expansion, combined with the unexpected slowdown in solar demand growth in late 2011, resulted in overcapacity, more intense competition and squeezed profits.[25]

**Capacity expansion and the slowdown in solar demand growth in 2011, resulted in overcapacity, more intense competition and squeezed profits.**

To boost domestic solar consumption and help meet non-fossil energy production targets, in August 2011, the NDRC set a new national FiT for solar power. The FiT was set at RMB 1.15/kWh before December 31, 2011, and RMB 1/kWh afterwards.[26] Partly as a result of the tariff, China installed 2.5-3 GW of solar in 2011.[27] However, the current FiT still has some unaddressed issues. Not only is the length of the FiT commitment unclear, but the unified national rate means most projects have concentrated in regions with high solar resources, such as Ningxia and Qinghai—far from large power-consuming provinces along the coast. As a result, coastal provinces—including Shandong, Zhejiang and Jiangsu—have set even higher regional FiTs to attract projects.[28]



Solar module manufacturers need strategies to cope with current market challenges. One is to pursue upstream or downstream integration along the value chain depending on core competencies, consolidating profits from all segments of the value chain to hedge risks. For example, Hanwha Group plans to establish in-house polysilicon production in South Korea, which it will supply to affiliate Hanwha SolarOne for cell and module manufacturing at a preferential price.[29] China Sunergy announced a deal to manufacture modules, develop and operate the world's largest building integrated photovoltaic (BIPV) project—a 7 MW rooftop system at the Nanjing South Railway Station—an example of module makers reaching out to build and operate solar systems.[30] Industry is trending toward consolidation to eliminate low-quality production; a number of smaller players have already gone bankrupt.[31] The third strategy is going outbound—through sales and production—to penetrate new international markets. Examples include Suntech Power entering the U.S. and LDK Solar investing in Greece.[32] The benefits of the outbound strategy include taking advantage of local subsidies, avoiding trade frictions, meeting local content requirements and improving service levels by locating closer to the customer.

## China's wind sector is maturing and expanding globally

In China's onshore wind sector, the central government has issued new standards for grid connection and has tightened wind farm approval policies to promote more orderly development. In October 2011, the China State Electricity Regulatory Commission (SERC) released the Security Regulations and Evaluation Standards for Wind Farm Grid

*23. Osborne, Mark, "Top executives from 14 leading Chinese PV manufacturers gather to fight SolarWorld," PV-Tech, November 30, 2011, www.pv-tech.org*

*24. "Solar cell industry: growing capacity, speeding integration," China Electronics News, May 24, 2011, epaper.cena.com.cn*

*25. "Module Pricing," Solarbuzz, www.solarbuzz.com, accessed on February 9, 2012*

*26. "关于完善太阳能光伏发电上网电价政策的通知" [Notice on policy improvement of solar PV feed-in tariff (FiT)], NDRC, www.sdpc.gov.cn, accessed on February 9, 2012*

*27. Osborne, Mark, "NPD Solarbuzz: China leads solar PV demand in Asia Pacific region with 2.9GW installed in 2011," PV-Tech, January 26, 2012, www.pv-tech.cn*

*28. "China Zhejiang to Set Higher Photovoltaic Power Price, 21st Says," Bloomberg, August 4, 2011, www.bloomberg.com; Liang, Zhongrong, "Shangdong released its regional FiT," Stockstar, July 22, 2011, finance.stockstar.com*

*29. "韩华：纵向一体化的联合部队" [Hanwha: a vertically integrated solar group], Solar PV Sources, August 23, 2011, www.solarpvsources.cn*

*30. "南京火车南站太阳能屋顶项目投资达2.7亿" [RMB 270 million investment for Nanjing South Railway Station], New Energy, www.newenergy.org.cn, accessed on May 16, 2011*

*31. "The PV industry is experiencing a downward spiral, 30% of SMEs have been shut down," Caijing, November 24, 2011, www.caijing.com.cn*

*32. "Suntech to provide solar panels for California power plant," SolarF, August 26, 2011, www.solarf.com; Choudhury, Nilima, "SPI Solar partner with Global Energy and LDK to develop 2MW facility in Greece," PV-Tech, January 18, 2012, www.pv-tech.cn*

Connection, mandating that new and existing wind turbines install and operate LVRT capability.[33] Such capability is expected to reduce grid disconnections—for wind plants over 100 MW, there were 193 such events from January to August 2011.[34] As a result, wind farm developers will face an incremental cost of RMB 150,000/MW on average. Overall, the standards signal a policy shift away from low-cost capacity toward higher-quality energy production.

Additionally, the NEA will no longer allow provincial Development and Reform Commissions (DRCs) to approve wind farms smaller than 50 MW, reflecting a desire for more controlled development. Provincial DRCs have approved 93% of onshore wind farms, but excessive approvals have at times contradicted national energy plans and contributed to grid connectivity problems.[35] As a result of the control measures, turbine and component manufacturers may experience slower market growth rates, though absolute growth will continue to be strong.

China's offshore wind sector has developed slowly, but recently the country has developed capacity for manufacturing the large capacity turbines that are required for offshore installations. In June 2010, China's first offshore project—the Shanghai Donghai Bridge 102 MW wind farm—started generating power under a tariff of RMB 0.978/kWh.[36] At the same time, China launched its first concession round for four projects totaling 1 GW; the winners were all state-owned enterprises (SOEs): China Datang Cooperation Renewable Power, China Power Investment, Shandong Luneng and Longyuan Power.[37] The tariffs ranged from RMB 0.62/kWh to RMB 0.74/kWh.[38] However, as of February 2012, none of the projects have started construction due in large part to conflicts with local government offshore zoning plans.[39] The second concession round is expected in the first half of 2012 with a total capacity of 2 GW.[40]



**Like the solar industry, Chinese wind farm developers and manufacturers seek opportunities in emerging overseas markets through outbound investment.**

Domestic manufacturing of large capacity wind turbines is considered critical for China to compete in the global offshore wind market, with Sinovel successfully assembling China's first 6 MW offshore turbines in June 2011.[41] Since then, Xinjiang Goldwind, Guodian United Power, Shanghai Electric and China Shipbuilding Industry Corporation have also announced plans to develop 5-6 MW large turbines by 2012.[42] Similar to the solar industry, Chinese utility-scale wind farm developers and manufacturers seek opportunities in emerging overseas markets through outbound investment. Chinese players Xinjiang Goldwind, Guohua Energy Investment, China National Machinery Industry Corporation and China Three Gorges Corporation are planning to build or invest in wind farms in Pakistan, Australia, Bolivia and Portugal.[43]

*33. "电监会：风电场的风电机组必须具备低电压穿越" [SERC: Turbines in wind farms must be capable of low-voltage ride-through (LVRT)], Easy Sources, October 11, 2011, www.easysources.cn*

*34. "风电安全监管报告 (2011年)" [Report on Supervision of Wind Farm Security (2011)], SERC, December 2011*

*35. "风电场投资建设管理新规或近期发布" [Revised measures on wind farm investment and construction to be released soon] Finance QQ, July 20, 2011, finance.qq.com*

*36. Guo, Fang, "风电三峡内幕" [Inside stories of China wind power], China Economic Weekly, August 18, 2011, paper.people.com.cn*

*37. "首批海上风电特许权项目困境待解二批招标即将启动" [The problems in the 1st offshore concession round projects are waiting to be solved, and the 2nd round is about to start], Hydro China Xibei Engineering Corporation, July 15, 2011, www.nwh.cn*

*38. "第二轮海上风电特许权招标规模或翻番" [The scale of second offshore wind concession round may double], Xinhua, June 16, 2011, news.xinhuanet.com*

*39. "首批海上风电特许权项目困境待解二批招标即将启动" [The problems in the 1st offshore concession round projects are waiting to be solved, and the 2nd round is about to start], Hydro China Xibei Engineering Corporation, July 15, 2011, www.nwh.cn*

*40. "第二轮海上风电特许权招标规模或翻番" [The total capacity of second offshore wind concession round may double], China News, June 16, 2011, www.chinanews.com*

*41. Yu, Chunlai, "华锐风电6MW机组中标海上项目" [Sinovel won the bidding of 6 MW offshore turbine project], National Business Daily, February 3, 2012, epaper.nbd.com.cn*

*42. "海上风电秀" [Offshore wind power show], China Value, November 27, 2011, www.chinavalue.net; Fang, Tiantian, "电二代的美好时代" [Glorious times for electric power companies], ifeng Finance, January 25, 2011, finance.ifeng.com*

*43. "Goldwind enters Pakistan wind power market," Onepakistan, December 18, 2011, www.onepakistan.com; "Bolivia to use Chinese wind turbines for first wind power project," Evwind, December 21, 2011, www.evwind.es; "Guohua pays US$ 88.6m for stakes in Hydro Tasmania wind farms," The Australian, December 22, 2011, www.theaustralian.com; "Portugal sells utility stake to China in 1st privatization linked to bailout," Washington Post, December 22, 2011, www.washingtonpost.com*

**Biogeneration and biodiesel experienced rapid growth due to favorable policies**

Bioenergy has also shown rapid growth due to recent policy announcements, including a new 12th Five-Year Plan target of 13 GW of total capacity and adding to a FiT policy previously released in 2010 for ag/forestry biomass. As a result, total biomass capacity has risen from less than 5 GW in 2010 to 5.8 GW in 2011.[44] A 100 MW biomass power plant, which is the world's largest using ag/forestry residues, was put into operation in Guangdong at the end of last year.[45] With China's large biomass resource potential, strong government support and improved project economics, bioenergy is expected to continue rapid growth. However, challenges remain, such as a poor feedstock supply chain, feedstock price volatility, difficult project financing conditions and uncertainty regarding grid connection standards.

## Market Opportunities

Attractive opportunities in renewable energy include expansion into new overseas markets for solar photovoltaic (PV) modules through relocating production or through mergers and acquisitions (M&A), creating wind turbine retrofit solutions to improve offshore and onshore wind farm efficiency, and pursuing biogas recovery and utilization solutions.



***Solar PV module suppliers investing overseas***

Chinese PV suppliers are already pursuing alternatives to export-centered business models. For example, by moving production factories into international target markets, Chinese suppliers can cut down logistics costs while also meeting local legal requirements for domestic subsidies or tax credits. Suntech Power, for instance, invested in an Arizona manufacturing facility.[46] Alternatively, PV suppliers can pursue M&A as a way to obtain market access, such as LDK Solar purchasing 70% equity in U.S. solar developer SPI.[47] Financial and legal advisors can provide services to facilitate such transactions, develop partnerships, secure funding and maneuver complex legal and tax environments.

**Moving Chinese factories into foreign markets cuts down costs while also meeting local legal requirements for domestic subsidies.**

***Onshore wind farm retrofit market and solutions to improve wind farm efficiency***

Chinese wind farms suffer from low-capacity factors and frequent operational troubles.[48] As the industry moves towards a more rational development with focus on quality and efficiency, the industry can expect increasing demand for wind farm retrofits, mostly related to gearbox repair and electronics upgrades, and requirements for improved operations and maintenance (O&M). Meanwhile, solutions for stronger and lighter blade and tower materials, improved blade shape and structure, more sophisticated siting technology, wind speed predication models, and energy storage technologies will all help improve operational efficiencies and increase capacity factors.[49]

*44. "《中国应对气候变化的政策与行动(2011)》白皮书" [Policy and action response to climate change (2011) white paper], State Council, November 22, 2011; "China constructing over 700 MW of biomass power capacity so far in 2011," Biomass-energy, September 30, 2011, www.biomass-energy.org*

*45. "世界最大生物质发电厂在广东投运" [World's largest biomass power plant starts operation in Guangdong], Ewise, November 22, 2011, www.ewise.com.cn*

*46. Cheyney, Tom, "Raising Arizona solar: Suntech bets on US market with Goodyear module manufacturing plant," PV-Tech, May 18, 2011, www.pv-tech.org*

*47. "Sunnyvale's LDK Solar Finalizes US$ 33 Million Deal for Solar Power Inc.," Silicon Valley Wire, March 31, 2011, www.siliconvalleywire.com*

*48. "风电安全监管报告 (2011年)" [Report on Supervision of Wind Farm Security (2011)], SERC, December 2011*

*49. Mahony, Melissa, "New material for longer, lighter wind turbine blades," SmartPlanet, November 5, 2010, www.smartplanet.com; "Bayer's new composite technology improves wind turbine blades," Green Optimistic, December 9, 2011, www.greenoptimistic.com*

***Biogas recovery from industrial agricultural, municipal and industrial organic waste***

Chinese industrial, municipal and agricultural waste produces large amounts of biogas, with only a small fraction—estimated less than 20% of total potential—currently captured and utilized. Given government carbon emission reduction efforts, stronger growth is expected for biogas recovery and utilization technology throughout the 12th Five-Year Plan period. Biogas recovery technology providers offering anaerobic digestion, gas purification or power generation solutions will profit from the increasing market demand.

## China's Solar Photovoltaic (PV) Value Chain

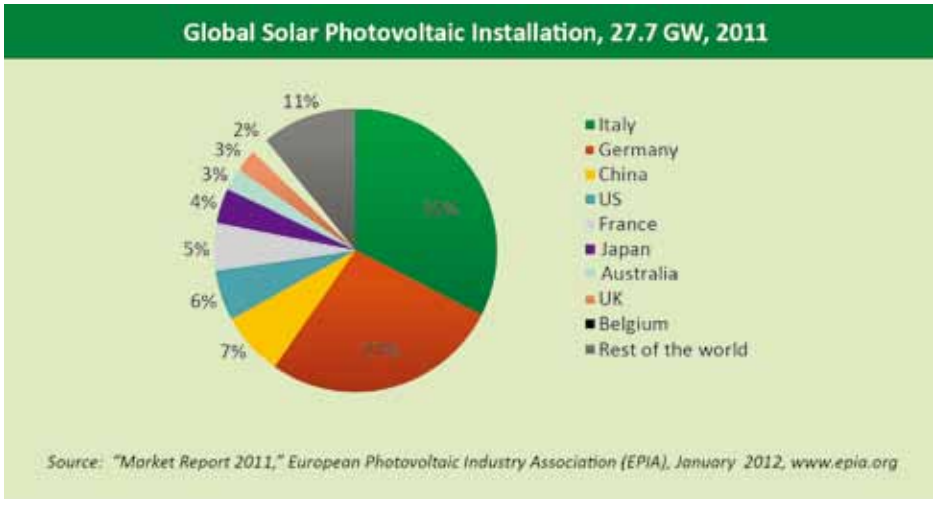
### Opportunity Assessment Summary

**Given current challenges in world solar markets, China's solar photovoltaic PV producers seek opportunities to reduce costs and preserve gross margins through vertical integration and industry consolidation.**

Solar producers face uncertain times: while global solar PV markets will continue to grow, rapidly falling prices, unstable subsidy schemes and module oversupply have resulted in falling margins across the value chain. Low-cost Chinese producers are raising production capacity to new records, in turn driving down selling prices and margins. At the same time, as domestic competition increases, the pressure on profits and market share has intensified. China's historically fragmented solar industry, with hundreds of small players across the value chain, are looking for strategies to strengthen financial performance, including vertical integration and capacity expansion, which is already widespread, and industry consolidation. Stakeholders should expect top players with strong cost advantages to continue to grow in size and market share. Thus far, however, vertical integration and expanding production capacity do not appear to guarantee profitability. Companies must also seek innovative strategies and partnerships to stay ahead of the market.

**Challenging overseas markets result in falling profits for Chinese module manufacturers**

Following a year of robust global growth in 2010 with 16.6 GW of installed capacity, solar PV continued its rapid expansion in 2011, adding an additional 24 GW.[50] Established European markets account for more than 75% of global market growth in 2011.[51] However, a substantial portion of these installations was part of a rush to

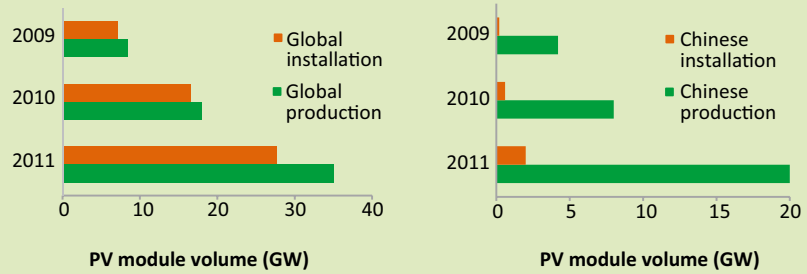



*50. "Global Solar PV to Rise 24% This Year, to 24 Gigawatts," Sustainable Business, November 16, 2011, www.sustainablebusiness.com*
*51. "Market Report 2011," EPIA, January 2012, www.epia.org*

benefit from the advantageous feed-in tariffs (FiT) and other incentives that were set to be reduced in mid-2011 through early 2012. Italy, for example, capped funding for large-scale installations, reduced FiTs beginning in 2012 and removed all tax breaks for solar production and installation. Due to continuing subsidy cuts, Chinese module manufacturer are facing weaker demand growth from Europe.

As a result, the U.S. is becoming a more attractive solar market. State-based incentives in California, New Jersey and Texas may make the U.S. the world's fastest growing market, with installation in 2011 doubling versus 2010. The U.S. is now China's largest solar PV destination outside Europe, accounting for up to 15% of total exports in 2011.[52]

**Global and Chinese Solar Photovoltaic Production Volume and Demand, GW, 2009-2011**

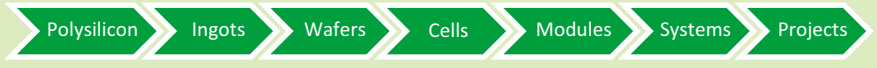



*Sources: "Market Report 2011," European Photovoltaic Industry Association (EPIA), January 2012, www.epia.org; "Global market outlook for photovoltaics until 2015," EPIA, May 2011, www.epia.org*

Long a major exporter of solar modules, China looks set to develop its domestic market and become one of Asia's largest producers of energy from solar. By the end of 2010, China had 860 MW of installed solar power capacity, whereas it manufactured nearly 8 GW of modules annually. This imbalance has left China's solar producers vulnerable to fluctuations in overseas markets. In 2010, production capacity outpaced demand by over 1 GW and, in 2011, the discrepancy may have grown to as much as 6 GW.[53] This rapid acceleration has had multiple effects on the industry. The first is a significant decline in prices globally, with average selling prices (ASPs) dropping 25% between January 2011 and January 2012.[54] The second effect is a growing fear of oversupply spreading throughout the industry, which could accelerate further declines in ASPs, and consequently hurt the financial performance of smaller, lower-tier producers.[55] Falling ASPs, caused by capacity expansions, as well as technology and manufacturing improvements and competition from low-cost producers, places pressure on gross profits across the value chain. Module producers, in particular, have experienced substantial declines. Some analysts estimate gross profit declines of 84% between 2008 and the end of 2011 for module producers relative to declines of 64% in aggregate profits across the value chain during the same period.[56]

## Vertical integration helps grow profits and hedge risk

**Polysilicon Photovoltaic Value Chain**




*52. "规避贸易壁垒 新能源冀企大举布局美国" [To avoid trade barriers, Hebei new energy enterprises enter U.S.], JRJ, February 21, 2012, finance.jrj.com.cn*
*53. "Global market outlook for photovoltaics until 2015," EPIA, May 2011, www.epia.org*
*54. "Module Pricing," Solarbuzz, www.solarbuzz.com, accessed on February 23, 2012*
*55. Williams, Andrew, "Growing Fears of PV Module Oversupply in 2011," Renewable Energy World, March 3, 2011, www.renewableenergyworld.com*
*56. "Solar Photovoltaic Industry 2011 Outlook - FIT cuts in key markets point to over-supply," Deutsche Bank, January 5, 2011, www.db.com*

All of the world's largest solar PV module suppliers in 2010 were vertically integrated to some degree, with companies such as Hanwha SolarOne (China) and REC (Norway) fully integrated from polysilicon production to project development. Vertical integration most commonly occurs across the ingot to module segments of the value chain (which includes wafers and cells), with capital and energy-intensive polysilicon production and service-oriented project development left to specialists. However, not all companies follow the same path to integration. Some producers, such as Yingli Green Energy and Hanwha SolarOne, began in the module segment of the value chain and gradually expanded into polysilicon production. LDK Solar, on the other hand, started out in wafer production and then simultaneously integrated upstream into polysilicon and downstream into cells and modules.[57]

Upstream integration can help control costs and secure supply, but faces high barriers. For many module producers, securing a high-quality, stable supply of polysilicon is critical to business and remains one of the biggest challenges. Polysilicon production is concentrated in a small number of companies, of which the top four produce more than 50% of global capacity.[58] In 2010, China imported 50% of its polysilicon, and much of its domestic supply came from small, low-quality producers.[59] Developing in-house polysilicon production capacity is a promising strategy showing advantages in cost reduction (since polysilicon makes up 15% of the total cost of a solar module), higher gross margin capture (50% in polysilicon production versus 20-30% in module manufacturing), smaller risk of price and supply fluctuations, and consistent quality. However, the investment and time required to develop in-house supply is high, and production is only efficient at a very large scale.



**China's ambitious 15 GW solar target in the 12th Five-Year Plan will create a 3 GW annual market.**

Downstream integration gives companies new revenue streams and access to new markets. While many solar companies in the U.S. and Europe have been active in project development, Chinese solar companies have focused on manufacturing modules and other components. With many markets across the world growing rapidly, companies look to project development and operations and maintenance (O&M) services as promising new revenue streams, as well as a path to secure demand for their own modules in new markets.[60] In China, the ambitious 15 GW target in the 12th Five-Year Plan will create a 3 GW annual market, and the national FiT has boosted domestic installation.

Downstream integration success in China will depend on business models dictated by the evolution of further market support policies, and largely will be determined by the role that large state-owned enterprises (SOEs) play in project development and ownership. The U.S. installation market also looks particularly promising as it shifts to more utility-scale projects.[61] Up to 1.6 GW of new capacity has been installed in 2011 in the U.S., with tax incentives and government loan guarantees piquing the interest of developers worldwide.[62] So far, few examples of Chinese-led projects exist, but this may change as Chinese companies gain more experience, and their ability to offer project financing through support from the China Development Bank or the Export-Import Bank of China may give them a competitive advantage.

### Industry consolidation is inevitable, but mergers and acquisitions (M&A) are still rare

Hundreds of Chinese companies occupy the module segment due to the relative ease of market entry compared to the more capital- or technology-intensive polysilicon and solar cell segments of the value chain. Turnkey manufacturing lines can be purchased, installed and rapidly put into production and, as a result, there are over 600 module producers in China compared to 167 cell companies and fewer than 50

*57. CGTI analysis*
*58. Shah, Abhishek, "List of World's Top (Solar, Semi) 8 Polysilicon Companies – Asia Rising as Big get Bigger," Green World Investor, March 2, 2011, www.greenworldinvestor.com*
*59. Research Report on China Polysilicon Industry, 2011-2012 (Shanghai: China Research and Intelligence, 2011)*
*60. This opportunity assessment focused on downstream opportunities in China and the U.S., but similar opportunities exist elsewhere in the world.*
*61. Utility-scale projects are more lucrative for project developers.*
*62. "Market Report 2011," EPIA, January 2012, www.epia.org*

polysilicon producers.[63] While hundreds of module companies exist, most production is concentrated in the factories of only a few top-tier producers, with the top five module companies accounting for over 60% of China's production capacity.[64] These large companies, like Suntech Power and Trina Solar, differentiate themselves by having over 1 GW of production capacity, sourcing select materials from foreign suppliers, using advanced manufacturing equipment and focusing resources on marketing and branding.[65] Some companies are even beginning to develop their own manufacturing equipment, one of the last areas of the solar value chain still dominated by foreign companies.[66]

Weak export markets and squeezed gross margins will eliminate many small manufacturers and force industry consolidation; however, few M&As have taken place to date. This may stem from difficulties related to integrating new companies with incompatible production equipment or management structures and, in many cases, expanding internal capacity is seen as simpler than acquiring it from other companies.

## China's Waste-to-Energy (WtE) Markets

### Opportunity Assessment Summary



**As China's waste volumes continue to rise, WtE technologies can improve waste processing capabilities and diversify China's energy sources.**

Waste is increasingly considered both a resource and an opportunity in China. The three WtE segments—municipal, agricultural and industrial—are at different stages of development, each with distinct characteristics and growth potential. While China recognizes that using waste resources for energy generation can mitigate growing air and water pollution, major challenges remain, including rising land prices, volatile landfill tipping fees and energy prices, intellectual property (IP) issues, financing limitations, and waste collection and local pollution concerns. However, with additional policy support and financial incentives, these issues could be addressed.[67]

**Strong growth potential for recovering energy from different waste types in China**

Municipal WtE currently accounts for less than 1% of China's power generation capacity, but can help solve China's power and fuel shortages.[68] Agriculture and forestry (ag/forestry) waste resources could supply China with 11 GW of energy by 2015, up from only 2 GW today.[69] Industrial waste currently presents the highest WtE power generation opportunity in China, and industrial waste heat and biogas from wastewater are the most immediate opportunities. Overall, the WtE value chain, which includes waste production, collection and processing, is highly fragmented.

**Agriculture and forestry waste resources could supply China with 11 GW of energy by 2015, up from only 2 GW today.**

*63. CGTI analysis*
*64. Ibid.*
*65. CGTI interviews*
*66. Ibid.*
*67. CGTI analysis and Partner interviews*
*68. "China Solid Waste Treatment Industry Report," Research in China, August 2011*
*69. "电力行业2010年发展情况综述" [2010 Power Generation Industry Development Statistics], CEC, June 27, 2011, www.tj.cec.org.cn*

**China's targets for producing biodiesel from waste cooking oil were 200,000 tons in 2010 and 1 million tons by 2015.**

### Municipal solid waste (MSW) incineration capacity is expected to double by 2015

Only a small proportion of China's MSW is used to generate energy, but the segment is growing rapidly. China is now the world's top MSW producer with waste growing at an astounding 8% per year.[70] In 2003, China collected 148 million tons of MSW and completed the harmless disposal (also called sound processing) of 75 million tons, or 51% of waste. In 2010, collection grew to 160 million tons with harmless disposal levels at 121 million tons, or 76% of waste.[71] Processing methods for municipal waste are gradually shifting from landfilling to recycling and WtE as the sound processing rate has increased from 51% in 2007 to 76% today.[72]

Currently, municipal waste that is processed is usually landfilled, but incineration is expected to grow dramatically to keep up with the growth rate of waste due to rapid urbanization, population growth and rising affluence. China's policy goal is to process 30% of municipal waste with incineration technology by 2020. China's municipal WtE capacity of incineration with power recuperation is currently only 1.6 GW, but is targeted to reach 3 GW in 2015.[73]

As of 2011, only 20 to 40 large landfills collect biogas out of the thousands of landfills in China, but growth is now driven by increasing market awareness and new landfill policy developments. The government considers landfilling as more economical in secondary cities with fewer space constraints than densely populated first-tier municipalities. Over 500 medium-sized landfills are expected to make up the next growth wave of biogas recovery installations.[74] Strong government relationships help companies obtain project approvals, but rising land prices and local opposition could hinder future landfill development, regardless of relationships.

Targets for producing biodiesel from waste cooking oil were 200,000 tons in 2010 and 1 million tons by 2015, with growth driven by government's effort to improve food security.[75] Biodiesel only provides 0.1% of China's transportation fuel, but the market is expected to grow four-fold by 2020.[76] Most biodiesel in China is generated from waste cooking oil and animal fat feedstock; the country generates over 4.5 million tons of waste oil per year.[77] To date, small-scale operators dominate China's biofuel industry; oil giants, such as Sinopec, are not involved.

### Plentiful resources are available for ag/forestry WtE, but policy support lags

China uses only 5% of its ag/forestry WtE potential, but this could grow to 25% by 2020 with adjustments in government policy.[78] Traditional ag/forestry waste biogas digesters and direct-fired power generation technologies are widespread, but more advanced technology in this segment is needed for power, gas and liquid fuel production.

Growth in the ag/forestry WtE segment is driven by available resources as well as social and environmental benefits, but is hindered by a lack of policy incentives, feedstock collection challenges and older commercial technologies. The ag/forestry market size is currently 2 GW from crop and forestry residues, with a policy target of 8 GW by 2015. While the government has stated that policy for the ag/forestry sector is

*70. Zhang, Dong Qing, et al., "Municipal solid waste management in China: status, problems and challenges," Elsevier, April 21, 2010, www.sciencedirect.com*
*71. "China Solid Waste Treatment Industry Report," Research in China, August 2011*
*72. Ibid.*
*73. "生物质能源十二五规划点评" [Comments on The 12th Five-Year Plan of Bioenergy], Financeqq, November 2, 2011 www.finance.qq.com*
*74. Zhang, Dong Qing, et al., "Municipal solid waste management in China: status, problems and challenges," Elsevier, April 21, 2010, www.sciencedirect.com*
*75. "Notification on Exemption of Consumption Tax for Biodiesel Refined by Waste Animal and Vegetable Oil," State Administration of Taxation, December 24, 2010*
*76. Liang, Yan, "China Resorts to Biodiesel Projects to Solve Energy Shortage," China View, January 16, 2008, news.xinhuanet.com*
*77. Liu, Yingling, "Used Cooking Oil to Fuel China's Expanding Car Fleet," Worldwatch Institute, October 12, 2006, www.renewableenergy.com*
*78. Wu, Chuangzhi and Haibin Li, "The Roadmap of Chinese Biomass Energy Development Presentation," Guangzhou Institute of Energy Conversion, December 3, 2008, www.biomass-asia-workshop.jp*

a priority, China missed its 2010 policy targets and has lagged in implementing additional measures.

China's 12th Five-Year Plan includes targets and standards that will speed adoption of ag/forestry WtE. New overall targets for the five year period total include producing 120 billion cubic meters ($m^3$) of biogas, installing 60 million household biogas digesters, producing 100 million tons of pellets and installing 8 GW of bioenergy capacity.[79]

One problem with distributed ag/forestry residues is that they must be utilized at or near the point of origin, particularly given increasing transport costs and related carbon emissions. Waste feedstock transport costs can account for 20-50% of the cost of energy generation.[80]

### China's industrial waste energy recovery market appears most attractive

Currently, China's industrial WtE market has less than 7 GW of waste heat recovery capacity; however, China has drafted a target to generate 31 GW from industrial waste energy recovery by 2015, combined with a 16% energy efficiency reduction goal by 2015 from 2010 levels.[81] While policy support is strong for industrial waste energy recovery, less attention has been given to waste solids, liquids and gas. As a result, prospects for waste heat recovery in China are very attractive. Recovering biogas from industrial wastewater appears moderately attractive, and other WtE forms are less so.[82]



China's potential industrial waste resources originate from at least 38 industries and fall into four broad categories, each with varying degrees of energy recovery opportunity, including energy waste (pressure and heat), liquid waste (sludge and wastewater), solid waste (process waste and hazardous waste), and gas waste (greenhouse gas and non-greenhouse gas). The large amount of industrial waste creates tremendous opportunity to develop and promote the industrial WtE market, particularly from energy and liquid wastes.

**Waste energy accounts for between 17% and 67% of total energy consumption depending on the industry, of which 60% is recyclable.**

Minimizing and recovering industrial waste energy is one of China's largest opportunities to save energy and improve overall manufacturing energy efficiency, since waste energy accounts for between 17% and 67% of total energy consumption depending on the industry, of which 60% is recyclable.[83] China's 11th Five-Year Plan emphasized industrial waste energy recovery, and support will continue throughout the 12th Five-Year Plan.

Among the 38 industries assessed, CGTI identified four industries that have the most attractive market potential for waste energy recovery: nonmetal mineral products (cement and glass), ferrous metals smelting and pressing (steel), chemicals (sulfuric acid), and non-ferrous metals processing. Since energy cost makes up the bulk of production cost—accounting for 40-45% for the glass industry—the prospect for positive project economics of energy recovery is attractive.[84] The cement industry is the most developed sector with 4.7 GW of installed WtE generation capacity, more than 50% of the sector's total potential so far. However, the market remains underdeveloped, in part due to poor energy auditing and a lack of data collection.

*79. Yue, Ben, "Bright future for biomass power in China," China Daily, July 11, 2011, www.chinadaily.co.cn*
*80. "Sino-German Project for Optimization of Biomass Utilization," China Biogas Sector, www.biogas-china.org, accessed on August 22, 2011*
*81. "China waste heat to energy capacity to reach 31 GW by 2015," Xinhua, August 26, 2011*
*82. CGTI analysis and Partner interviews*
*83. "Waste heat recovery: technology and opportunities in U.S. industry," U.S. Department of Energy, 2008; "中国余热发电行业的现状和发展趋势分析" ChinaConstruction Materials, Issue 11, 2010*
*84. "Current Situation of China's Waste Heat Generation and Analysis of its Development Trend," China Construction Material, Issue 11, 2010*

# Financing Utility-Scale Wind and Solar Power Projects in China

## Opportunity Assessment Summary

**China's rapidly growing utility-scale wind and solar capacity will require trillions of RMB in funding from 2012 to 2020. To fund the country's ambitious renewable installation targets, China will need a variety of financing models.**

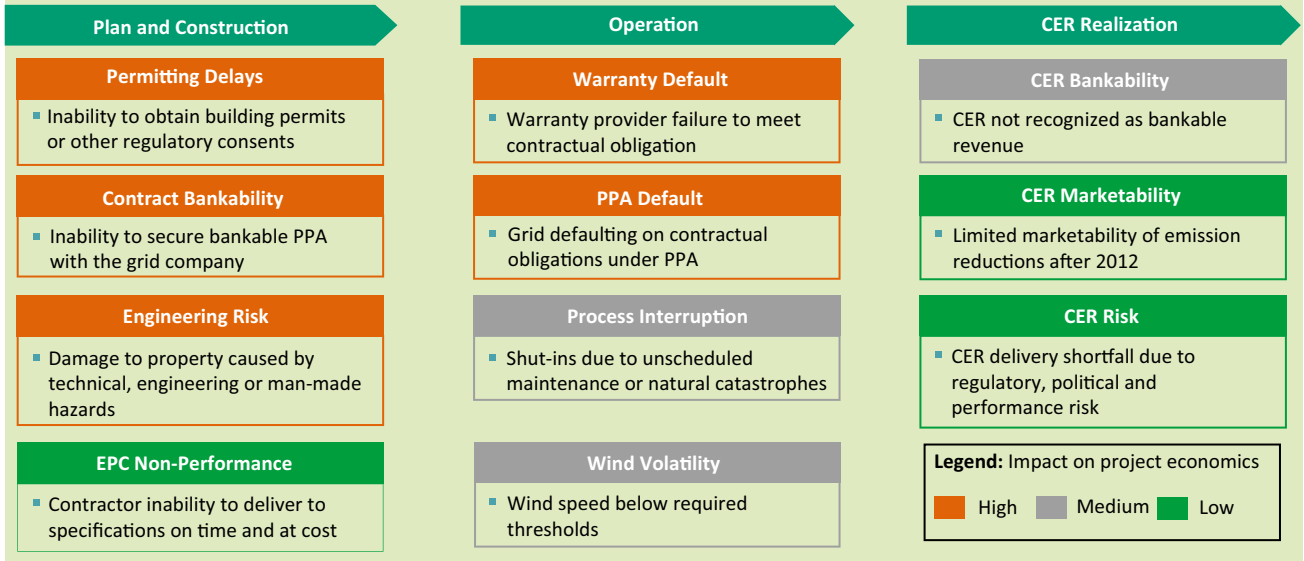
Given the high cost of renewable energy projects, it is perhaps not surprising that limited funding sources have become a bottleneck for project development. Debt, such as bank loans and bonds, is currently the main source for wind and solar financing, but good terms are only available to the largest enterprises or state-owned enterprises (SOEs), with little project financing needs. Direct government support for wind and solar includes tax credits, feed-in tariffs (FiTs), preferential land-use policies and low-interest loans. However, the current renewable energy surcharge is insufficient to fund the high cost of renewable energy projects. CGTI's sensitivity analysis of project economics suggests that wind plants can be economical only under highly favorable terms, and solar projects are currently uneconomical. Though China has become the world leader in wind manufacturing and installation, and solar installations are set to boom, the overall financing environment is unclear.

### Limited funding sources are a bottleneck for wind and solar projects

The rapid growth of China's wind and solar renewable energy projects masks a complicated financing picture. Though both wind and solar capital costs have fallen rapidly over the past few years, the risks of these projects remain elevated compared to conventional energy projects. Wind and solar projects have unique risks at each stage, which are illustrated below.



**Risk Profiles for Wind Power Project Lenders and Financiers**




**CER**: *Certified Emission Reduction*
**PPA:** *Power Purchase Agreement*
**EPC:** *Engineering, Procurement and Construction*

*Sources: "e-learning course on Insurance Risk Management for Renewable Energy Project," United Nations Environment Program, www.unep.org, accessed on February 1, 2012; CGTI analysis*

Loans, bonds and initial public offerings (IPOs) are the main source of funds for wind and solar to date. Relative to other countries, China has relatively little funding coming from private equity and venture capital (PE/VC), insurance or pension funds.

Bank loans currently provide about 80% of wind and solar project funding. Among commercial banks active in providing such loans, China's top four banks (Industrial and Commercial Bank of China, the Agricultural Bank of China, Bank of China, and China Construction Bank) provide the largest share. Commercial loans tend to have shorter terms than those in developed economies and have interest rates between 6-8%.[85] Development banks have also provided project funding—these include China Development Bank, the World Bank and the Asia Development Bank. Such funds are long-term, low interest (3-4%) loans open to both SOEs and private companies.[86] The downside of these loans is their limited availability combined with long application times and complex project assessment processes.

**Bank loans currently provide about 80% of wind and solar project funding in China.**

Given recent central government efforts to tighten credit, developers have turned to the nascent Mainland and Hong Kong bond markets to raise capital. In Mainland China in 2011, energy companies issued more than RMB 100 billion in bonds—terms range from 2-10 years with coupon rates from 4-6% depending on maturity. The drawback of this funding method is that it is generally only available to large SOEs. The so-called Hong Kong Dim Sum bonds in 2011 had coupon rates from 4.5-6.4%. Main issuers in the energy category were China Wind Power and Longyuan Power. However, compared to the Mainland bond market, the Dim Sum market is small, with only RMB 63 billion issued in 2011, of which only an estimated 6% was for wind and solar development.[87]



Equity issuances on the Hong Kong stock exchange are another important source of funding for renewable energy development in China. In 2009-2010, four SOE wind developers launched IPOs: Guodian's Longyuan Power, Huaneng Renewable Energy, China Datang Corporation Renewable Power and China Suntien Green Energy, which raised over US$ 28 billion to meet installation targets.[88]

### China promotes renewable energy with a range of financial incentives

China's government support for wind and solar energy projects includes tax credits, preferential land-use policies, FiTs and a renewable energy surcharge. China has several tax credit policies for renewable energy. In 2008, the government introduced a 100% corporate income tax exemption for the first three years of wind and solar operation, followed by a 50% exemption for the following three years.[89] This tax break is in addition to a 50% value-added tax (VAT) refund for electricity generated from wind power.

Preferential land-use policies are a second element of policy support for renewables: though there is no set national policy, state-owned land prices for recent wind farms in Gansu and Inner Mongolia have taken place at close to the lowest land sale prices nationally. In addition, some provinces, such as Ningxia, have exempted renewables from land transfer fees, construction fees and land-management fees.

The central government has used FiTs to subsidize the higher cost of wind and solar energy. In the case of onshore wind, since July 2009, the National Development and Reform Commission (NDRC) established a FiT system ranging from RMB 0.51-0.61/kWh depending on regions of various levels of wind resources. For solar, the national FiT has been set at RMB 1.15/kWh for projects approved before July 1, 2011 and in operation before December 31, 2011, and at RMB 1/kWh for the remaining projects.[90] The tariffs were determined in part by earlier government solar concession rounds for utility-scale plants. In addition to the national FiT rates, a number of provinces have adopted their own solar FiTs to reflect local conditions: Qinghai set a tariff of RMB 1.15/kWh

*85. CGTI interviews*
*86. Ibid.*
*87. Law, Fiona, "HSBC Banker: More Renewable Energy Firms Likely to Sell Offshore Yuan Bonds," The Wall Street Journal, May 4, 2011, www.online.wsj.com*
*88. "Green Investing 2011, Reducing the Cost of Financing," World Economic Forum, www.weforum.org, accessed on February 23, 2012*
*89. "宁夏‘三免一低’扶持新能源" [Ningxia supports new energy by 'three exempted and one lowered'], Ministry of Land and Resources (MLR), July 19, 2009, www.mlr.gov.cn*
*90. Landers, John, "China Implements a National Feed-In-Tariff Rate," Energy Trend, August 12, 2011, www.energytrend.com*

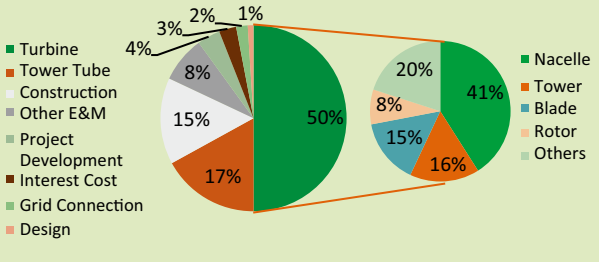
for projects online before September 30, 2011; Shandong has a FiT of RMB 1.2/kWh in 2012, Jiangsu set a FiT of RMB 1.4/kWh in 2011, and Zhejiang set a tariff of RMB 1.43/kWh in August 2011.[91]

To address a shortfall in wind, solar and biomass energy tariff revenues relative to power from traditional sources, the renewable energy surcharge—which is applied to all power sales—was raised to RMB 0.008/kWh for non-residential users in December 2011 and applied to all users in January 2012. While the increase will probably meet the excess cost of renewable power in 2012, projections for 2015 suggest that the surcharge could fall short again. Since grid companies must purchase all power sold to the grid, when the renewable energy surcharge funds fall short, this can discourage grid companies from actively seeking to connect renewable plants to the grid—a problem that has plagued wind power plants in particular in recent years.

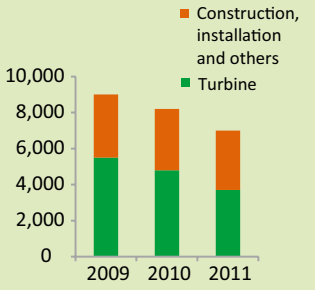
### Wind farm projects offer low but positive returns, and solar projects are unattractive

Wind and solar farms have fallen dramatically in price. Onshore wind farms in China can now be completed for around RMB 7000/kW.[92] About half of the cost of installation is for the turbine itself, with the tower accounting for a further 15%.[93] Turbine prices have fallen from RMB 6500/kW in 2008 to as low as RMB 3600/kW in late 2011, explaining a large amount of the reduction in total installed cost. Offshore wind capital costs are twice of onshore costs on average. Solar prices have fallen even more so than wind—photovoltaic (PV) system costs have decreased from RMB 74,000/kW in 2007 to as low as RMB 13,000/kW in late 2011.[94]

**China's Onshore Wind Farm Cost Structure, RMB 8,000/kW**




**China's Wind Farm Installed Cost, RMB/kW, 2009-2011**

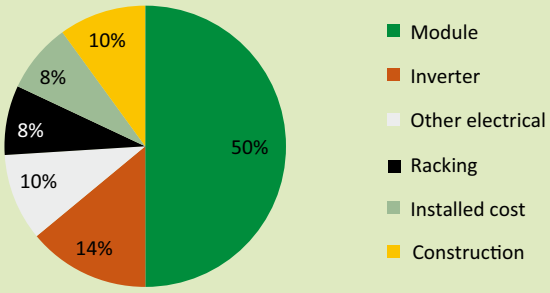



*Note: Estimated data based on interviews with wind farm operators and blade manufacturers.*
*Source: Krohn, Soren, et al., "The Economics of Wind Energy," Brussels: European Wind Energy Association, 2009*

Wind projects currently face a unique situation in China. The cost of a typical wind project ranges between RMB 7,000/kW and RMB 9,000/kW installed capacity. Banks are usually able to offer better financing terms for higher-quality, more expensive turbines. SOEs are able to access low-interest debt and may be able to finance up to 80% of projects at interest rates of around 7%, which is not possible for smaller developers or foreign players. Project debt in China is currently available only on the basis of floating interest rates; developers generally assume that interest rates will revert to mean over time, but rates can fluctuate and consequently increase project risk. CGTI analysis suggests that wind farm project internal rate of returns (IRRs) would be around 9-10%, with the assumptions of RMB 0.51/kWh FiT over the life of the project, a 20-year project life, a 23% capacity factor, a 1% insurance cost, and subsidies based on refunds for a portion of VAT tax payments in the project's initial years. Attractive capacity factors combined with improved financing terms could increase this IRR substantially.[95]

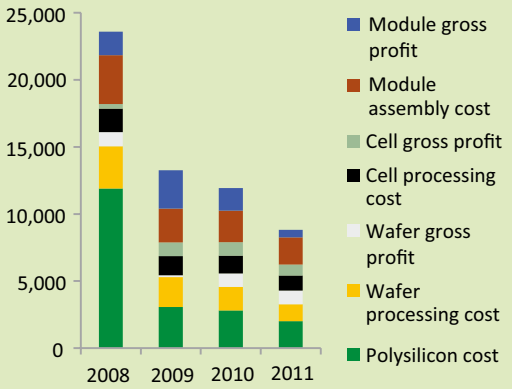
*91. CGTI analysis*
*92. CGTI interviews*
*93. "China wind power sector," J.P. Morgan, February 18, 2011*
*94. "Module Pricing," Solarbuzz, www.solarbuzz.com, accessed on May 10, 2011*
*95. CGTI analysis and Partner interviews*

**China's Solar Power Project Cost Structure, RMB 13,000/kW**




*Sources: "Solar Technologies Market Report," U.S. Department of Energy National Renewable Energy Laboratory, Open Energy Info, en.openei.org, accessed on January 15, 2010; "Module Pricing," Solarbuzz, www.solarbuzz.com, accessed on May 10, 2011; "PV Module Industry: Volume is Vanity, Profit is Sanity," IMS Research, November 17, 2010, www.pvmarketresearch.com*

**China's Module Cost and Profit, RMB/kW, 2008-2011**



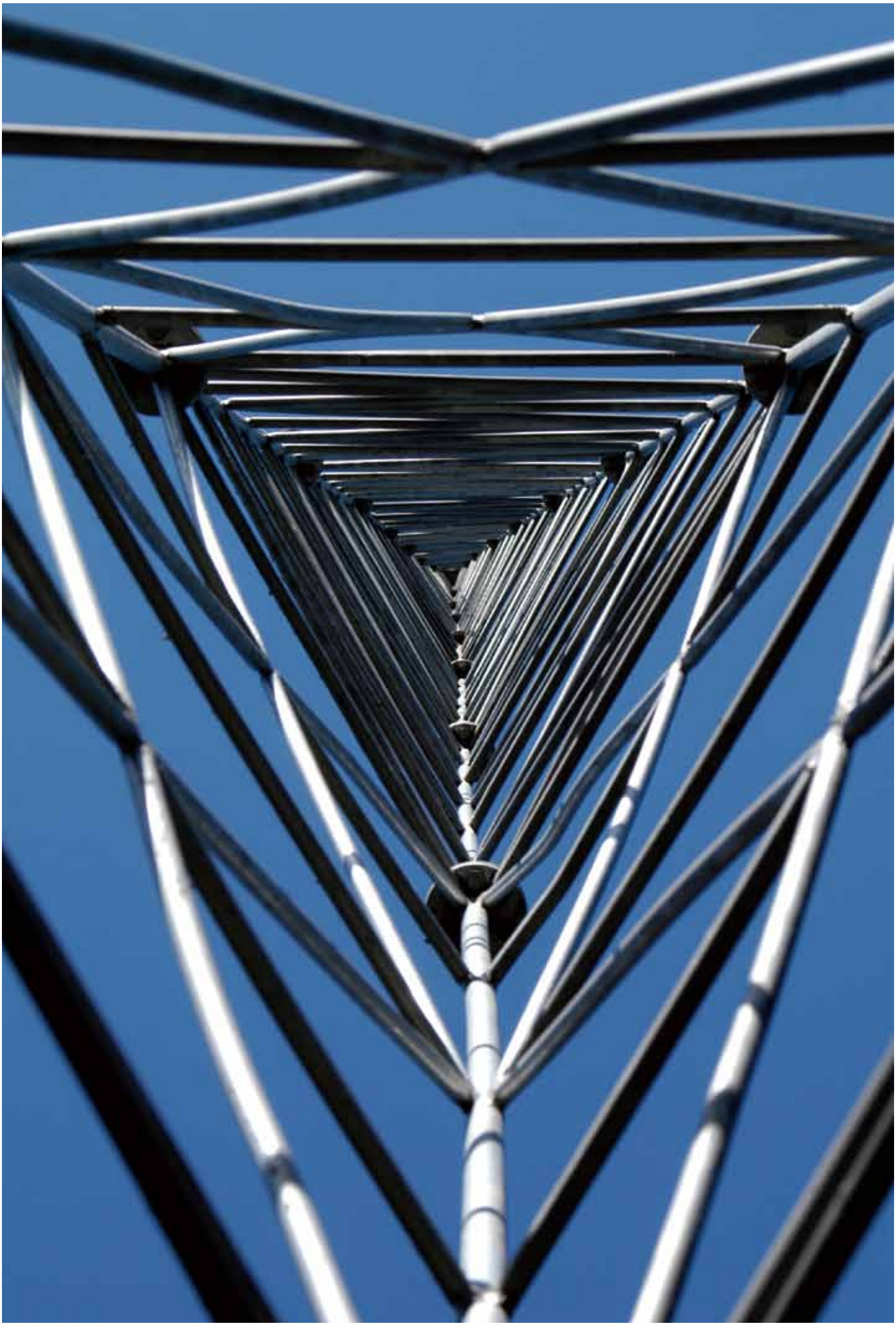

*Sources: "Solar Industry 2011 Outlook," Deutsche Bank, January 5, 2011; "探访目前中国最大太阳能发电站" [Visit to the present biggest PV station in China], Sina, September 29, 2009, news.sina.com.cn*



Based on a similar CGTI analysis, the projected IRR of solar projects is not economically attractive under current capacity factors, capital cost and FiTs. To achieve an IRR higher than 10%, projects would have either have to have a capacity factor higher than 20% (versus 15-20% currently), capital cost smaller than RMB 10,000/kWp (versus RMB 13,000-18,000/kWp now), or a FiT higher than RMB 1.3/kWh. Aside from the variables above, the financial structure of a project could also determine its economics. Under the currently modeled 50-70% debt/equity ratio and 4-8% interest rate, the project IRR always falls lower than 10%. Developers continue building solar projects under unfavorable conditions for several reasons, including gaining market share and experience, satisfying mandatory requirements for renewable energy generation, and anticipation of falling PV module cost or better financial incentives.

## The Path Ahead

This chapter provides an update of China's Renewable Energy sector and three Opportunity Assessments prioritized by CGTI Partner companies and supporting organizations in 2011. As the sector evolves, participants in the China Greentech Partner Program will continue to collaborate on additional opportunity areas. The first topic in 2012 covers prospects for global solar innovation and collaboration, with a focus on near-term partnership opportunities between China, U.S. and Europe. Other topics may include analysis of solar component technology and markets, wind turbine technologies, and biofuels. CGTI will also continue to track the evolution of China's Renewable Energy sector.



# Electric Power Infrastructure

**In 2011, China entered the construction phase of its 2009-2020 Strong and Smart Grid Plan, the world's largest effort to build a reliable, efficient and smart grid. Companies supplying the country's two main grid utilities will benefit.**

**State Grid and China Southern Grid serve 92% of the country's population.**

China's is pursuing the world's largest electric grid development program over the next decade—including large-scale adoption of smart grid technologies. Energy efficiency targets, a rising share of renewable energy, transmission of power over long distances, and expansion of electric vehicle (EV) charging infrastructure all represent tremendous challenges to China's grid companies. In response, central authorities adopted in 2009 a Strong and Smart Grid Plan that establishes by 2020 a complete, reliable, efficient and smart power grid. The plan places great emphasis and resources on expanding the high-voltage transmission system and improving reliability, as opposed to traditional smart grid technologies. The country's domestic industry is set to benefit most from this ambitious program. China's two grid operators, State Grid and China Southern Grid, serve 92% of the country's population. The grid's duopolistic structure will greatly facilitate technology standardization and execution of China's ambitious plans; however, market access remains an issue and only a small group of industry participants—most of them state-owned enterprises (SOEs)—may benefit. Despite the sheer size of China's electric power infrastructure markets, opportunities vary considerably across the value chain.

This chapter begins by providing an overview of Electric Power Infrastructure sector developments since the publication of the *China Greentech Report 2011*, and highlights a range of commercial opportunities for industry stakeholders. The chapter concludes by summarizing two Opportunity Assessments developed by the China Greentech Initiative (CGTI) in collaboration with Partner companies and organizations during 2011.

- China's Strong and Smart Grid Investment Plan Update
- Energy Storage for Intermittent Power Connectivity

The third Opportunity Assessment, on EVs and charging infrastructure, combines research from both the Electric Power Infrastructure and Cleaner Transportation sectors, and is presented in the Cleaner Transportation chapter of this Report. These summaries represent high-level findings of the detailed proprietary research and analysis developed in collaboration with and for the organizations participating in the China Greentech Partner Program.

*Senior Analyst Julien Bédin ( 朱立安 ) led the writing of this chapter with support from contributing writer Research Manager Ana Chiong (MangoStrategy) based on 2011 strategic research conducted by Senior Analysts Junda Lin ( 林骏达 ) and Sean Wang ( 王效 ).*

**Electric Power Infrastructure Sector Definition**

CGTI defines **Electric Power Infrastructure** as an integrated system of smart grids and networks that deliver power to users in an efficient and reliable manner from a broad range of generating sources. These grids and networks are usually supported by information technology infrastructure and applications. This definition is derived from the "smart grid" concept, which emphasizes the smart, efficient and reliable transmission, distribution and management of electricity.

# Market Update

### China's electric power infrastructure faces new challenges

The country's power sector is facing major shifts over the next ten years to enable industrial development, energy security and environmental protection. These include reducing China's energy intensity per unit of GDP, increasing reliance on renewable energy sources, transmitting power between distant provinces and accommodating new power demand from electric vehicles (EVs). The grid, as it is currently designed and operated, is insufficient to handle these changes. The 12th Five-Year Plan released in March 2011 sets ambitious targets for energy intensity reduction and environmental protection by 2015. China's power grid can contribute by improving power transmission efficiency, enabling demand-side adjustments, and connecting more renewable energy.

The percentage of non-fossil fuel in China's primary energy consumption is targeted to rise from 8% in 2010, to 11.4% by 2015, and 15% by 2020.[1] To achieve these goals, China will promote wind and solar power, but their intermittent nature challenges grid reliability. Pairing wind and solar power plants with energy storage facilities is one way to mitigate this issue, although most storage solutions have not reached the commercial stage—except for pumped-storage hydroelectricity, which has limitations.[2] An alternative solution promoted by central officials consists of building long-distance ultra-high voltage (UHV) lines to match power supply and demand at the national scale.

Matching power supply and demand via UHV lines would solve China's structural imbalance between regions with rich energy sources and those with high energy consumption. In 2011, the country's 12 coastal provinces—Heilongjiang, Jilin, Liaoning, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong and Beijing—accounted for 48% of total electricity produced, but 58% of total consumption.[3] 84% of China's vast coal reserves—accounting for 34% of global resources—are located in the west.[4] The country's hydropower resources are mostly located in the south and southwest. Wind resources are highest in remote regions in west and north China. Solar exposure is strongest in the Western provinces of Xinjiang, Ningxia, Gansu and Tibet.[5]

Since Chinese cities may account for 20% of global energy demand by 2025, improving sustainability of China's built environment creates major opportunities to reduce energy demand and mitigate environmental pollution.[6] Smart electric appliances

*1. "中国将大力发展非化石能源 争取2020年比重达到15%" [China will greatly develop non-fossil energy, with the target of 15% by 2020], China News, November 22, 2011, www.china.com.cn*

*2. China Greentech Initiative (CGTI) analysis and Partner interviews*

*3. "电力监管年度报告 (2010)" [Electricity supervision annual report (2010)], China State Electricity Regulation Council (SERC), April 2011*

*4. "2010年能源经济形势及2011年展望" [Energy structure in 2010 and outlook in 2011], National Development and Reform Commission (NDRC), January 28, 2011, www.sdpc.gov.cn; "关于加快推进煤矿企业兼并重组的若干意见" [Opinions on accelerating the mergers and acquisitions of coal mining enterprises], NDRC, October 16, 2010, www.gov.cn*

*5. Zhang, Qingfeng, et al., Rural Biomass Energy 2020: Cleaner Energy, Better Environment, Higher Rural Income (China: Asian Development Bank, 2010); Wang, Minnan and Jin Zhong, "Development of Distributed Generation in China," (New York: Institute of Electrical and Electronics Engineers (IEEE), 2009); The Power of Renewables: Opportunities and Challenges for China and the United States (Washington, D.C.: Committee on U.S., National Research Council, Chinese Academy of Sciences, Chinese Academy of Engineering, 2010)*

*6. Woetzel, Jonathan, et al., Preparing for China's Urban Billion (Shanghai: McKinsey Global Institute, 2009)*

and smart meters can change the way power is consumed: smart meters improve data collection, enable tiered pricing or time-of-use pricing, and support real time two-way communication between the grid operator and power users. The combination of smart appliances and meters when coupled with variable electricity pricing will allow real time power consumption adjustments that will facilitate power network management and accommodation of intermittent or distributed power generation sources.[7]

Expansion of China's EV fleet and charging infrastructure is also noteworthy. The central government has set a target of 500,000 EVs in circulation by 2015, supported by the world's largest charging station network.[8] EV charging creates additional power demand with new consumption patterns. The option for two-way power flows between EVs and the grid offers the benefit of compensating for power shortages by using stored power in plugged-in EV batteries, but requires specific management solutions and grid supervision. China's grid currently cannot support large-scale EV charging.

Conventional grids present a number of disadvantages, including fixed interval monitoring, analog control and inability to make real time adjustments, which are compounded by the size of China's grid network. To enable and respond to the major shifts described above, in 2009, the central government announced the Strong and Smart Grid Plan.

### In 2011, China entered the construction phase of its Strong and Smart Grid Plan

State Grid's Strong and Smart Grid Plan is divided into three phases between 2009 and 2020. Total allocation will reach RMB 3.8 trillion to support the pilot, construction and industrialization phases of the plan.[9]

**State Grid's Strong and Smart Grid Plan Overview, May 2009**

**3-Phase Deployment Plan**

**Phase One: 2009-2010** — Completed
***Pilot***

**Scope:**
- Establish technology and standards
- R&D for key technology and equipment
- Launch major demonstration projects

**Phase Two: 2011-2015** — Now
***Construction***

**Scope:**
- Build UHV transmission lines and distribution networks in urban and rural areas
- Initiate and develop Strong and Smart Grid operating controls and interactive systems
- Adopt key technologies and equipment

**Phase Three: 2016-2020** — Upcoming
***Industrialization***

**Scope:**
- Complete construction of Strong and Smart Grid
- Adopt world class standards for technology and equipment

*Sources: Chen, Hua and Ran Shi, "即将进入全面建设期的中国智能电网" [China Smart Grid entering a comprehensive construction period], China International Capital Corporation Ltd., April 7, 2010; "国家电网智能化规划总报告" [State Grid Smart Grid Plan Final Report], State Grid, February 2010*



*7. CGTI analysis and Partner interviews*
*8. "T10商定发展规划 2015年纯电动车要破50万辆" [T10 agreed development plan: over 500,000 EVs by 2015], China News, May 19, 2010, www.chinanews.com*
*9. "国家电网计划5年投资1.6万亿元基本建成智能电网" [State Grid plans to invest RMB 1,600 billion to build up Smart Grid in the next years], National Energy Administration (NEA), September 30, 2011, www.nea.gov.cn*

2011 marked the beginning of the construction phase, kicking-off arguably the most promising period for commercial stakeholders seeking a piece of the world's largest smart grid deployment. The construction phase is focused on building UHV lines and distribution networks in urban and rural areas, developing operating controls and interactive systems, and adopting key technologies and equipment. It is expected to run from 2011 until 2015. Allocated funds for the phase vary between RMB 1,500 billion and RMB 1,800 billion, with around 16% to 18% earmarked for smart grid solutions and another 15% to 18% set aside for UHV transmission lines. China's Strong and Smart Grid Plan is introduced in more detail later in this chapter.

### China's grid duopoly helps State Grid execute the Smart Grid Plan

Following a power sector reform in 2002, State Grid and Southern Grid together own and operate 84% of the country's 3,171 grid companies and serve 92% of its citizens.[10] State Grid delivers electricity to 26 out of China's 31 provinces; it ranked seventh in the 2011 Fortune Global 500 list and is the largest utility in the world.[11] Southern Grid has responsibility over the grid in five Southern provinces: Guangdong, Guangxi, Yunnan, Guizhou and Hainan. This duopolistic structure facilitates standardization and integration of smart grid technology across China's vast territory, and spreads investment costs over a wider revenue basis.

**State Grid and Southern Grid together own and operate 84% of the country's 3,171 grid companies and serve 92% of its citizens.**

State Grid started to vertically integrate its operations in 2009 by acquiring what has since become a 60% stake in leading domestic electric power equipment manufacturer Xuji Group and a 100% stake in Pinggao Group. The National Development and Reform Commission (NDRC) authorized the transactions despite market concerns that the deal would breach the country's power sector reform policies aimed at downsizing grid companies by encouraging affiliate spin-offs.[12] With ownership in leading technology suppliers, State Grid can develop solutions to meet its specific needs.



State Grid is gradually shifting toward centralization to drive technology adoption, promote standardization and lower costs. Centralization began in the first half of 2010 when more than 85% of purchasing contracts at Level 1, such as for high-voltage equipment, were procured centrally.[13] State Grid also partnered with the consulting firm Accenture to build a unified information technology (IT) platform for bidding.[14] The platform—launched in June 2011—handles bidding, contract management, supplier management and other procurement processes.[15] State Grid's procurement criteria also evolved over the recent years, shifting more towards technology considerations rather than price. As a result, foreign and private domestic companies may gain procurement contracts previously granted to lower-cost companies and large state-owned enterprises (SOEs). For example, in January 2011, Landys+Gyr—since purchased by Japanese conglomerate Toshiba—won a contract for 10,000 commercial and industrial meters from State Grid in a centralized procurement award.[16] Though the size of the contract awarded is small, it is considered an achievement in a sector that has historically been dominated by domestic smart meter companies.

During the first phase of State Grid's Strong and Smart Grid Plan, the utility established technology standards, completed research and development (R&D) for key solutions, and launched major demonstration projects. The technical and operational knowledge gained from completing 228 demonstration projects across the value chain helped the company establish standards for smart grid technology adoption—some of which have no international equivalent. State Grid appears eager to take the lead in setting international standards, and has already sponsored a number of international

*10. "电力监管年度报告 (2010)" [Electricity supervision annual report (2010)], SERC, April 2011; Shan, Juan, "Population now stands at 1.341 billion," China Daily, March 1, 2011, www.chinadaily.com.cn*
*11. "Global 500," CNN Money, 2011, money.cnn.com, accessed on February 17, 2012*
*12. Yang, Yue, "State Grid's Xuji Takeover Completes," Caixin English, February 6, 2010, english.caixin.com*
*13. CGTI analysis; Level 1 equipment refers to high voltage equipment that generates, transmits and distributes power, such as generators, transformers, interrupters, automatic switches, connectors and similar devices.*
*14. "国网信息化工程建设实现成本最优控制" [National network of information projects to achieve cost-optimal control], Beijixing Power Network, October 19, 2009, news.bjx.com.cn*
*15. Zeng, Huijuan, "电子商务平台：集约化管控的利器" [Electronic commerce platform: concentrated management and control tools], China E-Government, August 26, 2011, www.e-gov.org.cn*
*16. "Landis & Gyr shows just how to prosper in China," Smart Grid Today, January 4, 2011, www.smartgridtoday.com*

conferences on the subject. If foreign countries adopt China's domestic grid standards, opportunities for Chinese technology exports to foreign markets would expand.

China's grid industry offers limited market access to technology suppliers that have not yet formed commercial relationships with either State Grid or Southern Grid. As a result, established domestic companies—often current or former SOEs—have benefited most from the country's vast grid technology markets. The recent changes in State Grid's procurement decision-making process may further favor the large established players, while also offering improved prospects for specific technology-driven markets.

Southern Grid follows a more decentralized approach to procurement, with the central levels of the organization establishing lists of pre-approved suppliers with which provincial and local subsidiaries can further negotiate contract details. Executives from CGTI's Partner organizations indicate that Southern Grid is also usually more accessible than its Northern counterpart. The utility is already working with foreign EV charging company Better Place on battery swapping models, and with BYD—a leading domestic car and battery manufacturer and emerging player in the electric power industry—on battery charging technology.

### Foreign companies establish partnerships to gain market share

Foreign companies are developing partnerships with established domestic firms to improve market access with the two grid companies. In May 2011, French IT consultancy and system integrator Atos Origin signed a joint venture (JV) with Chinese telecom equipment provider ZTE to deliver advanced meter management solutions and smart grid-related IT services to utilities in China.[17] U.S. smart meter provider Echelon and domestic company Holley Metering have agreed to collaborate on advanced smart metering product development.[18] In September, U.S.-based light-emitting diode (LED) manufacturer Powersav, Xinlong Electrical and Wuhu Huarui Power Transmission and Transformation Engineering agreed to co-develop advanced transmission and transformation equipment in China.[19] European power equipment company ABB and State Grid's Nanjing Automation also announced plans to develop smart grid supporting equipment.[20]

**Expertise gained from JV partnerships and large procurement contracts may provide an edge when competing overseas.**

Partnerships with domestic companies not only help foreign companies position in the Chinese market, but also allow domestic partners to refine technology offerings and adapt internal management to foreign standards. While domestic companies are currently focused on serving huge domestic infrastructure needs, the expertise gained from these JV partnerships and economies of scale gained from State Grid and Southern Grid's large procurement contracts may give them an edge when competing overseas in the future.

### Chinese utilities expanding in foreign markets

State Grid started investing abroad in 2007 with a US$ 3.95 billion successful bid for a 25-year contract to manage the Philippines' entire electricity grid (along with local partners).[21] In December 2010, the utility acquired 3,200 kilometers of electric lines in Brazil for US$ 1.8 billion—the largest completed Chinese investment in Brazil at the time.[22] In February 2012, State Grid purchased a 25% stake (for EUR 387.2 million) into Redes Energéticas Nacionais (REN), Portugal's national grid utility. The investment also includes EUR 1 billion from the China Development Bank to help the

*17. "Atos Origin and Chinese telecom equipment provider ZTE form joint venture to capitalize on growing Chinese energy market," Atos Origin, May 4, 2011, atos.net/en-us*

*18. "Echelon and Holley Metering Sign Agreement to Develop and Sell Advanced Smart Grid Solutions for the China Market," Echelon, August 3, 2011, www.echelon.com*

*19. Johnstone, Heather, "PowerSav invests in joint venture in China," Power Engineering International, September 1, 2011, www.powerengineeringint.com*

*20. "ABB与国电南自合资成立扬州国电南自开关有限公司" [ABB Partners Nanjing Automation to form Yangzhou Guodian Nanzi Switch Company], Guodian Nanjing Automation Co., Ltd., www.sac-china.com, accessed on February 17, 2011*

*21. "国家电网开始发展海外市场" [State Grid starts expanding in overseas markets], OFweek, February 3, 2012, smartgrids.ofweek.com; Landingin, Roel and Richard McGregor, "China State Grid group wins Philippine auction," Financial Times, December 12, 2007, www.ft.com*

*22. Ho, Charles and Lap Chan, "Commentary: The Investments of China's State-owned Enterprises in Brazilian Infrastructure: Assessing the Implications of State Grid's Entry," Harvard Asia Quarterly, March 25, 2011, asiaquarterly.com; "Milbank Advises on China's Biggest Completed Investment in Brazil," Milbank Press Release, January 10, 2011, www.milbank.com*

Portuguese company meet refinancing needs until 2014 and complete a EUR 3.2 billion investment plan through 2016.[23] In February 2012, Reuters reported that State Grid was considering purchasing a controlling stake in U.S. power company AES Corp.'s wind power business.[24]

China's Strong and Smart Grid Plan will give State Grid and Southern Grid unprecedented experience in large-scale deployment of smart grid solutions. Their suppliers will also benefit from the plan and become more competitive when seeking to expand in foreign markets, with a near-term focus on emerging countries.

**China's Strong and Smart Grid Plan will provide unprecedented experience in large-scale deployment of smart grid solutions.**

## Market Opportunities

**China's ambitious Strong and Smart Grid Plan creates a wide range of opportunities across the power sector value chain. However, market needs and access vary greatly, with transmission, communication and demand side areas more open to competition than generation, transformation, distribution or dispatch areas.**

### *Intermittent power management*

China's non-fossil fuel consumption is targeted to rise to 15% by 2020. However, the intermittent nature of many non-fossil fuels power sources, such as wind and solar, poses challenges to the reliability of the grid. Integration of intermittent wind and solar power requires weather measurement, modeling and forecasting tools to foresee power output losses due to unfavorable weather conditions. Integration and management tools also help increase output. Monitoring and management software offer real time control over grid-wide supply loads and predictive maintenance operations. For instance, under the pilot phase, large-scale wind power generation smart control systems in Jiuquan, Gansu province, increased power output of nine wind power systems by 14% on average. Flexible alternating current transmission solutions (FACTS) help manage intermittent power sources and include series compensators, static var compensators, mechanically switched capacitors and voltage-source converters. As illustration, the Shanghai Nanhui Wind Power Flexible Direct Current Transmission Project used a voltage source converter to increase a wind power station's low-voltage ride-through (LVRT) capacity by 50%.

### *UHV transmission lines*

China is pursuing the most ambitious investment in ultra-high voltage (UHV) lines in the world. China needs to transmit electricity over thousands of kilometers from remote west and southwest sources (hydro, wind, solar and coal) to demand centers in coastal provinces. To limit power losses during transmission, 1,000-kV alternating current (AC) or 800-kV direct current (DC) power lines are used. These UHV lines require transformation equipment to increase voltage at the power supply source, then decrease voltage to 115 kV or less for local use at the city level. Foreign technology providers are working with State Grid on specific solutions. In October 2011, French multinational Alstom signed a deal with State Grid's subsidiary China Electric Power Equipment and Technology Co. (CET) to develop UHV direct current (UHVDC) power transmission systems. The two companies will cooperate on 1,100-kV and 800-kV converter transformer technology development and manufacturing.[25] To monitor transmission infrastructure, State Grid began construction of a power line monitoring center. Other solutions include real-time monitoring and thunderstorm surveillance. For example, State Grid established the Zhejiang Hangzhou Power Division Transmission Line Status Monitoring Center, which combines collection, processing, saving, displaying and application of line data, as well as integrated transmission and

*23. "State Grid buys stake in Portugal Redes Energéticas Nacionais (REN)," China Daily, February 3, 2012, www.chinadaily.com.cn*
*24. "China's State Grid in talks to buy AES' U.S. wind assets:sources," Reuters, February 27, 2012, www.reuters.com*
*25. "Alstom signs transmission deal with China Electric Power," Power Engineering International, October 28, 2011, www.powerengineeringint.com*

distribution management systems.[26]

### *Distribution automation and smart demand-side solutions*

During the pilot phase, State Grid focused on standardization of research, design, construction and operation of automated distribution equipment. This included analyses of automation processes to respond to various distribution and demand patterns with specific projects located in Beijing, Hangzhou, Yinchuan and Xiamen. As a result, future systems must offer a combination of the following capabilities: system auto-protection and restore, customer participation, efficient operations, and ad-hoc and distributed power integration. The deployment of smart solutions on the demand side led to large smart meter procurement contracts for leading domestic meter manufacturers—and a few foreign companies. As mentioned earlier in this chapter, in early 2011, Landys+Gyr won a contract for 10,000 meters from State Grid in a centralized procurement award.[27] While China is focused on replacing mechanical meters with automatic meter reading (AMR) by 2015, the country plans to roll-out the more interactive advanced meter infrastructure (AMI) in a second wave. AMR technology automatically collects consumption, diagnostic and status data from electric metering devices and transfers information to a central database. AMI offers additional functionalities including two-way interactions between end users and utilities and real-time consumption data measurement and reporting.

### *Electric vehicle (EV) charging infrastructure*

The 12th Five-Year Plan on Electric Vehicles targets 1 million EVs on the road by 2015. This can translate into opportunities related to battery development, charging stations, swapping equipment and management software. As of March 2011, State Grid has completed 87 stations with 7,031 charging posts, and plans to construct a total of 2,351 stations with 220,000 charging posts by 2015.[28] Southern Grid is working with U.S.-Israeli company Better Place on battery swapping station development and with domestic car manufacturer and battery developer BYD on battery technology.[29] Overall, there are opportunities for domestic and foreign equipment and software to manage charging stations—either direct charging or battery swapping—and to optimize electricity flows between EVs and the grid. More information about China's EV development and charging infrastructure can be found in the Cleaner Transportation chapter of this Report.



## China's Strong and Smart Grid Investment Plan

### Opportunity Assessment Summary

**In 2011, China entered the construction phase of its 2009-2020 Strong and Smart Grid Plan, the world's largest attempt to build a reliable, efficient and smart grid. Solution attractiveness varies based on market access, industry structure and technology offerings.**

**State Grid is executing the RMB 3.8 trillion Strong and Smart Grid Plan across three phases—pilot, construction and industrialization.**

The Strong and Smart Grid Plan (2009-2020) aims to build a more efficient and reliable power transmission and distribution network, as well as resolve current power transmission and distribution challenges. State Grid is executing the RMB 3.8 trillion Strong and Smart Grid Plan across three phases—pilot, construction and industrialization. After a successful two-year pilot phase, State Grid started the construction phase (2011-2015), including ultra-high voltage (UHV) lines and distribution networks in urban and rural areas, remote monitoring, two-way communications, and

*26. Huang, Shihong, "国网智能电网试点总结及 2011 年展望" [State Grid Smart Grid Pilot Project Summary and 2011 Outlook], Essence Securities, January 8, 2011*

*27. "Landis & Gyr shows just how to prosper in China," Smart Grid Today, January 4, 2011, www.smartgridtoday.com*

*28. "国家电网十二五将建充电站2,351座" [State Grid to build 2,351 charging stations under the 12th Five-Year Plan], Reuters, March 3, 2011, cn.reuters.com*

*29. "China Southern Power Grid and Better Place open EV battery switch experience center in Guangzhou," Green Car Congress, December 12, 2011, www.greencarcongress.com; Bradsher, Keith, "In China, Power in Nascent Electric Car Industry," New York Times, December 26, 2011, www.nytimes.com*

electric vehicle (EV) charging infrastructure. Meanwhile, Southern Grid is studying State Grid's plan for guidance and has also initiated a few projects in specific areas including transmission lines and EV charging stations.

### The pilot phase accomplished most objectives

State Grid reached its goals under the pilot phase, which included carrying out demonstration projects for a range of grid solutions, and establishing technology choices, research and development (R&D) guidelines and standards in preparation for large-scale implementation during the construction phase. Between 2009 and 2010, State Grid carried out 228 demonstration projects in 26 provinces across 21 solution areas, including generation, transmission, transformation, distribution, premise, dispatch and communications.[30] For example, integration of wind, solar and energy storage solutions were tested in the Zhangbei project in Hebei province. This project included the world's largest integrated renewable energy generation-storage system with 100 MW wind power, 50 MW solar power and 20 MW energy storage in four lithium iron phosphate ($LiFePO_4$) batteries. These batteries were mainly supplied by BYD and China Aviation (Luoyang) Lithium Battery Co., Ltd.[31] State Grid also worked on improving transmission capabilities, with the installation of the world's first UHV 1,000-kV alternating current power line running 640 kilometers from Shanxi to Hubei.[32] On the demand side, State Grid installed 50 million smart meters in 2010, allowing for a better understanding of industrial, commercial and residential users' electricity consumption patterns. Other projects included the construction of six intelligent communities in Beijing, Chongqing and Hebei, a smart building in Shanghai, and 18 smart substations ranging in size from 110 kV to 750 kV.[33]

**Companies supplying State Grid will benefit from large economies of scale when competing for similar contracts in foreign markets.**

### Pilot phase achievements helped China develop advanced technical standards

In 2010, State Grid released 22 core standards, also known as the Smart Grid Technical Standard System, covering power generation, intelligent transmission, substations, distribution, utilization and dispatch technologies.[34] In total, 93 standards were established across eight sectors of the industry. Six standards did not have prior equivalents in China. Eight of the standards had no equivalent at the international level, and only five standards were directly adopted from international examples.[35] State Grid's standards differ from both China's national standards and international standards set up by the International Electrotechnical Commission (IEC). State Grid hopes the central government will adopt these standards nationally to promote better integration of smart grid technologies, which is likely since State Grid already covers most of the country's provinces.[36]

China is seeking more involvement in international standard setting. In January 2012, China participated in an international conference on smart grid standards as part of the International Electrotechnical Commission Technical Committee 8 (IEC TC 8).[37] State Grid's suppliers are counting on China's influence on the global stage. Considering the scale of China's grid development plans, local companies supplying State Grid will benefit from large economies of scale when competing for similar contracts in foreign markets.



*30. Chen, Hua, and Ran Shi, "即将进入全面建设期的中国智能电网" [China Smart Grid entering a comprehensive construction period], China International Capital Corporation Ltd., April 7, 2010*
*31. Zhai, Ruimin, "世界最大储能电池求解风电、太阳能光伏储输难题" [World's largest battery storage looking to solve problems in wind power and solar power storage and transmission], NetEase Finance, January 11, 2012, money.163.com*
*32. "坚强智能电网" [Strong and smart grid], Phoenix Finance, www.ifeng.com, accessed on February 17, 2012*
*33. Sun, Ashely, "SGCC got achievements in constructing Strong Smart Grid," Metering China, October 14, 2011, www.meteringchina.com*
*34. Liu, Yiyu, "State Grid, GE to create smart grid standards," China Daily, January 11, 2011, www.chinadaily.com.cn*
*35. "智能电网技术标准体系规划" [Smart Grid Technical Standard System Scheme], State Grid, June 2010*
*36. Hart, Melanie, "China Pours Money into Smart Grid Technology," Center for American Progress, October 24, 2011, www.americanprogress.org*
*37. "国际电工委员会批准'用户侧电源连接电网'标准提案立项" [International Electrotechnical Commission (IEC) Approves Proposal of 'User Side Power Connectivity to Grid' Standards], China Electricity Council (CEC), February 9, 2012, www.cec.org.cn*

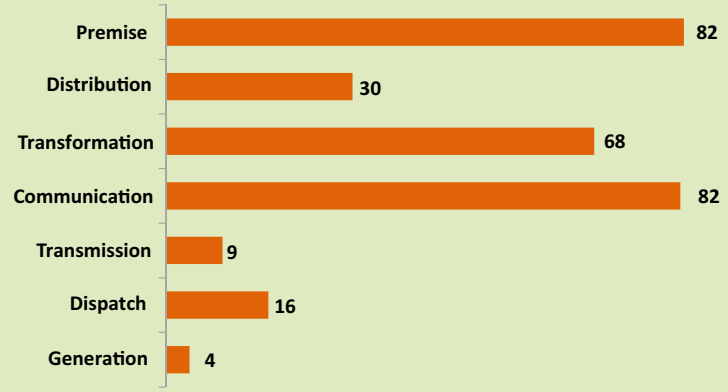
### In 2011, China entered the construction phase of its Strong and Smart Grid Plan

The construction phase began in 2011, and is arguably the most promising period for commercial stakeholders. The construction phase is focused on building UHV lines and distribution networks in urban and rural areas, developing operating controls and interactive systems, and adopting new technologies and equipment. It is expected to run from 2011 through 2015. Funding for the construction phase is between RMB 1,500 billion and RMB 1,800 billion, with around 16% to 18% earmarked for smart grid solutions, while 15% to 18% is set aside for UHV transmission lines. Northern, Eastern and Central regions, the main demand centers, will continue to receive the largest share of the funding.

State Grid plans to implement projects across the following identified focus areas:

- **Generation:** Accommodate 90 GW wind and 8 GW solar capacity, and establish a research center to enhance generation and interconnection technologies by 2015.
- **Dispatch:** Upgrade and build dispatch capability to cover 80% of regions and 50% of counties by 2015.
- **Transmission:** Complete three north-south and three west-east UHV line networks.
- **Transformation:** Build 5,100 new and retrofit around 1,000 smart digital substations by 2015.
- **Distribution:** Establish smart distribution systems, and reach a reliability ratio of 99.97% by 2015.
- **Premise:** Set up intelligent communities, install 230 million smart meters, 2,900 recharge and swapping stations, and 540,000 recharge poles by 2015.
- **Communication:** Deploy fiber optic power line connections to end users.

**Construction Phase Planned Allocation, RMB billion, 2011-2015**




*Source: "国家电网智能化规划总报告" [State Grid Smart Grid Plan Final Report], State Grid, February 2010*

Roughly 60% of State Grid's investment funds are planned to go to premise, distribution and transformation sectors, while the communication sector will receive around 28% of investment.[38] However, on the smart meter and smart community elements of the plan, there is reason for caution. An executive from one CGTI Partner company warned: "State Grid might scale back its smart community development plans in the construction phase since the domestic market for intelligent household appliances is not mature enough."[39]

*38. "国家电网智能化规划总报告" [State Grid Smart Grid Plan Final Report], State Grid, December 2009*
*39. CGTI Electric Power Infrastructure Working Session, December 13, 2011*

# Energy Storage Solutions for Intermittent Power

## Opportunity Assessment Summary

### China's energy storage market continues to grow, but the largest market—utility-scale energy storage—remains in its infancy.

The utility-scale energy storage market for intermittent renewable power in China could reach RMB 72 billion by 2015.[40] However, despite the potential for energy storage to facilitate grid connectivity of intermittent power sources, such as wind and solar, few economically-viable opportunities exist for large-scale adoption. Energy storage offers a spectrum of applications to reduce intermittent power's disturbance to grid systems. Yet high costs, unproven technology and lack of policy direction make storage a tough sell over the next few years. Wind and solar farm developers are unlikely to install energy storage infrastructure unless it offers clear financial and operational benefits. Grid companies are also reluctant for three reasons: storage equipment is expensive, conventional power sources, such as coal, are much cheaper and easier to dispatch, and UHV transmission line network construction is currently the priority for grid infrastructure spending, leaving little room for storage R&D. Without aggressive government support, the utility-scale storage market will remain small in the near term.

**The utility-scale energy storage market for intermittent renewable power in China could reach RMB 72 billion by 2015.**

### Intermittent power supplies require better prediction, dispatch and management

Intermittent wind and solar power pose challenges for the stability and reliability of China's power grid. At the end of 2009, the China Electricity Council (CEC) reported over 30% of wind-generated electricity was not transmitted to the grid.[41] In early 2011, the Ministry of Industry and Information Technology (MIIT) reported that 16-30% was not transmitted.[42] The challenges will likely grow over time: as the government's 2015 renewable energy targets are met and perhaps exceeded, the targets for wind and solar capacity and energy delivery must be upgraded.[43]

Electric Power Infrastructure

Conventional energy sources, such as coal, natural gas, oil and emerging generation sources, are inexpensive and stable, but costly for State Grid to dispatch on short notice. Many of these sources do not require storage to balance supply and demand discrepancies. The inherent volatility in voltage of intermittent renewable electricity can threaten grid stability, resulting in power transmission operators disconnecting wind and solar sources to accommodate conventional power generation. The current grid system requires accurate and long-term predictability to minimize wasted energy resources. Balancing renewable and conventional energy supply often requires advance notices of 24 to 48 hours to coordinate.

### Types of energy storage solutions that improve grid connectivity

Energy storage offers a spectrum of applications that reduce intermittent power's disturbances to the grid. There are three main types of energy storage solutions: mechanical, such as pumped-storage hydroelectricity, compressed air and kinetic flywheel technology; electrochemical batteries, such as lead-acid, lithium, vanadium, zinc and sodium sulfur; and electromagnetic, such as superconducting magnet energy storage. A range of energy storage technologies exists between the high energy and high power extremes, each with varying characteristics, including capacity, duration and reaction speed. These solutions can offer ancillary services to the grid, and increase the grid's ability to dispatch and manage intermittent renewable energy power depending on the user's needs.

*40. CGTI analysis; average cost calculation based on storage capacity reaching 15% of wind and solar capacity installations by 2015 (120 GW * 15% * RMB 4,000/kW = RMB 72 billion).*

*41. "可再生能源十二五规划将调整风电方向" [Renewable Energy 12th Five-Year Plan Planning for More Wind Focus], CEC, June 21, 2011, cec.org.cn*

*42. Li, Junfeng, et al., 2010 China Wind Power Outlook (Beijing, China: China Renewable Energy Industries Association (CREIA), Greenpeace, 2010)*

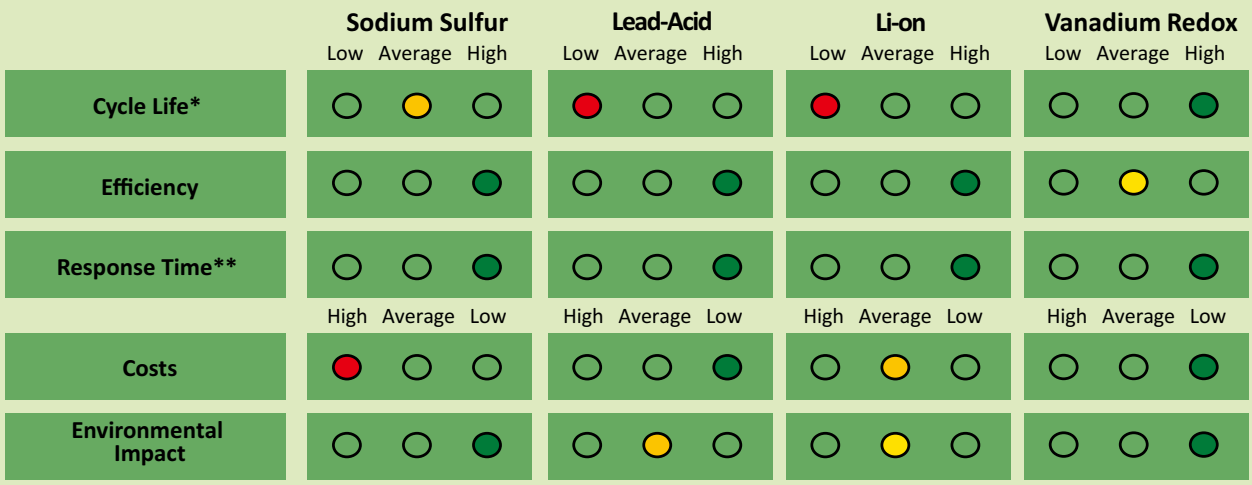
*43. Ibid; "可再生能‘十二五’规划将调整风电方向" [Renewable Energy 12th Five-Year Plan Planning for More Wind Focus], CEC, June 21, 2011, cec.org.cn*

**At the end of 2010, China had approximated 16 GW of pumped storage hydropower capacity, with plans to increase capacity to 70-80 GW by 2020.**

- **Pumped-storage hydroelectricity:** Among mechanical storage solutions, only pumped hydroelectricity is widely adopted today. Large capacity pumped hydro is ideal for bulk storage and load-leveling. However, relatively low reaction speeds, high environmental and social impacts, and high administrative requirements make implementing pumped hydro challenging. At the end of 2010, China had approximated 16 GW of pumped storage hydropower capacity, with plans to increase capacity to 70-80 GW by 2020, in line with hydroelectric power development.[44]
- **Compressed air:** Compressed air is also ideal for bulk storage and load-leveling. Because the technology requires a strong underground cavity to contain the compressed air at storage sites, has high capital costs, and has issues related to land use rights, only a handful of projects exist around the world.[45]
- **Flywheel storage:** Flywheel energy storage has power burst capability, making it ideal for maintaining frequency stability. Flywheels are ideal for wind power storage, but are less suitable for solar, and energy can be wasted when stored energy is not fully used. Given high capital costs, initial government funding may be needed to encourage the large-scale adoption of flywheel energy storage.[46]
- **Batteries:** Electrochemical storage solutions—sodium sulfur (NaS), advanced lead-acid, zinc (Zn), lithium-ion (Li-ion) and vanadium redox batteries (VRBs)—can be ranked across five characteristics: cycle life, efficiency, response time (range), environmental impact and cost. NaS batteries present good overall efficiency and response time, but high costs and average cycle life. Advanced lead-acid batteries fare relatively well on response time and costs, but their poor cycle life and high environmental impact raise concerns. EV developments have spurred interest and investments in advanced lead-acid and Li-ion. Li-ion batteries have strong response time and efficiency, but poor cycle life and high costs and environmental impact. Finally, VRBs have high performance across most criteria, but have only moderate efficiency. VRBs are suitable for small-scale adoption in remote areas, which seems compatible with State Grid's plans.



## Electrochemical Battery Technology Solution Assessment




*Note: *For Cycle Life, low = short, high = long; **For Response Time, low = long, high = short.*

*Source: CGTI analysis and Partner interviews for the Energy Storage Solutions for Intermittent Power Opportunity Assessment discussed during an April 2011 Working Session*

*44. "抽水蓄能2020年规划目标将大幅提升" [China's 2020 Pumped Hydro Energy Storage Planning Target Will Dramatically Increase], China News, June 22, 2010, www.chinanews.com*
*45. Yu, Zhe, "美国一总投资4亿美元的压缩空气储能项目被迫中止" [400 Million US Compressed Air Energy Storage Project Forced to Cease], China Energy Storage Network, August 5, 2011, www.escn.com.cn*
*46. Mulliken, Bruce, "Next to Go Mainstream: Mass Energy Storage," Green Energy News, March 20, 2011, www.green-energy-news.com*

### High costs, unproven technology and lack of policy direction impede growth

Making generalizations about the overall cost of energy storage can be complex, given the number of existing storage technologies, connection methods and government subsidies. Overall, executives from CGTI's Partner organizations indicate that storage can add up to 50% to the cost of installation for wind power.[47] Pumped hydro is the most common storage type, due to its relatively low cost of approximately RMB 4,000/kW.[48] Other storage solutions cost approximately RMB 6,000-7,000/kW.[49] State Grid and Southern Grid prefer generation that incurs the least cost to the grid or is strategically significant. Conventional energy generation is typically the most economical, and does not require storage support to balance demand and supply discrepancies. By placing higher priority on conventional energy generation and UHV construction, the grid companies have curbed the advancement of energy storage solutions.

**Energy storage can add up to 50% to the cost of installation for wind power.**

Storage only adds value when there is a consistent demand for stored energy, which ensures high utilization of storage solutions and relatively prompt payback periods. As one wind developer noted, "We are profit-driven. We need to be able to calculate and increase the wind farm's overall return. Therefore, unless there are policy requirements, we won't consider storage."[50]

Talent is another issue: CGTI interviews with Partner organizations reveal that one obstacle preventing the government from taking more proactive approaches to storage, both in terms of incentives and regulatory guidance is the lack of individuals with sufficient cross-sector understanding to implement new policies. As a result, most storage technologies have remained at small-scale demonstration stages. Until energy storage is prioritized, market growth will be slow.

## The Path Ahead

This chapter provides an update of China's Electric Power Infrastructure sector and two Opportunity Assessments prioritized by CGTI's research team and Partners in 2011. As the sector evolves, participants in the China Greentech Partner Program will continue to collaborate on additional opportunities areas. Research areas in 2012 will focus on energy storage, distribution and demand-side solutions. CGTI will also continue to track the overall evolution of China's Electric Power Infrastructure sector.



*47. "从间歇性到不稳定性：我们能管理好风能吗?" [From intermittent to instability: can we handle wind power?], Industry Sourcing, November 9, 2010, cn.industrysourcing.com; CGTI analysis and Partner interviews*
*48. "抽水蓄能, 国产化之路任重道远" [Pumped Hydro Energy Storage, A Long Way to Localization], China Energy Network, March 31, 2011, www.china5e.com*
*49. Ibid.*
*50. CGTI Partner interviews*

# Green Building

**Though China's green building market is tiny compared to the immense size of the construction market, the government's building energy efficiency policy will require rapid industry expansion over the next five years, covering a broad range of products and services.**

**Despite support, many ESCOs currently suffer from quality control and financing issues.**

Green building certifications are rapidly increasing throughout mainland China, but have fulfilled only a tiny fraction of their potential. Government sees energy service companies (ESCOs) as a main driver of building energy efficiency since they can bridge the stakeholder incentive disconnect. Despite this support, many ESCOs currently suffer from quality control and financing issues. Building energy efficiency solutions often have suboptimal economics for developers, but the relatively new concept to China of integrated design can have a significant impact on their cost effectiveness. The overall market is gaining momentum by new financing sources which are emerging to improve project economics, though the path for accessing subsidies remains difficult due to lack of clear valuation methods and weak government monitoring and enforcement capabilities.

This chapter begins by providing an overview of Green Building sector developments since the publication of the *China Greentech Report 2011*. It then summarizes three Opportunity Assessments developed by the China Greentech Initiative (CGTI) in collaboration with Partner companies and organizations in 2011:

- Optimal Green Building Design
- Building Energy Efficiency for New Construction
- Green Building Financing

These summaries represent high-level findings of the detailed proprietary research and analysis developed in collaboration with and for organizations participating in the China Greentech Partner Program. The chapter concludes with an outlook on additional opportunities and issues in the Green Building sector that CGTI intends to explore in 2012.

*Analyst Lini Fu* (付莉霓) *and Manager Lixuan Zhou* (周丽璇) *led the writing of this chapter with support from contributing writers Tsinghua University Research Specialist Michael Brewer* (麦克) *and Director of Research Analytics Anders Hove* (侯安德) *based on 2011 strategic research conducted by Analysts Jing Wang* (王静) *and Han Hao* (郝瀚).

**Green Building Value Chain**

**Green Building** covers planning, building and operating solutions that are more efficient, healthy and sustainable than conventional solutions for an equivalent level of comfort and service throughout all stages of a building's life cycle.

| Master Planning | Control Planning | Design | Civil Construction | Engineering | Property and Energy Management | End User Products | Building Retrofit |
|---|---|---|---|---|---|---|---|
| **Infrastructure** | | **Design and Construction** | | | **Management** | | **Retrofit** |
| **Activities** | | | | | | | |
| Eco-city programs | Rural building plans | Green building certification | Green civil contracting | Building automation | Energy management system | Indoor environment | Energy efficiency retrofit |
| Subsidy programs | Heat reform | New building standards | Prefabricated housing | Building intelligence | Facilities management | Appliances green labeling | Interior retrofit |
| **Products** | | | | | | | |
| Power supply | Water supply | Construction material | Building envelope | HVAC | Cabling | Fire and security | Furniture |
| District heating | Gas supply | Renewable products | Plumbing | Digital building control | Lighting | Sanitary ware | Appliances |

*Source: CGTI analysis*

# Market Update

### Central and local government announced new policies to promote green buildings

China's 12th Five-Year Plan emphasizes energy efficiency of buildings with specific targets and promotion of key areas, such as the achievement of 65% energy consumption reduction versus existing building stock. Applicable technologies include building integrated renewable energy, heat pumps, ice storage, energy-saving materials and material recycling.[1] New construction policies emphasize the use of environmentally friendly materials and energy efficient design standards. Northern China energy efficiency policies focus on heating systems and metering retrofits, such as the Energy Saving Warm House project.[2]

2011 saw the introduction of several major green building policies and plans. The upcoming China Green Building Movement Plan is designed by the Ministry of Housing and Urban Development (MOHURD). It targets large new construction and retrofit areas and offers developers incentives in the form of a 1% increase in floor area ratio return—the right to expand the floor space allowed on a given land area—for each star in the 3-Star green building certification system.[3] The Public Facilities Energy Efficiency Improvement Plan, released by the Ministry of Finance (MOF) and MOHURD, reduces energy consumption per unit area of selected public facilities by 10% and large public facilities by 15% by 2015, and enhances energy auditing, management and energy consumption control.[4] The Notice on Integrated Financial Policy on Energy Efficiency and Emission Reduction released by the National Development and Reform Commission (NDRC) and the MOF will subsidize projects that meet assessment criteria, to be implemented by local government finance and emissions reduction departments.

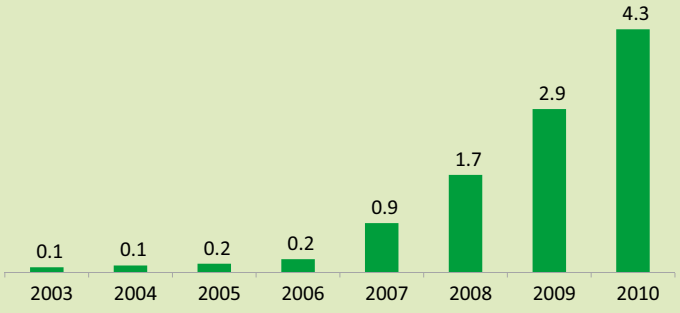
*1. "建筑业发展十二五规划" [12th FYP for Construction Industry Development], Ministry of Housing and Urban-Rural Development (MOHURD), July 2011*
*2. "国务院关于印发'十二五'节能减排综合性工作方案的通知" [Notice on Printing and Distributing the Energy Saving and Emission Reduction Plan], State Council, September 7, 2011*
*3. "中国绿色建筑行动计划草案" [Chinese Green Building Movement Plan Draft], MOHURD, April 2011; China Greentech Initiative (CGTI) interviews*
*4. "财政部、住房城乡建设部关于进一步推进公共建筑节能工作的通知" [Ministry of Finance (MOF) and MOHURD's Public Facilities' Energy Efficiency Improvement Plan], MOHURD and MOF, May 4, 2011*

Central and local governments have also issued solution-specific policies to encourage and regulate adoption of renewable energy, exterior insulation, solar thermal systems, lighting and shading.[5] These policies indicate that the central government is getting serious about building energy efficiency, and more specific measures and incentives will follow, potentially radically expanding the currently small green building and building energy efficiency market in China.

### Certified green buildings and eco-communities are just emerging

Heating, ventilation and air conditioning (HVAC), lighting, and building envelope solutions represented a RMB 30 billion market opportunity in 2011, part of a much larger energy efficiency retrofit market the government is promoting. The government has selected 40 cities to undergo a minimum of 4 million square meters ($m^2$) of energy efficiency retrofits that cost between RMB 2,500-3,000/$m^2$ and are eligible to receive a subsidy of RMB 20/$m^2$, in effect creating a market worth RMB 400 billion.[6]

**Total ESCO Project Investment in China, billion US$, 2003-2010**




*Source: Sun, Xiaoliang, et al., "China's ESCO Industry: Saving More Energy Everyday Through the Market," Wordpress, May 31, 2011*

The government plans to use energy service companies (ESCOs) as a major driver of building energy efficiency and aims to streamline the industry over the next few years. Though ESCO investment has grown steadily over the past decade, it is still hindered by weak finances and quality control issues. There are approximately 2,000 ESCOs registered in China, but only a quarter meet China's Energy Management Company Association of China (EMCA) membership standards. Quality issues arise from a lack of expertise, technical capacity and financial resources, since fewer than 70% of registered ESCOs have more than RMB 20 million in registered capital.[7] The difference in energy conservation work quality causes gaps in expectations for MOF subsidies, and collecting MOF subsidies in a timely manner may also be difficult. The issue of capital is compounded by the burden of 70% up-front financing, which ESCOs typically bear, creating unstable debt ratios for less-established firms that often cannot obtain bank loans to grow into more sustainable businesses.[8] Most real estate and building market investors expect two-year payback periods, which is unrealistic given that energy efficiency retrofits may offer only seven to eight year payback periods at a minimum. However, banks are starting to provide specialized services for ESCOs and the government has issued policies to ease financing for public building retrofit projects.



*5. "关于开展节能减排财政政策综合示范工作的通知" [Notice on Integrated Financial Policy for Energy Efficiency and Emission Reduction], National Development and Reform Commission (NDRC) and MOF, June 22, 2011*

*6. "未来两年建筑节能市场规模4000亿元" [Building Energy Efficiency Market Could Reach RMB 400 Billion Over the Next Two Years], QQ Finance, July 6, 2011, www.finance.qq.com*

*7. Fawkes, Stephen, "Energy efficiency and energy service companies (ESCOs) in China: Saving more than wind generates," Energy World, December 2011*

*8. Sun, Xiaoliang, et al., "China's ESCO Industry: Saving More Energy Everyday Through the Market," Wordpress, May 31, 2011*

The total number of 3-Star and Leadership in Energy and Environmental Design (LEED) certified buildings doubled in 2011, but they remain a small portion of the total building market. 3-Star is quickly gaining momentum, growing from 53 certifications in 2010 to 151 in 2011, outnumbering the 82 new LEED certifications in 2011.[9] This is due in large part to government policy measures, increased enforcement and subsidies specific to 3-Star. Residential buildings were the fastest growing sector in 2011 for green building certification. The majority of residential buildings rated under the 3-Star system received the full three stars and the majority of LEED-certified buildings received a Gold rating.[10]

**The China Green Building Movement Plan allocates RMB 10-20 million in subsidies for low-carbon neighborhoods.**

Low-carbon neighborhoods are also emerging as an attractive opportunity due to policy support, such as the China Green Building Movement Plan, which allocates RMB 10-20 million in subsidies for communities with at least 30% of buildings certified as green buildings.[11] Compared to eco-cities and low-carbon cities, low-carbon neighborhoods require less investment and tend to have simpler stakeholder structures.

One fundamentally important factor in building energy efficiency is ensuring a strong coordination exists between all major stakeholders throughout every phase of a project to achieve performance-based targets. Stakeholders must overcome a number of challenges to accelerate the adoption of green building design:

- **Building design can have simulation gaps:** conventional design practices do not use energy simulation models, and design changes can be made without assessing their effects on environmental performance.
- **Energy models are questionable:** building owners, developers and chief architects have disproportionate power in project decision-making, amplifying the risk of model tampering.
- **Local design institutes (LDIs) impede integrated design:** officially, only LDIs are qualified to design buildings, while foreign companies operate in a consulting capacity. Additionally, architecture, design and engineering disciplines are separate within most LDIs. Collaboration and coordination is an issue, as will be discussed in greater detail in the Optimal Green Building Design Opportunity Assessment below.
- **Design professionals lack expertise:** architects and engineers typically lack multi-disciplinary experience and expertise. Most Chinese architects specialize in structural engineering.
- **Monitoring is virtually nonexistent:** green buildings are rarely monitored after construction and few have been operational for five years or more, limiting access to building performance data.
- **Green building materials are difficult to source:** green building materials are often not available in China. Many products are prohibitively expensive and most are imported.[12]

Given all of these challenges, policymakers have their work cut out for them in crafting incentives and standards to expand the small but growing building energy efficiency market.



*9. "LEED Projects and Case Studies Directory," U.S. Green Building Council (USGBC), www.usgbc.org, accessed on December 23, 2011*
*10. "建筑节能与科技" [Building Energy Saving and Technology], MOHURD, www.mohurd.gov.cn, accessed on December 23, 2011*
*11. "中国绿色建筑行动计划草案" [Chinese Green Building Movement Plan Draft], MOHURD, April 2011; CGTI interviews*
*12. CGTI interviews*

### Good market prospects for insulation material providers

Progress on energy efficient insulation materials market was hampered by several notable building fires in 2010, which led the government to implement fireproofing standards under the Number 65 Document focusing on safety.[13] This mandate now requires most buildings to use grade A inorganic insulation materials, rather than the traditional grades B1 and B2 organic insulation materials. The organic insulators—such as expandable polystyrene (EPS), extruded polystyrene foam (XPS) and polyurethane (PU)—are very good insulators, but often offer poor fireproofing. Phenolic foam insulation outperforms other insulation types for fireproofing, but price remains highest at RMB 1100/$m^3$. Though B2 materials may be permanently prohibited due to their level of combustibility, several CGTI interviews suggest that because the fires were caused by improper construction and onsite management rather than insulation material, the Number 65 Document may be revised. Industry players remain positive about market prospects for energy efficient insulation.

### A range of HVAC energy efficiency solutions are becoming popular

The heat pump market size reached RMB 1.8 billion in the first six months of 2011 with 22% year-on-year growth. Over 68% of China's Renewable Energy Building Demonstration programs have geothermal heat pumps.[14] However, many challenges impede growth since heat pumps—depending on design configurations and project scale—can have high upfront costs and payback periods of five to eight years, which may deter some developers.[15] On the manufacturing side there is a lack of comprehensive standards, and low entry barriers attract lower quality products, which may negatively affect consumer perceptions of the technology. Since most systems have inadequate monitoring mechanisms, they may operate at suboptimal levels.[16]

**The heat pump market reached RMB 1.8 billion in the first six months of 2011 with 22% year-on-year growth.**

Ice storage air conditioning utilizes heat exchangers during evening hours to chill water and create ice, which can then be used during the daytime for cooling. Ice storage systems can be used in most building settings, but are particularly economical in localities with peak-trough energy pricing. The NDRC's Measures for the Orderly Use of Electricity encourages energy storage during trough price periods and has started promoting energy efficiency equipment, such as ice cooling and heat pumps. However, the peak-trough difference of most cities in China remains less than those of some developed countries—from 3:1 to 5:1 in China, compared to 10:1 elsewhere.[17] Ice storage also has a 30% incremental cost and higher operations and maintenance (O&M) costs compared to typical central air conditioning systems. Currently less than 1% of new building floor area is served by ice storage air conditioning systems.[18]

Building heating, cooling and power (B-CHP) systems, offering building combined heating and power systems, are currently in the demonstration stage. The government set a 1,000-project target for 2011 and 50 GW installed capacity target for 2015. The focus is on large public and commercial buildings and the policy offers a subsidy for natural gas and equipment. However, B-CHP is hampered by higher upfront costs, a payback period of 7-10 years, low electricity prices and a lack of policy support for grid connectivity.[19]

Capillary Radiation Systems, a heating system that provides heating by using radiation through capillary pipes set in the floor, window or roof, are fully commercialized and have a high market penetration rate in Liaoning, Heilongjiang and Jilin provinces. The

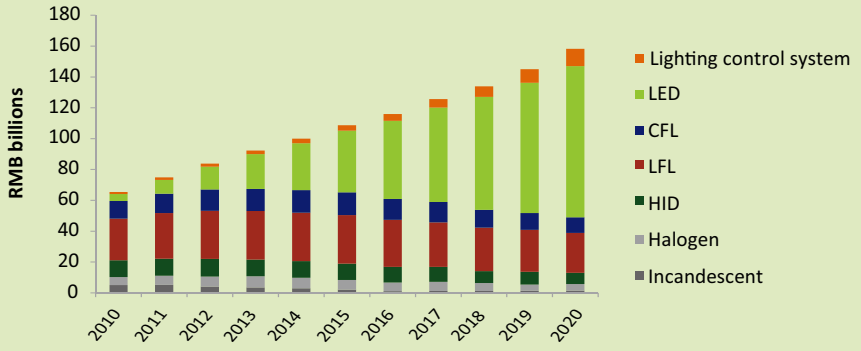
*13. "中华人民共和国公安部关于进一步明确民工建筑外保温材料消防监督管理有关要求的通知公告" [Notice on Further Enhancing Supervision and Management of Exterior Insulation System for Residential Buildings by Ministry of Public Security], Ministry of Public Security, September 6, 2009*
*14. "上半年中国中央空调行业发展报告" [2011 H1 Central Air Conditioning Market Development Report], Ehvacr, August 10, 2011, www.news.ehvacr.com*
*15. Ibid.*
*16. "水地缘热泵之'疯'" [The 'Craziness' of Water and Geothermal Heat Pump], co188, www.co188.com, accessed on August 13, 2011*
*17. "浅谈我国冰蓄冷空调的发展现状" [Discussion on Ice Storage Air Conditioning Market Development], CALMAC, September 3, 2010, www.ice-storage.com*
*18. "高灵能源领跑冰蓄冷产业" [Gaoling Energy Leading Ice Storage Industry], Dashijie, www.ditanshijie.com.cn, accessed on September 3, 2011*
*19. "论小型冷热电联产" [Discussion on Small Cooling, Heating and Power (CHP) Project], China Building Design Net, www.cnjzsj.com, accessed on August 15, 2011*

technology is mainly applied in high-end buildings, larger commercial buildings, and high-end residential buildings. These systems have low lifecycle maintenance costs, but are subject to technological issues, such as dew condensation, and tend to have higher upfront costs.[20]

### Energy-saving lighting is a high priority

In 2011, government released a plan for switching to energy-saving lighting which could save 190 billion kWh annually—equal to 2% of forecasted electricity demand in 2030.[21] By the end of 2012, China will have phased out all 100W incandescent bulbs, followed by the prohibition of 60W incandescent bulbs by 2014, and 15W incandescent bulbs by 2016.[22] In 2014, halogen energy efficiency standards will be released, which are expected to prohibit the production, import and sale of unauthorized halogen lights. Though China's policies limiting incandescent bulbs slightly lag those of some developed countries, the 2014-2015 midterm review, policy evaluation and adjustment will ensure that the policies are implemented effectively. According to a McKinsey forecast, this phase out of incandescent lighting will position light-emitting diodes (LEDs) to capture most of the market beginning in 2016, with 10-15% annual growth to an estimated value of nearly RMB 100 billion by 2020.[23] The growth of LED technology will be driven by price declines of approximately 30% per year through 2015 and 10-15% through 2020, as well as improvements in brightness, efficiency and light quality. The scale of the automobile sector and computer and television backlight sector will also help LEDs break into the general lighting market.[24]

**China's Forecast General Lighting Market by Technology, RMB billions, 2010-2020**




*Sources: "China's Green Revolution," McKinsey & Co., February 2009; "Light the Way: Perspectives on the Global Lighting Market," McKinsey & Co., July 2011*

Since lighting accounts for greater than 20% of overall building energy use, this represents an appealing market opportunity. Retail, office and residential buildings are the largest lighting opportunities and will account for 60% of the market in 2020, positioning them to drive market growth. The general lighting market is forecast to grow from RMB 73 billion in 2011 to RMB 150 billion in 2020.[25] The current market shows clear tradeoffs between upfront cost and long-term efficiency-related energy savings. For example, LED technology is the leader in green lighting and has high lifecycle efficiency, but also has very high upfront costs. However, with the volatile

*20. Huang, Xuezheng, "商业楼宇天然气冷热电联产分布式电源应用价值分析" [Economics Analysis of Heating, Cooling and Power for Buildings (HCP-B)], Energy Conservation Technology, July 2005*
*21. "中国逐步淘汰白炽等路线图" [Compact Fluorescent Lamp (CFL) Phasing Out Plan], NDRC, November 30, 2011*
*22. West, Larry, "China Latest Nation to Commit to Energy Efficient Lighting," About.com, October 3, 2007*
*23. "China's Green Revolution," McKinsey & Co., February 2009; "Light the Way: Perspectives on the Global Lighting Market," McKinsey & Co., July 2011*
*24. "淘汰白炽灯提上日程节能灯市场将迎光明前景" [Phasing Out Incandescent Lighting is Brought to the Agenda], August 10, 2011, finance.eastmoney.com*
*25. "China's Green Revolution," McKinsey & Co., February 2009; "Light the Way: Perspectives on the Global Lighting Market," McKinsey & Co., July 2011*

prices of rare-earth raw material components, high production costs and efficiency sensitivity to heat, there is still room for technology improvement.

Intelligent lighting systems, which have automated or mechanical abilities beyond those of traditional and stationary illumination, are poised to grow 25% annually through 2013. In 2010, the hotel lighting systems market is RMB 187 billion, the residential market is RMB 186 billion, and the commercial market is RMB 134 billion.[26] Eastern China led overall market size by value, growing by 44% in 2010. The hotel, residential and commercial sectors are the largest users of intelligent lighting systems and drivers of this expanding market.

**Despite market growth, green building materials only account for 5% of the entire building material market.**

## Market Opportunities

### *Green Building Design*

China's green building design faces unique challenges that impede market growth, including high upfront technology installation costs and lack of standards. Leading international and domestic design institutes, consultancies and solution providers are well positioned to work with China's green building community earlier in the planning process. In doing so, China's developers, owners and local design institutes (LDIs) can better adopt integrated design approaches to advance green building design, thereby improving energy efficiency and lowering long-term costs.

### *Building Energy Efficiency Retrofits*

Government promotion of public building energy efficiency retrofits in 40 cities creates a potential RMB 400 billion market over the next two years. Energy service companies (ESCOs) and solution providers can help local government articulate efficient designs and requirements. They can also partner with municipalities to provide energy efficiency solutions, such as insulation material retrofits and high efficiency heating, ventilation and air conditioning (HVAC) system solutions, to reduce the energy intensity of existing buildings. An example is the German Technical Cooperation program, which has completed projects with Tangshan, Beijing and Urumqi to retrofit residential buildings for better energy efficiency.

### *Green Building Material Production and Supply*

Despite green building market growth, green building materials only account for 5% of the entire building material market. The market may see rapid growth as government strengthens enforcement of material codes and clarifies financial incentives, developers integrate more green principles into the sourcing process, and suppliers provide cheaper green building materials. The sustainable indoor material market is also growing, driven by mandatory government standards, higher consumer awareness, the Kangju Initiative (a national demonstration project for modern residential buildings),[27] and a growing fit-out market. Eco-materials, air purification, floor heating and smart lighting are the most attractive indoor environment technologies. As mentioned above, the lighting control systems market is projected to grow by 21% through 2020.[28]

### *Integrated Energy Efficiency Solutions Provision*

Public and commercial building energy efficiency is the focus of the 12th Five-Year Plan. Integrated solutions are the key to achieving energy efficiency targets. Rather than just selling products and equipment, more companies are starting to promote integrated solutions. For example, Siemens is promoting Total Building Solutions, integrating building automation, fire and safety, and lighting and power distribution

*26. "China's Green Revolution," McKinsey & Co., February 2009; "Light the Way: Perspectives on the Global Lighting Market," McKinsey & Co., July 2011*

*27. "Kangju Initiative," Center for Housing Industrialization, accessed on December 2, 2010; "国家康居住宅示范工程成套技术量化评价指标" [Technical Indicator of Quantifying Integrated Solutions for National Kangju Initiative Projects], MOHURD, accessed on December 2, 2010; CGTI analysis*

*28. " China's Green Revolution," McKinsey & Co., February 2009; "Light the Way: Perspectives on the Global Lighting Market," McKinsey & Co., July 2011*

systems. Carrier Corporation, a subsidiary of United Technologies Corporation, has partnered with Shanghai Electric Group to establish a new joint venture to deliver building system energy-saving services and solutions across China.[29]

### *Green Building Operation and Energy Efficiency Management*

The market for green building operation and energy efficiency management is growing. For example, Schneider Electric signed an agreement with Tangshan Caofeidian New District in December 2011 to provide a Remote Energy Management platform and related services. The agreement helped Tangshan urban planners design and combine energy efficiency and green building solutions, while also managing energy consumption and carbon footprint monitoring.[30]

When China introduces carbon-trading pilot projects and studies carbon tax impact, technologies for calculating and monitoring carbon emissions will receive increased attention as stakeholders prepare for the pending cost changes. Companies with the ability to audit energy savings and calculate carbon emissions will be well positioned for this opportunity. The Daiwa Institute of Research Holdings, an organization that provides information services on consulting and system solution sectors, analyzed the impact of a carbon tax on building sector raw material costs. Results from the study suggest that some segments of the building sector raw materials industry, such as cement, should expect a negative impact on future revenues if no offset measures are considered.[31]

### *Low-Carbon Neighborhood Development Design and Energy Solutions*

Relative to low-carbon cities, low-carbon neighborhood designs feature smaller investment requirements, simpler stakeholder structures and shorter project terms. Low-carbon neighborhood developments can also benefit from larger subsidies than are currently available for green buildings alone. An example is the MOMA Beijing neighborhood apartment complex, designed by Steven Holl Architects and constructed in 2009, which received the first Leadership in Energy and Environmental Design (LEED) Neighborhood certification. More developers in China are looking to low-carbon neighborhood solutions, which may require renewable energy and district energy solutions.[32]

Green Building

## Optimal Green Building Design

### Opportunity Assessment Summary

**China's tremendous conventional and green building growth, mounting environmental strains, and strong regulatory support imply high market potential for green building design, but stakeholders must first embrace integrated design principles and overcome widespread flaws in current design practices.**

**Certifications of green buildings grew by 25% in the first quarter of 2011.**

To achieve energy efficiency goals, China's government is extending favorable policies for green buildings in the 12th Five-Year Plan. The mandates and incentives issued by the government have been indispensible drivers of green building design in China, and the market experienced 25% growth in green building certifications in the first quarter of 2011. Yet while the market has grown rapidly, design practices are still playing catch-up. Lapses in integrated design have placed green buildings at risk of falling short in actual operations. Challenges to green building design include data gaps in energy simulation models, issues with local design institutes (LDIs), insufficient industry expertise, inadequate post-construction monitoring, and difficulty in sourcing green building materials. Optimal green building design techniques, which include labeling systems, passive design, Net Zero energy design and intelligent building, can

*29. "Carrier establishes Joint Venture for Building System Energy-Saving Service," Carrier, January 11, 2012*
*30. "唐山湾生态城与施耐德电气签署战略协议" [Tangshan Eco-City Signed Strategic Agreement with Schneider Electric], Caofeidian New Area, Tangshan Bay Eco-City, January 5, 2012*
*31. "大和：征碳税加快水泥业整合，惟维持行业正面评级" [Daiwa: carbon tax speeds up cement industry restructure], Zhenhua Securities, January 11, 2012*
*32. CGTI interviews*

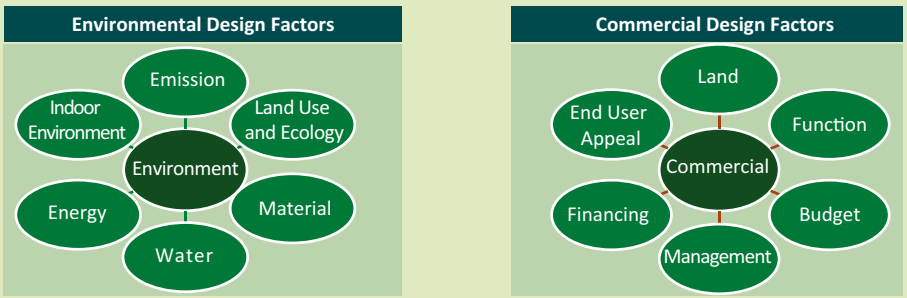
integrate green building technologies to achieve environmentally and commercially sustainable objectives.

### Green buildings are essential for balancing China's development and environmental goals

China's expanding building industry has a large environmental footprint: buildings currently account for approximately 20% of China's primary energy consumption, 30% of China's electricity use and cause roughly half of all urban carbon emissions.[33] Buildings consume 74.8 billion metric tons of potable water every year, nearly 50% of China's supply, and produce 35.5 billion metric tons of municipal wastewater.[34] As a major contributor to municipal solid waste, building construction generates 45-60 million metric tons per year, or 30-40% of China's total.[35] These figures will continue to grow with increasing urbanization.

**Optimal Green Building Design**

**Optimal green building design** delivers high environmental performance while also being commercially feasible for developers and appealing to end users.




*Source: CGTI analysis*

The Chinese government views green buildings as a means to balance its development and environmental goals. While conventional design emphasizes cost, quality and other traditional parameters, optimal green building design balances these parameters with building functionality, features and materials to deliver high commercial and environmental performance. Green building design also considers building constraints, such as timeframe, budget and location, within the context of energy, land and water use.

Aggressive regulatory targets and incentives created by the Ministry of Housing and Urban Development (MOHURD) as part of the 12th Five-Year Plan will accelerate the green building market. MOHURD has mandated that new buildings reduce energy consumption by 65% compared to the existing building stock, up from a 50% reduction in the prior Five-Year Plan.[36] Other supportive policies include an expansion of district heating reform and energy conservation in large public buildings,[37] and subsidies for highly rated 3-Star buildings up to RMB 75/m$^2$ (the subsidy depends on the incremental cost of improvements).[38]



*33. "我国的建筑能耗现状与趋势" [China's Building Energy Consumption Current Status and Future Trends], Jianshe99, April 14, 2011, www.jianshe99.com; "韩启德：中国的建筑使用能耗占社会总能耗28%" [Han Qide: China's Building*
*34. Accounts for 28% of the Total Energy Consumption], Public Net, April 14, 2011; "城市碳排放建筑占半数低碳房地产将成趋势" [Buildings Account for Half of the Urban Carbon Emission], Xinhua, April 14, 2011, www.news.xinhuanet.com*
*Zhang, Tianzhu, et al., "实施城市居民生活污水派饭收费标准的测算分析" [Analysis on the Charging Standards of the Municipal Domestic Waste Water Treatment], (Beijing: 中国科技论文在线), www.paper.edu.cn*
*35. "建筑固体废物资源化综合利用" [Reuse of the Construction Waste], 环卫科技网, April 18, 2011, www.cn-hw.net*
*36. Levine, Mark D., Assessment of China's Energy-Saving and Emission-Reduction Accomplishments and Opportunities During the 11th Five-Year Plan (Berkeley, CA: Lawrence Berkeley National Laboratory, 2010)*
*37. CGTI analysis*
*38. "Green Building Conference: Reduce Carbon, Increase Quality-Green Buildings, Improve City Life," 7th International Conference on Green and Energy Efficient Building & New Technologies and Products Expo, March 28-30, 2011*

### Integrated design can be difficult to implement in China

Decisions in conventional design are made to maximize quality and minimize cost within project constraints. Specialization among building disciplines can increase efficiency, but can also impede the open and frequent dialogue necessary to implement integrated design. This is exaggerated in China, where LDIs—state-licensed, third-party institutions—design and approve all buildings in China. LDIs tend to centralize and control technical aspects of building design, including structural, electrical and mechanical engineering. Integrated design may be more difficult to achieve if the project design team and LDI remain as separate entities, as they often are in China.[39]

**China's building market is reluctant to embrace green building solutions due to high upfront costs.**

Integrated design requires several steps beyond those of traditional design practices. During the pre-design phase, the developer, owner, architects and engineers determine sustainability goals and set performance targets. Throughout the design process, energy simulations identify high-potential energy-saving features and weigh tradeoffs between design decisions. After construction, the design team commissions building systems, educates building operators and monitors building performance.[40]

### Building market professionals have insights into green building design challenges

Four themes useful to further understanding optimal green building design in China include green building design practices, commercial feasibility, design decision-making, and implementation and operation.

Green building design practices include common systems, features and technologies found in green building design in China. Technology suppliers must enter the design process early so energy models can explore tradeoffs between competing materials and technologies. Owners, architects and LDIs require further education on integrated design processes before these practices can be embraced in China. While single suppliers of green building products—such as windows, lighting, and heating, ventilation and air conditioning (HVAC) systems—are abundant, integrated solutions packages are rare. Simple solutions, such as efficient insulation, can have a large impact without the need for sophisticated or integrated technologies.[41]

Commercial feasibility of green building design explores tradeoffs between conventional and green building design features. Common metrics include upfront investment, cost premiums and payback periods associated with green building design decisions.[42] During a panel discussion of a Green Building Working Session, participants highlighted the following additional points:

- Developers consider cost as the most important factor when pursuing projects. While recovering up to 25% of incremental investment for green building solutions through government grants and subsidies may be possible, this typically represents a small fraction of total building costs.
- China's building market players are reluctant to embrace green building solutions due to high upfront costs. Initial investments, commissioning, building intelligence systems and monitoring can be expensive.
- Compulsory building mandates can be effective drivers while China's green building market matures.
- Although in the long run commercial solutions cannot depend on subsidies, financial incentives for green building technologies, including tax breaks, can encourage buyers to enter the market, setting economic forces in motion to reduce costs.



*39. CGTI analysis*
*40. CGTI interviews and analysis*
*41. China Greentech Partner Program Green Building Working Session, May 31, 2011*
*42. Ibid.*

Green building design decision-making covers stakeholder motivations, incentives and deterrents. Establishing standard metrics, such as energy saved per unit area, would lend transparency to design decisions, allowing decision-makers to quickly identify and weigh green building design benefits and tradeoffs. Additionally, architects can specify green building materials during the design phase, but local contractors may not procure them during construction. Developers are also hesitant to shoulder additional costs for green building products without quality assurance. Finally, land is a major cost: developers have been known to pursue green practices simply to acquire land from periodic government programs.[43]

### Design is not enough—implementation is critical to success

Proper implementation and operation of green building design features ensures that buildings perform in accordance with design intentions. This entails strategies and best practices for installation, commissioning and operation of green building features.[44] Installation is relatively easy to verify for building systems with measurable performance indicators, such as HVAC systems, but discrete building materials are difficult to assess. For example, operational savings from efficient insulation can be difficult to demonstrate, especially over the long term.

Property developers show increasing interest in owning the buildings they develop, which may help to align green building incentives. Nevertheless, misaligned incentives remain a major problem. Since building operation companies typically assume control after construction, developers have little incentive to invest in green building technologies that generate operational savings.

## Building Energy Efficiency for New Construction

### Opportunity Assessment Summary

**Policies are creating opportunities for building energy efficiency, though many technologies remain cost prohibitive.**

The fundamental driver for building energy efficiency is the target in the 12th Five-Year Plan to reduce new building energy consumption by 65% versus existing building stock. The Plan emphasizes five aspects of building energy efficiency: shading, heating, ventilation and air conditioning (HVAC), building envelope, integrated renewable energy, and lighting. Foreign and domestic examples show energy efficiency is viable in new construction, yet China's developers find the economics unappealing due to high upfront costs and payback periods greater than 10 years. Efficient lighting stands out as the most economically viable solution, and the market may reach RMB 80 billion by 2015. Other energy efficient technologies will rely on policy support to reach commercial scale. However, current financial incentives are insufficient due to high up-front costs, low electricity prices and misalignment of stakeholder incentives.

**The 12th Five-Year Plan calls for reductions in new building energy consumption by 65% versus existing building stock.**

**China's government increased energy-saving targets and is keen to cooperate internationally on building efficiency**

As noted above, China has set aggressive policies on new building energy efficiency versus existing stock for 2015. Some policies are specific to China's five climate zones, such as Standards for Design of Residential Buildings in Hot Summer and Cold Winter Areas released by the Ministry of Housing and Urban Development (MOHURD) in 2001. Some local government standards go beyond those of the central government. Beijing, for example, has mandated that all new residential buildings achieve a 75% reduction in energy consumption versus existing building stock.[45]

The Chinese government is eager to collaborate with foreign companies to increase the domestic capacity to improve building energy technology. MOHURD acknowledged that local governments lack expertise in collecting energy consumption statistics,

*43. China Greentech Partner Program Green Building Working Session, May 31, 2011*
*44. Ibid.*
*45. "'民用建筑节能条例'公布" [Residential Building Energy-Saving Standards Announcement], China News, September 12, 2011, www.chinanews.com*

which is a major driver for building energy efficiency.[46] By analyzing local building energy consumption data and creating plans for improving local building energy efficiency, foreign companies with the requisite skills can work with organizations, such as the China Green Building Council to coordinate with local governments and identify attractive projects. These working relationships may help companies acquire project and construction funding from government sources and property developers. Companies providing total solutions that can save energy and reduce carbon emissions are more likely to be successful in developing relationships with local governments that pave the way for future projects.

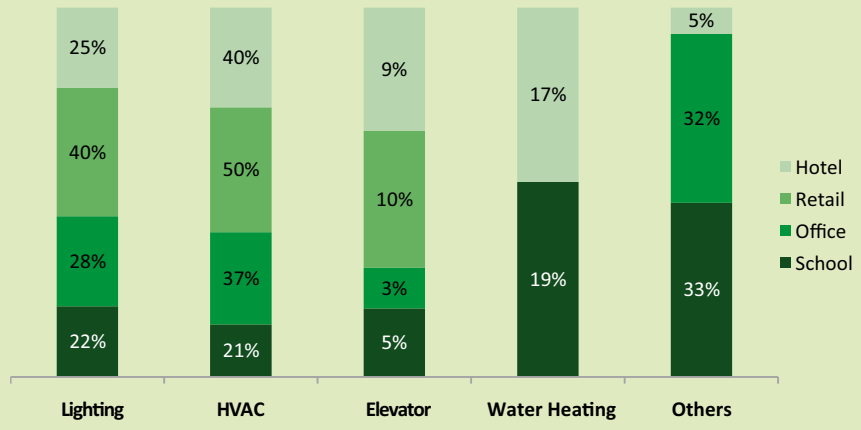
### Real estate investment and cost savings drive the market for building energy efficiency

Through 2020, real estate investments in China are expected to grow at 10-12% and building energy consumption is projected to double, representing a major opportunity for well-positioned building energy efficiency solutions providers. China's urban floor area construction has increased steadily over the past decade, during a time when new construction floor space in China represented nearly half of total global additions.[47]

Concerns about real estate speculation, housing affordability and potential asset bubbles have led to efforts to slow the overheating residential construction market; as a result, urban commercial floor area surpassed its residential counterpart for the first time in 2009, and has been steadily widening the gap since. Real estate investments have been rapidly increasing, particularly between 2009 and 2010, which saw a 25% increase, and is expected to reach RMB 216 billion by 2016 and RMB 315 billion by 2020.[48] Rapid growth has the potential to double China's building energy consumption by 2020 without major energy efficiency measures. The problem presents opportunities for solutions providers that understand the potential for improving energy efficiency. The greatest energy efficiency opportunities are in retail buildings, however, where half of the total energy consumption is HVAC-related and 40% comes from lighting.[49] Hospitals, premier hotels and transit have the highest energy consumption (greater than 300 kilograms of carbon equivalent per $m^2$ annually) coupled with the longest operating hours (over 14 hours per day, over 360 days per year). In addition, hotels and hospitals are under high pressure to cut operating costs.



**Public and Commercial Energy Consumption in China by Use**




*Note: The data is based on the statistics of different public and commercial buildings in Beijing.*

*Source: "中国建筑节能年度发展研究报告" [Annual Report on Construction Energy Saving Development in China], Tsinghua University Construction Energy Saving Institute, 2010*

*46. CGTI Government Outreach Meeting with MOHURD, August 2011*
*47. Hong, Wen and Margarethe P. Laurenzi, Building Energy Efficiency: Why Green Building Are Key to Asia's Future (Hong Kong: Asia Business Council, 2007), p. 160*
*48. "China's Green Revolution," McKinsey & Co., February 2009*
*49. "中国建筑节能年度发展研究报告" [Annual Report on Construction Energy-Saving Development in China], Tsinghua University Construction Energy Saving Institute, 2010*

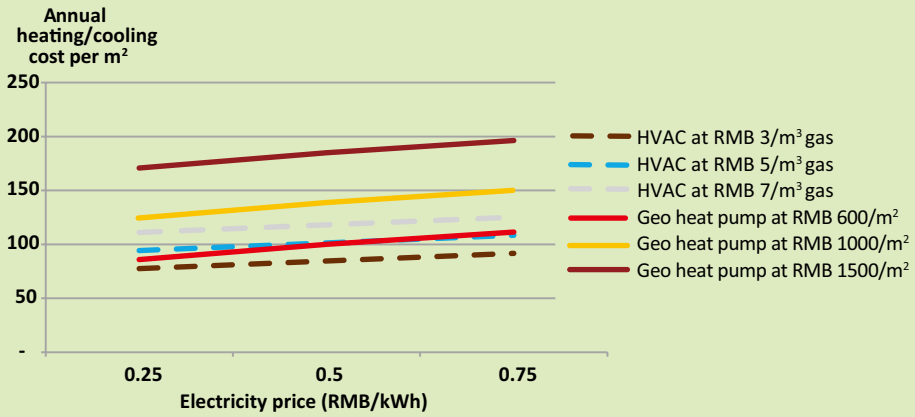
### Lack of technical capacity and stakeholder misalignment hinder development

China has a shortage of professionals qualified to implement integrated building design and perform operations and maintenance.[50] Though government energy efficiency targets are driving the building efficiency market, provincial governments lack the ability to implement these targets, and this may take several years to rectify. Insufficient economic incentives to justify building energy efficiency improvements are compounded by the lack of incentive alignment between property developers, building owners, and users, as well as the complexities of multiple ownership of a single property. Finally, public awareness of the economic and health benefits of green buildings is low.[51]

### Many potential energy efficiency solutions remain financially unattractive

Most energy efficient HVAC technologies are available in China and domestic research and development (R&D) capability is improving. Unfortunately, property developers lack financial motivation to implement energy efficiency solutions due to factors including up-front costs being 30-50% higher, payback periods of 7-10 years, and uncertain lifecycle costs given varying fuel and power prices. Additionally, there is often a lack of skilled technicians to operate HVAC systems properly. The government is setting strong targets to promote energy efficient HVAC solutions and providing subsidies for certain technologies like building heating, cooling and power (B-CHP). These policies are currently insufficient, however, as some technologies, such as ice storage air conditioning systems, lack sufficient support and standards are low to non-existent.[52]

**Cost of Heating/Cooling in China: HVAC vs. Geothermal Heat Pump, per m²**




*Source: "浅谈我国冰蓄冷空调的发展现状" [Discussion on Ice Storage Air Conditioning Market Development], CALMAC, accessed on September 3, 2011*

A CGTI sensitivity analysis comparing conventional HVAC and geothermal heating suggests heat pumps are not yet economical at small scale. The analysis considers a 300 m² home in Chengdu which logged 900 hours annually for both heating and cooling under the assumption that gas prices ranged from RMB 3 to RMB 7, power prices ranged between RMB 0.25/kWh and RMB 0.75/kWh, geothermal heat pump capital costs ranged from RMB 600/m² to RMB 1,500/m², and the average heat pump energy efficiency rate (EER) was 3.8 with 90% heating thermal efficiency and 3.7 EER for cooling. The analysis shows that small geothermal heat pumps can deliver savings over HVAC assuming low-end capital costs of RMB 600/m². However, for this range of power and natural gas cost, a conventional HVAC system was still less expensive. Heat

*50. CGTI interviews; "Optimize Operational and Maintenance Practices," WBDG Sustainable Committee, August 18, 2011, www.wbdg.org; "Siveco China's GM to speak on, 'Green buildings: the operation and service perspective,' in Beijing," Siveco, June 3, 2011, www.sivecochina.com*

*51. CGTI analysis and interviews*

*52. "论小型冷热电联产" [Discussion on Small CHP Project], CNJZSJ, accessed on August 15, 2011; Wenku Baidu, "商业楼宇天然气冷热电联产分布式电源应用价值分析" [Economics Analysis of HCP-B], wenku.baidu.com, accessed on August 13, 2011; CGTI analysis*

pumps may be more cost effective when applied to large scale projects, based on input from several CGTI Partner companies.

## Green Building Financing

### Opportunity Assessment Summary

**Though building energy efficiency improvements are economical ways to meet China's energy and emissions policy goals, green building financing channels are insufficient to strongly encourage green buildings and energy efficiency retrofits.**

China's green building market has expanded rapidly in recent years, albeit from a low base, but given tightening financing conditions for the real estate market, developers need to diversify funding sources for green buildings and retrofit projects. Government subsidies for green buildings and energy efficiency projects are the most important measures for promoting these projects. In addition, China has policies to support energy service companies (ESCOs), though this market is still underdeveloped. Given the carbon reduction potential of building energy efficiency projects, foreign funding is also an option in some cases. Overall, China has fewer financing channels for such projects than other countries, and introducing financing methods used outside of China—such as the platform of investment and financing companies (PIFCs), sustainable energy utilities, and utility on-bill financing—will require further financial market reform and other policies.

**The China Green Building Movement Plan sets subsidies of RMB 75/m² for typical 3-Star building projects.**

#### China has many policies encouraging green buildings, and 2011 was particularly active

In 2011, China introduced several major building energy efficiency and green building policies. In April, the government issued a draft China Green Building Movement Plan,[53] setting subsidies for green buildings at one third of the incremental cost—implying RMB 75/m² in the case of typical 3-Star building projects. The plan may exempt 3-Star buildings from property taxes and allow additional land use for developers of 3-Star-rated buildings. The plan also sets subsidies of RMB 10-20 million for communities with 30% of buildings certified as green buildings, and encourages local government financing incentives. In May, the Ministry of Finance (MOF) and the Ministry of Housing and Urban Development (MOHURD) established a 2015 target for reducing energy consumption per unit area of some public facilities by 10% and large facilities by 15%, announcing central government retrofit subsidies of RMB 20/m².[54]

The central government is using subsidies for green building-compliant projects to promote ESCOs as the main building financing model in China, and encouraging local governments to do so as well. In this framework, ESCOs would not be subject to operating taxes and equipment provided to building owners would be exempted from the ESCO's value-added tax (VAT). ESCOs would also not be liable to pay corporate taxes for their first three years of operation and, for the following three years, would pay taxes at half the normal rate. Lastly, the government has encouraged banks to introduce easier financing for ESCOs and offered simplified administration for loans.[55]

#### Despite favorable policies, green buildings face many obstacles

At the policy level, a number of challenges remain for green buildings. The application for government subsidies lack transparency at both central and local levels, and newly announced policies do not yet have detailed implementation plans or timetables. Another issue is that the government currently prioritizes new building energy efficiency over retrofits, though retrofits may have a greater need for capital.



53. *"以奖代补政令推绿色建筑发展" [Incentives used to develop green building], China Green Building, April 7, 2011, www.chinagb.net*
54. *"财政部住房城乡建设部关于进一步推进公共建筑节能工作的通知" [MOF and MOHURD Public Facilities Energy Efficiency Improvement Plan], MOHURD and MOF, May 4, 2011*
55. *"以奖代补政令推绿色建筑发展" [Incentives used to develop green building], China Green Building, April 7, 2011, www.chinagb.net*

At the broader level of the real estate market, the central government's tight lending policy has made financing more difficult for all real estate-related projects. Strict financial regulation, as the next section will discuss in greater detail, has held back financial innovation and prevented relatively simple financing methods available in other countries from being adopted locally.

Lastly, policymakers have yet to address some of the most basic issues surrounding green buildings. Developers and the public do not have easy access to green building financing information. The basic, long-standing misalignment of interests between developers, owners and occupants can be addressed through ESCOs, but also requires tougher standards and enforcement. Short-term payback periods demanded by developers and investors is yet another issue, not helped by the fact that many ESCOs lack sufficient track records to gain confidence with developers and lenders.

### China has several special methods of financing green buildings

Though China's banking sector is dominated by state-owned banks, only a few banks have offered special financing terms for green building projects. Most commercial banks only consider green building features as a minor aspect when evaluating loans. Another area where commercial banks have played a role is in facilitating international organizations that finance local green building projects. Special bank financing for green building projects has its pros and cons. On the one hand, such financing supports an urgent policy need to encourage green building projects, which otherwise face hurdles in a market dominated by short-term thinking and classic misaligned incentives between builders, owners and occupants. On the other hand, special financing could encourage developers and banks to pursue low-quality projects—sometimes referred to as greenwashing—for large or excessively risky real estate projects otherwise ineligible for financing.

ESCOs have proliferated in China. Private equity and venture capital (PE/VC) firms have provided equity, international institutions have partnered with commercial banks to make loans to ESCOs, and equipment sellers have provided equipment leasing loans. In two high-profile cases of ESCOs financing from international institutions, the Asian Development Bank (ADB) provided an RMB 800 million risk-sharing guarantee to Standard Chartered Bank to provide financing to Johnson Controls, and the International Finance Corporation (IFC) made similar risk-sharing guarantees to Beijing Commercial Bank, Industrial Bank, and Shanghai Pudong Development Bank to make loans to ESCOs.[56]

PIFCs are agencies authorized by the local government to collect and finance affordable housing projects. Given the risk sharing guarantee from local governments, PIFCs obtain funding from bank loans and bond purchases. Based on the local affordable housing development plan, PIFCs set up fund dispensing targets to either project investors or developers. PIFCs have a number of advantages: projects can obtain full funding prior to construction start, and PIFCs simplify financial challenges by combining financing for construction and energy efficiency elements under government oversight.

**International institutions and foreign governments have played a major role in financing green building demonstration projects in China.**

International institutions and foreign governments have played a major role in financing green building demonstration projects in China. Such demonstration projects showcase technologies and methods for improving energy efficiency. In most cases, international institutions have initially partnered with Chinese commercial banks to provide loans. Chinese banks lead project assessments, while the international organizations provide financial and technical assistance. Energy-savings measures are calculated based on both Chinese and international systems. Building owners then pay back loans from the energy savings achieved.

In a few cases, foreign governments themselves have stepped in to provide financing. The French Development Agency funded a Euro 20 million project with Wuhan City targeting 37 public buildings for energy efficiency retrofit.[57] Examples of

*56. "渣打银行携手亚洲开发银行 提高中国楼宇能效" [Standard Chartered Bank Partners With Asia Development Bank to Improve Building Energy Efficiency], jrj, November 29, 2011, www.jrj.com.cn*
*57. "French loans help Hubei Province go greener," People's Daily, June 2, 2011, www.peopledaily.com*

retrofit equipment and projects include upgrading wall structures, improving heating, ventilation and air conditioning (HVAC) systems, upgrading water and electricity supply systems, and adding efficient lighting. The projects target energy savings of around 20-30%, and owners use energy savings to pay back the loans over four years. The drawback of such programs is that funding is limited and difficult to obtain outside of pilot projects.

### Further innovative financing examples are available from abroad

There are a number of financing options, currently unavailable in China, which could help improve the financing channels for green buildings and energy efficiency projects:

- **Carbon Trading:** China's new carbon trading platform, which is in its design phase, may include green buildings. These green building carbon credits could be sold in acceptable carbon markets or transferred in carbon-related projects. In Japan, which began a cap-and-trade program in April 2010, facilities with annual energy consumption of at least 1.5 million liters of crude oil equivalent are targeted for inclusion in carbon trading markets. At the end of 2010, 1,300 commercial buildings were involved in the program.[58] Such programs enable building efficiency projects to benefit from carbon reductions, but require measurement, baselines, standards and central administration, which are presently absent in China.
- **Sustainable Energy Utility (SEU):** In the U.S., state governments are mainly responsible for regulating electric utilities. In Delaware, the state has created a SEU using US$ 30 million in state-authorized bonds.[59] The state has screened energy efficiency projects and established measurement standards. The bonds pay for the difference in cost between conventional and high-efficiency energy equipment, enabling building owners to install such equipment at no incremental up-front cost.
- **Utility On-Bill Financing:** Also in the U.S., the state of New Hampshire and the New Hampshire Electric Company have offered utility on-bill financing for energy efficiency equipment. The program, called Pay-As-You-Save, is currently in its pilot stage. The utility invests in energy efficiency equipment, guaranteeing the building owner at least 20% to 30% in energy savings. The owner then pays back the cost of the equipment loan based via regular monthly utility bills, simplifying financing for the owner or occupant.



### Economic Analysis of Energy Efficiency Projects

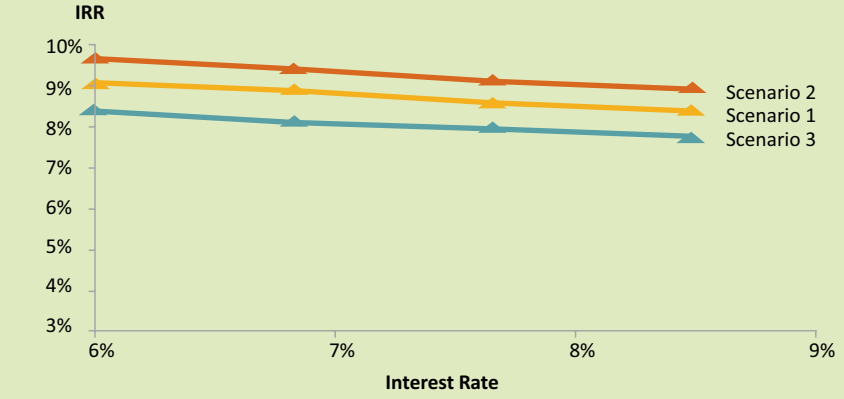
CGTI performed an economic analysis of two large energy efficiency projects, both of which indicated that government policy remains essential to making such projects work. To analyze the economics of energy efficiency retrofit projects in China and the impact of policies and interest rates on project returns, CGTI adapted data from a residential energy retrofit project carried out in Tangshan through a collaboration between the Chinese government and the German Technical Cooperation (GTZ).[60] The Tangshan residential project had a floor area of 2,156 $m^2$ and cost RMB 173/$m^2$—it was funded in cash by the government (53%), the Sino-German project fund (25%), a heat supply company and residents.[61] The project attained energy savings of 63% through a variety of methods, including new exterior wall insulation, low-emissivity windows, heating pipe and radiator retrofits. The best insulators have low U-values, a measure of how well a building material transmits heat. The insulation changes increased energy performance from a U-value of around 0.4 to around 2.0, while the window retrofits improved their U-values from 1.9 to 4.5.

**Government policy is essential to making energy efficiency projects work.**

*58. Kats, Greg, et al., "Energy Efficiency Financing Models and Strategies," Capital E, 2011*
*59. Ibid.*
*60. "Energieeffizienz durch Modernisierung im Gebäudebestand" [Energy efficiency through modernization in building stock], GTZ, September 8, 2011*
*61. "Summary Report of the Demonstration Project in Tangshan," Tangshan Construction Bureau and Tangshan Energy Efficiency Office, October 2008*

CGTI compared returns if the project had been financed with 50% debt using a 6.7% five-year commercial loan in this scenario. The analysis used the RETScreen model to calculate the internal rate of return (IRR) for the project using cost and energy-savings data derived from the original GTZ study.[62] The analysis examined three scenarios: (1) a five-year loan with interest rates ranging from 6% to 9%, (2) a five-year loan with an additional RMB 20/m$^2$ subsidy, and (3) a five-year loan with a loan subsidy that reduced interest rates by 3% from the base rate. The RMB 20/m$^2$ subsidy provided the most attractive returns, but none of the cases showed an IRR above 11%, suggesting that market players would not currently consider the project attractive under these financing terms—despite the huge energy savings and low overall cost of the project.

**Sensitivity Analysis For Tangshan Energy Efficiency Retrofit Project**




*Source: CGTI analysis*

The Siemens Center in Wangjing, built in 2008, is a 30-floor modern commercial office building with a floor area of 58,730 m$^2$. The building was a showcase of green building economics: the energy optimization improvements cost RMB 29.4 million, or RMB 500.6/m$^2$. The enhancements save an estimated 3.1 million kWh per year, reducing carbon emissions by 8,970 tons annually. The specific solutions applied include a movable chilled beam system, an outdoor air heat recovery system, an indirect water-side cooling system, lighting systems, double-façade low-E glass and window reflective film.[63]

Using the incremental cost of the building improvements, CGTI analyzed the economics of the Siemens case assuming 50% five-year commercial debt financing at 6.7%. The analysis ignored operations and maintenance costs, and calculated annual energy savings worth RMB 4.1 million. The analysis considered five cases: (1) a base case with no incentives, (2) a government subsidy reducing interest rates 3% versus the base case, (3) an RMB 50 per ton carbon tax, (4) an RMB 75/m$^2$ government subsidy for the improvements, roughly equivalent to the amount qualified by a 3-Star approved project, and (5) a 25% electricity price increase. Overall, the analysis showed that only the RMB 75/m$^2$ subsidy scenario and the higher electricity price scenarios were sufficient to boost the IRR above 10%.

The results of these two sensitivity analyses suggest the economics of energy efficiency can be challenging even for highly-effective energy efficiency improvement projects—in the first case, the retrofit of an extremely energy-inefficient residential building and, in the second, enhancements to a newly-built modern office building. In both cases, a per unit area government subsidy boosted returns substantially. In the second case, a hypothetical increase in electricity prices also helped returns. In both cases, the short-term financing method employed (five-year loans) reduced returns substantially compared to longer-term financing—several CGTI Partner companies

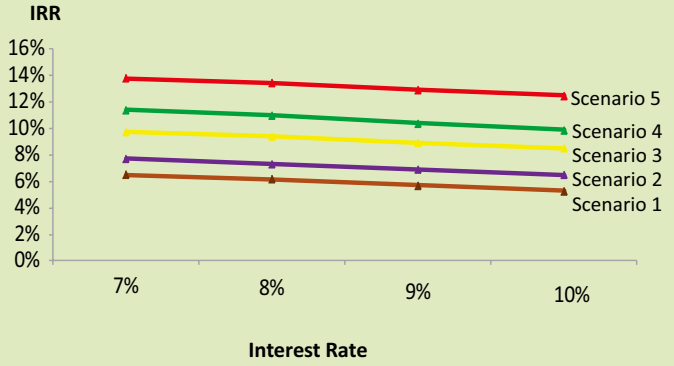
*62. The RETScreen Clean Energy Project Analysis Software is provided by the Government of Canada to analyze energy performance and financial data of various clean energy solutions and projects.*

*63. "中国低碳建筑案例分析" [China Low-Carbon Building Case Study], The Climate Group, Beijing: Politics Brief, March 2011*

indicated that this accurately reflects the financing available in China for such projects. Overall, interest rates were a less important sensitivity factor versus subsidies and energy costs. For those developers and investors with hurdle rates over 20%, the results of this analysis would be disappointing—none of the project scenarios offered returns in that range.

**In energy efficiency projects, interest rates were a less important sensitivity factor versus subsidies and energy costs.**

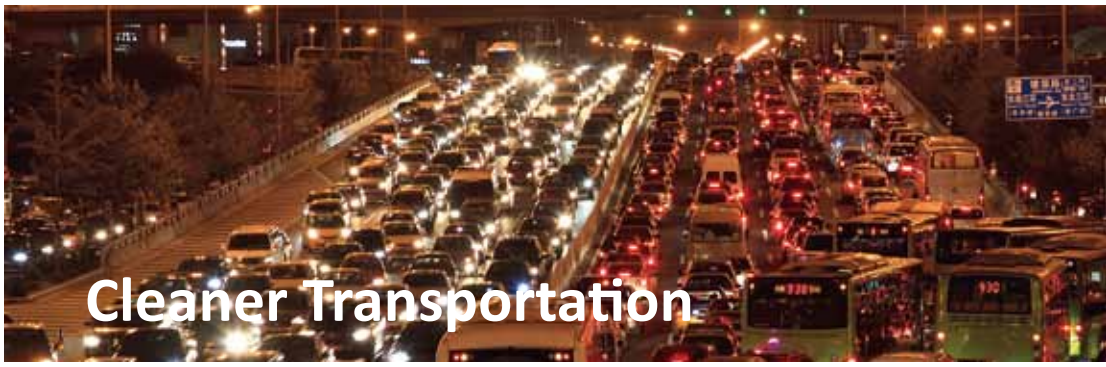
**Commercial Energy Efficiency Project Sensitivity Analysis**




*Source: CGTI analysis*

## The Path Ahead

This chapter provides an update of China's Green Building sector and three Opportunity Assessments prioritized by CGTI's research team and Partners in 2011. As the sector evolves, participants in the China Greentech Partner Program will continue to collaborate on additional opportunity areas. The first topic in 2012 covers building retrofit market, with a focus on the ESCO industry landscape. Other topics may include: green building technology development in China and low-carbon communities and zones. CGTI will also continue to track the evolution of China's Green Building sector.



# Cleaner Transportation

**The Cleaner Transportation sector is an important element of China's plan to reduce carbon emissions and fossil fuel use.**

To reduce dependence on oil imports and cut emissions, the Chinese government is pursuing a range of transportation policies which include development and adoption of new energy vehicles (NEVs), improved fuel efficiency, high-speed rail and biofuels. NEVs are an important element of China's focus on innovation.[1] NEVs also were selected as one of the seven strategic emerging industries (SEIs) under the 12th Five-Year Plan, which translates into government financial and regulatory support.[2] China continues to raise conventional vehicle emission and fuel economy standards and, despite a major rail accident in 2011, the nation continues to complete new high-speed rail lines. In contrast, there have been few developments in the past year on biofuels.

This chapter begins by providing an overview of Cleaner Transportation sector developments since the publication of *the China Greentech Report 2011*. It then summarizes three Opportunity Assessments developed by the China Greentech Initiative (CGTI) in collaboration with Partner companies and organizations throughout 2011:

- Cleaner Internal Combustion Engine (ICE) Vehicles
- Fleet Electrification
- Electric Vehicles (EVs) and Charging Infrastructure

CGTI's Partner companies prioritized each of these Opportunity Assessments as critical to the growth of China's Cleaner Transportation sector within the next two to three years. These summaries represent high-level findings of the detailed proprietary research and analysis developed in collaboration with organizations participating in the China Greentech Partner Program. The chapter concludes with an outlook on additional opportunities and issues in the Cleaner Transportation sector that CGTI will explore in 2012.

**Cleaner Transportation Sector Definition**

CGTI defines **Cleaner Transportation** as solutions that increase energy efficiency, reduce emissions and improve resource utilization to minimize the negative impact of transportation on the environment. These solutions span four major subsectors: road, rail, air and waterways.

*Senior Analyst Sean Wang* (王效) *led the writing of this chapter with support from contributing writer Research Manager Ana Chiong (MangoStrategy) based on 2011 strategic research conducted by Senior Analyst Junda Lin* (林骏达) *and Manager Lixuan Zhou* (周丽璇).

*1. "President Hu urges efforts to promote strategic emerging industries (SEIs)," Xinhua, May 31, 2011, news.xinhuanet.com*
*2. "China Encourages Private Enterprises to Invest in SEIs," China Briefing, August 18, 2011, www.china-briefing.com*

# Market Update

### Vehicles are a major China policy focus

The 12th Five-Year Plan named the new energy vehicle (NEV) industry as one of China's pillar industries as it expressed its intention to shift growth towards cleaner and higher-tech industries. The Plan also implemented policies to encourage electric vehicle (EV) technology transfer from foreign to local automakers. Pilot programs were carried out to demonstrate the application of EVs in real-world settings and encourage consumer adoption. Since China's EV industry is still in a nascent stage, important technologies, such as batteries and charging infrastructure solutions, are still encountering challenges.

Though EVs seem to be the focus in the past year, conventional vehicles remain important to China's automotive industry. The government realizes that these vehicles will continue to dominate China's roads in the near term. As such, China continues to evolve policies on fuel efficiency and carbon emissions. Cleaner internal combustion engine (ICE) solutions are also being promoted.

### NEVs are a strategic emerging industry (SEI), but there is no clear roadmap

In late 2010, the Ministry of Industry and Information Technology (MIIT) completed a draft of the Energy Saving and New Energy Vehicle Development Plan (2011-2020). Now that MIIT has integrated feedback from relevant ministries, the draft is ready for submission to the State Council.[3] The delay was said to be caused by disagreements over the technology roadmap and standards, but stakeholders are now hopeful that the revised plan will be released in 2012. The plan targets the sales of 1 million NEVs, with pure electric and hybrid vehicles accounting for 50% by 2015.[4]

Additionally, the Ministry of Science and Technology (MOST) also quietly launched its 12th Five-Year Plan on the Electric Vehicle Industry in May 2011.[5] Industry observers believe that this parallel and low-key publication of the MOST Plan is a reflection of the unsettled debate over the EV roadmap.[6] The MOST Plan calls for sales of 1 million EVs by 2015, twice the amount targeted by NEV Development Plan.[7]

**NEV Definition**

**New Energy Vehicles (NEVs)** are defined by the Ministry of Industry and Information Technology (MIIT) as vehicles that use unconventional fuel power as their power source (or use conventional fuels with a new drive system), integrated with advanced drive and control technologies to form a new technology platform and vehicle system.



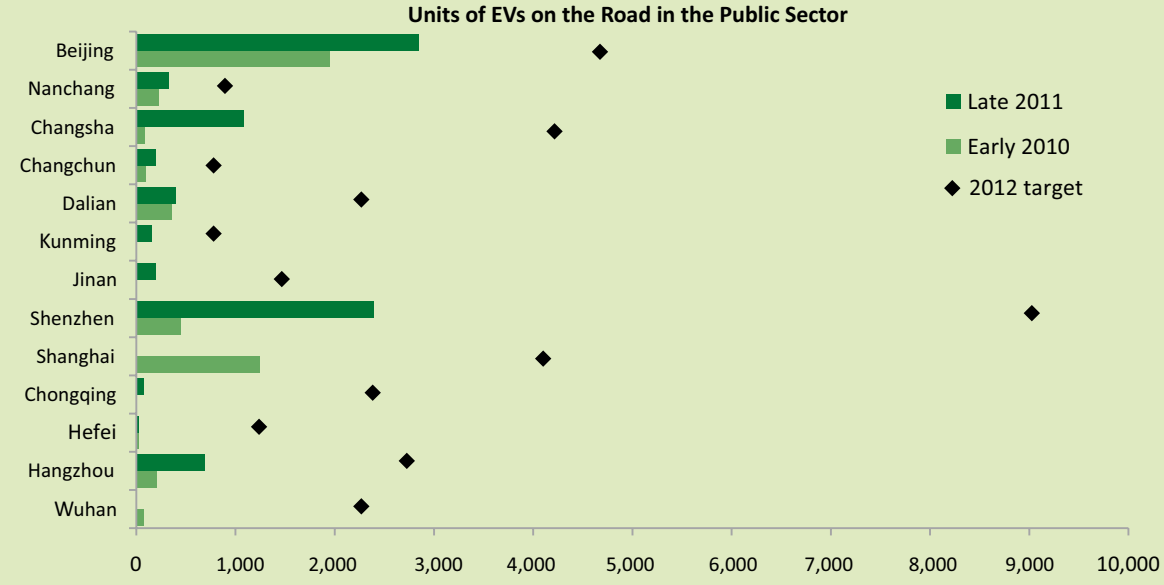
The disagreement on the technology roadmap came about because the two agencies, MIIT and MOST, have different priorities. MIIT advocates the development of both energy-saving and NEVs since it oversees the development of China's auto industry, and hybrid and cleaner conventional vehicles represent a huge market. MOST's focus, on the other hand, centers on promoting advanced technology and innovation, hence its interest in the development of battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs).

*3. "China to Promote Seven SEIs," Business China, September 9, 2010, en.21cbh.com*
*4. Li, Fangfang, "China plans to take lead in new-energy vehicles," China Daily, April 8, 2011, usa.chinadaily.com.cn*
*5. Geng, Huili, "The 12th 5-year plan from MOST on EV has been quietly carried out," EEO, May 20, 2011, www.eeo.com.cn*
*6. Ibid.*
*7. Ibid.*

## Public sector: leading the adoption of EVs

The Tens of Cities, Thousands of Vehicles Program has expanded to include 25 cities by April 2011, up from 10 cities when the program was launched in 2009.[8] As of November 2011, the program has deployed around 8,500 vehicles, mainly hybrid electric vehicle (HEV) buses—not quite near the target of 30 cities and 30,000 units expected by December 2012.[9] In theory, China should have developed 30 cities (10 cities per year, starting in 2009) with each city launching 1,000 units of NEVs.[10] Due to limited budget, safety issues, immature products, inadequate infrastructure, and an unclear technology roadmap, however, the program is behind on its targets.[11]

**Update on the First 13 Pilot Cities in the Tens of Cities, Thousands of Vehicles Program**




*Sources: "再议我国新能源汽车发展战略和发展目标" [Re-Suggest New Energy Vehicle Development Strategy and Target], 东方汽车网, www.mag.oauto.com, accessed on November 2, 2011; CGTI interviews and analysis; Jie Zheng, et al., Strategic Policies and the Ongoing Demonstration Program of Electric Vehicle Deployment in China (Beijing: World Bank, 2009); CGTI interviews and analysis*

The private market has also been slow to adopt EVs even though the government has offered subsidies, reduced vehicle taxes and granted license plate lottery exemptions. CGTI interviews suggest that the low supply of EVs, the lack of charging infrastructure and high costs are major obstacles preventing consumers from buying EVs.

Some industry participants hope that low-speed EVs will help lift the EV industry, as more vehicle types are legalized for on-road use. Though e-bikes, a form of low-speed EV, currently dominate the courier fleet, the demand for other types of low-speed EVs, including cars, in lower-tier cities and rural areas is increasing. China currently produces low-speed EVs, but they are generally intended for the export market. In response to the domestic expansion of the low-speed EV market, Hunan and Shandong provinces have issued local administrative standards to maintain the segment's legitimacy.[12] MIIT and MOST are also conducting pilot projects in various cities to study market opportunities and considering whether to expand their list of eligible EVs.[13]

*8. "China to benefit from emerging Global Electric Vehicle demand, though challenges remain," World Bank, April 20, 2011, www.worldbank.org*
*9. China Greentech Initiative (CGTI) analysis*
*10. Zhang, Yale, China 12 Cities EV Demonstration Project: Final Report (Shanghai: Automotive Foresight Co., Ltd., October 2011)*
*11. Ibid.*
*12. "低速电动车蜕变之路 身份问题引专家争论" [Evolvement of Low Speed EV Caught Experts' Debate Over Legitimacy Issues], China Automobile Daily, January 18, 2011*
*13. "工信部研讨二版目录 低速电动车有望合法" [Ministry of Industry and Information Technology (MIIT) in Revision of a 2nd Edition of List of Legitimate EVs to Hit the Road, Low Speed EVs Expected to Go Legal], Autosina, December 30, 2010*

### Growing pains for the battery and battery charging segments

Historically, China's EV battery market has had weak research and development capabilities, hindering improvement of materials, cell design and battery management systems. The battery industry also has had a low degree of production automation, affecting battery quality and consistency. Additionally, industry standards for EV batteries are not fully developed, resulting in different battery designs and performance capacities. To overcome these challenges, the government allocated RMB 10 billion under the Energy Saving and New Energy Vehicle Development Plan (2011-2020) to support battery research and produce better battery technologies.

Like the rest of the world, China's vehicle battery charging station infrastructure is beset with challenges, mostly related to design, construction, station operations and customer use. Charging station design and construction issues include limited space inside the car for batteries, high upfront costs, insufficient financial incentives, inadequate station technical standards, and EV charging model uncertainty.[14]

Despite these problems, various organizations are already hoping to install charging infrastructure in China's major cities. Thousands of charging stations are planned for Beijing, Hebei, Henan, Hubei, Guangdong, Hangzhou, Shanghai and Jiangsu by 2015.[15] State Grid and China's oil companies currently dominate charging infrastructure construction, but other groups, such as auto manufacturers, professional services companies and real estate developers, are showing interest as well.

### Implementing stricter emission and fuel economy standards

The private sector's slow adoption of EVs indicates that conventional vehicles will continue to dominate China's vehicle mix at least in the short term. The 12th Five-Year Plan calls for reductions in transportation fossil fuel consumption by 16% and China's overall carbon dioxide ($CO_2$) emissions by 17% from 2010 levels by 2015.[16] To help achieve these targets, the government issued a directive instructing officials to purchase fuel-efficient and electric vehicles in 2012.[17] The government also intends to implement stricter emission and fuel economy standards, which would meet standards of developed countries.

**Conventional vehicles will continue to dominate China's vehicle mix at least in the short term.**

The China IV emission standard, which is equivalent to the Euro IV standard, was implemented in 2011 in some Tier 1 cities, such as Beijing, Shanghai and Guangzhou, and will be adopted nationwide in 2013.[18] Phase III of China's fuel economy standard, which aims to improve the fuel economy versus Phase II by 8% (from 17% to 25%), depending on weight class, is expected to be fully implemented by 2015.[19] With the 2008 implementation of Phase III standards, by 2016 China will have saved 26.6 billion liters of gasoline, avoiding 63.3 million tons of $CO_2$ emissions.

Cleaner ICE solutions are also being encouraged. Studies show that they have the potential to improve the fuel efficiency of light-duty vehicles (LDVs) by up to 9%, at an incremental cost of only US$ 70.[20] In the near term, cleaner ICE vehicles will have the largest potential impact on transportation sector oil consumption and carbon emissions.



*14. "工信部研讨二版目录 低速电动车有望合法" [Ministry of Industry and Information Technology (MIIT) in Revision of a 2nd Edition of List of Legitimate EVs to Hit the Road, Low Speed EVs Expected to Go Legal], Autosina, December 30, 2010*
*15. "新能源汽车:"电池租赁+换电"模式敲开电动汽车产业化之门" [New energy vehicles: "Battery Lease + Power Station"- the new business model opens the door of EV industry], Founder Securities, June 24, 2011, www.foundersc.com*
*16. "The 12th Five-Year Plan: China will reduce energy consumption intensity sharply," China News, March 5, 2011, www.chinanews.com*
*17. "China gives new-energy vehicles official nod," Xinhua, November 25, 2011, news.xinhuanet.com*
*18. "China IV Emissions Regulations Deadline Delayed," Original Equipment Manufacturer (OEM) Off-Highway, January 10, 2012, www.oemoffhighway.com; "China to introduce Chinese IV emission vehicles this month with new policy," China Car Times, June 24, 2011, www.chinacartimes.com; China's emission standards are based on European regulations, and specify the allowed volume of pollutant for each car type.*
*19. An, Feng, et al., Global Overview on Fuel Efficiency and Motor Vehicle Emission Standards: Policy Options and Perspectives for International Cooperation (New York: United Nations (U.N.) Department of Economic and Social Affairs, May 2011*
*20. CGTI analysis*

## Cost-Benefit Analysis of Cleaner ICE Technologies in the US for Light-Duty Vehicles

| Technology | % $CO_2$ Reduction | Incremental Cost (US$) |
|---|---|---|
| Turbocharged downsized engine | 6% | 624 |
| Cylinder deactivation | 6% | 160 |
| Variable valve timing and lift | 4% | 192 |
| Engine friction reduction | 2% | 75 |
| Gasoline direct injection | 2% | 278 |
| Six-speed dual clutch | 9% | 70 |
| Continuously variable transmission | 6% | 208 |
| Six-speed automatic | 6% | 99 |
| 10% weight reduction | 7% | 592 |
| Aerodynamic drag reduction | 3% | 42 |
| Low-rolling-resistance tires | 2% | 6 |
| Stop-start | 8% | 394 |

Engine Transmission Vehicles Hybrid

*Note: Costs and $CO_2$ reduction data are from a U.S. study and may vary in China.*

*Source: "Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards," U.S. EPA Office of Transportation and Air Quality, April 2010, p. 3-91; data shown are averages of ranges given in this report.*

Cleaner ICE solutions can be applied to the engine, transmission, or drivetrain; however, improvement in transmission technologies appears to be more cost-efficient compared to other solutions.[21] Use of 10% corn-based ethanol-gasoline blend (E10) can also reduce emissions.[22]

### Despite an unclear path to achieving biofuel targets, companies are entering the sector

Biofuel development is another area where China has ambitious goals, but has failed to meet targets announced in 2010—with no clear path to implementation. Most recent data available show the fuel mix for road transportation was 93.4% fossil fuel and 6.6% alternative fuels in 2011.[23] The government's 12th Five-Year Plan for the automobile industry calls for 20% alternative fuel use by 2020, but with fossil fuel use expected to grow by 51% over this period, and without a clear policy roadmap for increasing fuel supply and infrastructure, it remains unclear how alternative fuel consumption can achieve this dramatic increase over this period.[24]

However, both foreign and domestic enterprises have made strategic moves into China's biofuel market, which the Ministry of Agriculture estimates has a potential production capacity of 14 million tons of fuel ethanol by 2020 and 25.5 million tons by 2030.[25] In 2009, the National Development and Reform Commission (NDRC) approved China Petroleum and Chemical Corporation's (Sinopec) manioca tree biodiesel production project in Nanchong with a total capacity of 60,000 tons.[26] In September 2011, an official from Sinopec announced that the company planned to increase production capacity of biofuel by 1.1 million tons and import 470,000 tons of biofuel by 2015.[27] COFCO Group started a cooperation with Denmark's Novozymes in 2006 to transform crop straw into industrial ethanol through cellulose technology, while

*21. CGTI analysis*

*22. "E10 Emissions," U.S. Department of Energy (DOE), www.afdc.energy.gov, accessed on February 14, 2012*

*23. Consumption data for each alternative fuel are calculated on an energy adjusted basis. Data are CGTI estimates based on interviews. China does not publish official data on alternative fuel consumption in the transportation sector.*

*24. "中国未来车用能源发展的思考" [Thought on China's Vehicle Used Alternative Fuels Development], Nevfocus, November 25, 2011, www.nevfocus.com*

*25. Li, Yannan, "中国生物质燃料发展前景的探讨" [Discussion on China's Biofuel Development Prospectus], China New Energy Network, September 2, 2010*

*26. Ibid.*

*27. "中国石油计划提高生物燃料产能" [Sinopec Plans to Increase Production Capacity for Biofuel], China Transmission Network, September 9, 2011*

Coskata and Dupont are actively seeking partners in China to produce bioethanol using agricultural and forestry waste materials.[28] Despite these commercial partnerships, development of China's biofuel market requires additional standards, policy reforms and financial incentives.

The government has introduced some policies for the biofuel market, including the B5 standard on Biodiesel Mixed Fuel, announced in 2011, which legalized biodiesel sales in China's oil market.[29] In addition, mounting public concern about food safety and reused waste cooking oil led the government to increase support for waste cooking oil recovery technologies. In December 2010, the Ministry of Finance (MOF) and State Administration of Taxation (SAT) approved consumption tax exemptions for pure biodiesel made from waste animal and vegetable oil and, in mid-2011, clarified the definition of such oil.[30] However, major policy and implementation challenges remain. Poor law enforcement and weak feedstock collecting systems have reduced the effectiveness of policies already announced. Since few qualified enterprises operate in the waste oil collection market, illegal waste oil-to-cooking oil factories have driven up feedstock prices. To overcome problems, government may need to increase supervision over the waste oil collection process, establish new standards on biodiesel quality, and promote the use of biodiesel in public transportation systems to increase demand.[31]

## High-speed rail expansion slowed in 2011

China continues to expand its high-speed passenger rail network to link major cities and relieve freight transportation bottlenecks. By the end of 2010, the country had 8,358 kilometers of high-speed rail in operation, making China the world leader in terms of operating distance.[32] If current development plans are realized, the network will have 16,000 kilometers of high-speed rail by the end of 2015.[33] However, after a series of scandals with the Ministry of Railways,[34] and a deadly July 2011 rail accident, the government reduced high-speed operating speeds and introduced other improvements to improve safety.[35] The speed reduction also addressed profitability and line maintenance problems.[36] Since then, financing high-speed rail projects has become more difficult. In late 2011, regional governments had trouble finding funds to support new high-speed rail corridors, and in some cases, contractors were unable to pay worker salaries for already-completed line sections.[37] The lack of profits on many existing lines has led to difficulties in financing new lines—for example, though the Guangzhou-Wuhan line has carried over 150,000 passengers since opening in 2009, the line has experienced a cumulative RMB 3 billion operating loss.[38]

**China has plans for 16,000 kilometers of high-speed rail by the end of 2015.**

## Challenges limit growth of EV segment

EVs will be a development focus in the 12th Five-Year Plan for the automobile industry, with the government launching a series of policy incentives to further encourage the market; however, the industry still faces major challenges and EV policies to date have been insufficient to promote widespread EV adoption. The public



*28. "峰回路转的中国生物燃料产业" [A Turning Point for China's Biofuel Industry], China Forestry Bio Energy Network, September 24, 2009*
*29. "我国生物柴油调合燃料(B5)标准正式发布" [Standard on Biodiesel Mixed Fuel (B5) has been released], General Administration of Quality Supervision, Inspection and Quarantine, Standardization Administration, November 29, 2010*
*30. "关于明确废弃动植物油生产纯生物柴油免征消费税适用范围的通知" [Notice on the definition and scope of consumption tax exemption of pure biodiesel made from waste animal and vegetable oil], Ministry of Finance (MOF), State Administration of Taxation (SAT), June 15, 2011*
*31. Ibid.*
*32. "统计局:中国铁路营业里程世界第二 高铁排榜首" [Bureau of Statistics: The Operating Mileage of China's Railway Ranks Number 2 in the World, High-Speed Rail Ranks Number 1], ChinaNews, March 4, 2011, www.news.163.com*
*33. Ibid.*
*34. "铁道部及铁道部部长就'7.23'事故作出深刻检查" [The Ministry of Railway and its Director Make Sincere Self-Criticism over the 7.23 Accident], Ministry of Railways of the People's Republic of China, November 28, 2011, www.china-mor.gov.cn*
*35. Xin, Dingding, "Putting high-speed travel back on track," China Daily, December 13, 2011, www.chinadaily.com*
*36. Liu, Yan, "高铁产业链面临重建融资陷入困境配套商将被洗牌" [High-speed rail industry chain is facing reconstruction, financing encounters difficulty as supporting facility providers are facing reshuffle], HLJNEWS, August 12, 2011, www.hljnews.cn*
*37. Zhang, Ao, "铁路数千亿融资难解近渴高铁建设将进入缓慢期" [Hundreds of billions of railway financing intractable thirst high-speed rail construction will enter a slow period], Sohu, November 20, 2011, news.sohu.com*
*38. Chung, Jenny, "在建高铁需千亿元事故或使融资打折扣" [To build high-speed rail need hundreds of billions of dollars, accident might hinder financing], HC360, July 27, 2011, info.wujin.hc360.com*

sector, including public transportation and government vehicles, will likely lead the NEV market, whereas development in the private sector will remain slow due to a lack of charging standards, infrastructure and battery technology. Biofuels and rail will experience slower policy growth over the coming year.

## Market Opportunities

**Many technologies exist that can improve fuel economy by up to 10%—most at an incremental cost of less than US$ 500 for light-duty vehicles.**

**High potential opportunities in the Cleaner Transportation sector include those in cleaner internal combustion engine (ICE) drivetrains, battery raw material supply, and commercial vehicle emission reduction solutions.**

### *Advanced ICE drivetrains*

Advanced drivetrains include more efficient engine and transmission technologies, as well as various degrees of electric hybridization. Many mature, commercially available engine and transmission technologies exist that can improve fuel economy by up to 10%—most at an incremental cost of less than US$ 500 for light-duty vehicles.[39] Examples of these technologies include variable valve timing and lift (VVT/L), downsizing with turbo-charging and gasoline direct injection (GDI), automated manual transmission, dual-clutch transmission and continuously variable transmission (CVT). There are also practical low-cost hybrid technologies ranging from micro-hybridization, which automatically shuts down and restarts the internal combustion engine to reduce the amount of time the engine spends idling, to full hybrids, which provide full electric drive at low speeds. Given the need for improved ICE efficiency to achieve emissions and oil consumption-related policy goals, it will be essential for domestic and foreign carmakers, plus parts suppliers, to introduce more such improvements over the next decade.

### *Supply of battery raw materials*

As battery technology improves and battery production rises, demand for battery raw materials is growing. Four categories of raw materials—anodes, cathodes, electrolytes and diaphragms—will each require additional supply. For a typical lithium battery in China, roughly 30-40% of the cost is for the anode, 20% is for the cathode, 8-12% for the electrolyte, and 25-30% is for the diaphragm. Market prices for anode materials range from RMB 50,000/ton for lithium manganese oxide ($LiMnO_2$) to RMB 500,000/ton for lithium cobalt oxide ($LiCoO_2$). Cathode materials cost RMB 60,000/ton, electrolyte materials cost between RMB 80,000/ton to 100,000/ton, and the diaphragm materials cost RMB 8-15/square meter ($m^2$).[40] The market for anode materials is competitive: companies, such as Tibet Mining, possess raw material reserve and crucial mining rights, and BYD's acquisition of 18% of Tibet Mining in September 2010 was a strategic move to consolidate the upstream market.[41] Citic Guoan's Citic Mengguli will focus on technological development of anode materials for plug-in electric vehicle (PEV) batteries, while Binbin Holdings is focused on the integrated production chain of anode, cathode and electrolyte materials, ranking third in world anode material suppliers list.[42] In contrast with the anode market, the cathode market in China appears more industrialized. China Baoan, Binbin Holdings and Changsha Hairong lead the supply sector, and together essentially meet the country's demand for cathode material.[43] Currently, Japanese manufacturers control about 70% of the electrolyte market for lithium hexafluorophosphate ($LiPF_6$) batteries. Morita Chemicals produces around 600 tons of electrolyte annually in Jiangsu to feed China's domestic



*39. "Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards," Office of Transportation and Air Quality, U.S. Environmental Protection Agency (EPA), April 2010, www.epa.gov; CGTI analysis*

*40. "New Energy Vehicle Battery Market Research Report," Huachuang Securities, March 2, 2010*

*41. "比亚迪毫无悬念拿下西藏矿业锂矿股权" [BYD Acquired Equity of Tibet Mining's Lithium Mine], China Securities, September 16, 2010, company.cnstock.com*

*42. "New Energy Vehicle Battery Market Research Report," Huachuang Securities, March 2, 2010*

*43. "拉动产业投资，电动汽车技术研发‘争上游’" [EV Technology R&D Compete for Top Spot, Providing Incentives for Investment into the Industry], China Economic Herald, December 10, 2011, www.ceh.com.cn*

market.[44] The supply of diaphragm materials is mainly imported.[45]

### *Emission reduction solutions in commercial vehicles*

In November 2011, the Ministry of Industry and Information Technology (MIIT) issued the Industrial Technology Innovation for the 12th Five-Year Plan, a document outlining the clean commercial vehicle technologies the government seeks to improve. These include efficient ICE, advanced speed variation devices, special engines for normal hybrid power, technology for electromechanical coupling devices, advanced electronic control technology, low-resistance parts and fuel cell engine technologies.[46] Emission reduction solutions are likely to benefit component vendors and original equipment manufacturers (OEMs) that specialize in relevant technology fields, such as BYD, Wanxiang EV, Foton Automobile, Ankai Fleet and other involved companies and manufacturers.[47] Mercedes-Benz's partnership with BYD in 2010 is a case of how advanced foreign carmakers can enter the Chinese EV market. This partnership allows for information and advanced experience to be exchanged regarding electric vehicle (EV) structure, battery technology and electric drives.[48] Domestic fleet manufacturer Ankai is launching its low-emissions bus in Beijing's public transportation market, selling 100 vehicles to Beijing Public Transportation Group and has established 232 Ankai service depots nationwide—demonstrating domestic carmaker interest in the public and commercial market.[49]

## Cleaner Internal Combustion Engine (ICE) Vehicles

### Opportunity Assessment Summary

**The government's emissions policies are pushing the ICE vehicle market to adopt cleaner technologies, creating opportunities in China's booming automotive market.**

China's automotive market is the world's largest and continues to expand rapidly, but despite high expectations for the growth of electric vehicles (EVs), conventional ICE vehicles will continue to dominate for the next decade. There are many mature and cost-effective technologies to make China's ICE vehicles cleaner, including alternative fuels, advanced engines and transmissions, hybrid drivetrains, exhaust after-treatment devices and other general vehicle improvements. However, China focuses most of its policy support on EVs, relying on increasingly stringent fuel economy and emission standards to promote cleaner ICE technologies. Regulatory challenges and a highly cost-sensitive market are the main obstacles for many advanced ICE technologies.

### Urgent need for cleaner ICE vehicles, particularly in the heavy-duty segment

China's automotive market is now the world's largest in terms of vehicles sold, with vehicle sales topping 18 million in 2010, and expected to reach 24 million by 2012.[50] China had approximately 74 million vehicles on the road at the end of 2010, and the fleet is expected to exceed 200 million by 2020.[51]

**The automotive market in China is now the world's largest in terms of vehicles sold, with sales reaching 24 million by 2012.**

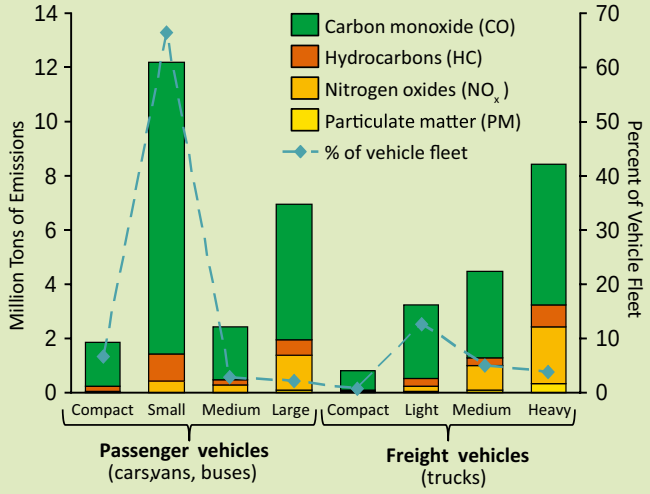
Many expect China to emerge as a leader in vehicles with alternative powertrains, but these vehicles presently account for only a small fraction of cars in China. Pure and hybrid electric vehicles accounted for less than 1% of total sales volume in 2010, and alternative fuels only accounted for 3% of China's total on-road fuel consumption

*44. "新能源汽车：电解液自给自足，核心电解质国产化有待突破" [New Energy Vehicle: Electrolyte Self Sufficient, yet Nationalized Production Awaits for Breakthrough], PingAn Securities, September 30, 2011, finance.qq.com*
*45. "New Energy Vehicle Battery Market Research Report," Huachuang Securities, March 2, 2010*
*46. "Planning on Industrial Technology Innovation for the 12th Five Year Plan," MIIT, November 14, 2011*
*47. "汽车节能减排技术路线逐渐清晰" [Automobile Energy Efficiency and Emission Reduction Technology Roadmap Evolved Clearer], Huatai United Securities, November 15, 2011*
*48. Prado, Kharl, "Mercedes-Benz and BYD to Enter Chinese EV Market," Benzinsider, March 12, 2010, www.benzinsider.com*
*49. "十二五减排提速，安凯国V排放公交车占据先机" [Ankai's National Emission V Standard Public Fleet Takes Lead As the 12th Five Year Plan Speeds up Emission Reduction], Tom Motors, March 16, 2011, auto.tom.com*
*50. "2010年汽车产销及经济运行情况信息发布稿" [Information released on the 2010 vehicle production and sale in China], China Association of Automobile Manufacturers (CAAM), January 10, 2011, www.caam.org.cn*
*51. "中国汽车保有量最高可达4.5亿辆" [China's Auto Fleet May Reach 450 Million], China Cars, February 21, 2011, news.chinacars.com*

in 2009.[52] Even the most optimistic scenarios do not forecast EVs to account for more than 13% of sales by 2020.[53]

China's large and growing vehicle fleet is a major source of air pollution and greenhouse gas emissions. In 2009, heavy-duty buses and trucks were only 15% of the fleet, but emitted 86% of its oxides of nitrogen ($NO_x$) and 92% of its particulate matter.[54]

**Vehicle Emissions in China, million tons, 2009**




*Notes: Total fleet was 62 million vehicles in 2009 and 85 million vehicles in 2010; data refers to on-road motor vehicles with 4 or more wheels.*
*Source: "China Vehicle Emission Control Annual Report," Ministry of Environmental Protection, 2010*

Heavy-duty vehicles also contribute a disproportionate amount of other local pollutants, accounting for roughly half of carbon monoxide (CO) and hydrocarbons emitted from the fleet.[55] China does not currently track data on $CO_2$ emissions from vehicles, but based on typical fuel consumption and vehicle use data, heavy-duty buses and trucks in China likely emit roughly three times more $CO_2$ than light-duty vehicles.[56]

## Fuel economy standards push adoption of efficient drivetrain technologies

Following the introduction of fuel economy standards for light-duty vehicles in 2005, foreign automakers—which currently hold 70% of passenger car sales in China through local joint ventures (JVs)—brought more advanced technologies into China.[57] Domestic automakers, such as Chery, partnered with global design firms and boosted research and development (R&D). Currently, the majority of new car models in China feature some advanced drivetrain technologies, such as turbocharged engines with variable valve timing, and almost all automakers are now developing gasoline direct injection engines.[58] However, consumer price-sensitivity hinders the pace of uptake.

Market penetration for these technologies has lagged behind that of other countries, primarily due to cost. On the supply side, costs to upgrade are particularly high for

*52. Humphrey, John, et al., "Drive Green 2020: More Hope than Reality?" J.D. Power & Associates, November 2010, businesscenter.jdpower.com*
*53. "Study Powertrain 2020: China's ambition to become market leader in E-Vehicles," Roland Berger Strategy Consultants, July 2009, www.rolandberger.com*
*54. "China Vehicle Emission Control Annual Report," Ministry of Environmental Protection (MEP), 2010*
*55. Wagner, Vance, "Diesel Particulate Matter Control Strategies and Technologies in China," Vehicle Emission Control Center (VECC), November 10, 2010, baq2010.org*
*56. Wagner, Vance, "Developing a First-Ever National Mobile Source Emissions Inventory for China," VECC, MEP, 2008; Wang, M., et al., "Projection of Chinese Motor Vehicle Growth, Oil Demand and $CO_2$ Emissions through 2050," Argonne National Laboratory, December 2006, www.ipd.anl.gov; rough calculation based on data for vehicle miles traveled of different vehicle classes.*
*57. CGTI analysis*
*58. Wang, Zhao, "Fuel Economy Standards in China: Status and Challenges," China Automotive Technology and Research Center (CATARC): Bangkok, August 24, 2010, www.uncrd.or.jp*

domestic automakers, which need to invest, develop or buy technology. Upgrade cost is especially burdensome for low-end vehicles with smaller engines, a segment mostly targeted by local businesses.[59] On the demand side, while the majority of consumers are price-sensitive, many do not consider future savings from fuel economy when purchasing a car.[60]

## China's low-end heavy-duty market has minimal uptake of advanced ICE technology

Advanced engines and exhaust technologies face challenges, but simple improvements offer substantial benefits for heavy-duty trucks. In contrast to the light-duty market, domestic manufacturers dominate China's heavy-duty market, accounting for 90% of vehicle sales and 80% of diesel engine sales for buses and trucks.[61] These manufacturers focus mostly on the low-end segment to meet demand from China's low-margin transport industries, in which fleet operators usually buy inexpensive, undersized, low quality and dirty engines. Low engine quality can result in slower shipping time, higher fuel consumption and increased emissions.

Government policy promotes indigenous innovation in China's diesel engine market, but there are few concrete measures in this area. This lack of support decreases incentives for local diesel engine makers to invest in R&D of more advanced, efficient technologies.

## For the heavy-duty segment, emissions policies face challenges

China's increasingly stringent emission standards promote cleaner technology in the heavy-duty market, but challenges remain. Fuel economy standards for heavy-duty vehicles are still being developed.[62] The new 10% $NO_x$ reduction target in the 12th Five-Year Plan has implications for heavy-duty vehicles; however, diesel fuel quality presents a major challenge. State-owned oil companies have lagged in ensuring nationwide supply of low-sulfur diesel, fuel quality has hindered implementation of emission standards in China, and the Ministry of Environmental Protection (MEP) delayed implementation of Euro IV standards from 2010 to 2012.[63] Achieving Euro IV will be challenging for China: Europe has achieved this goal with 50 parts-per-million (PPM) sulfur diesel, whereas China may try to achieve the standard with 350 PPM sulfur diesel. Beijing, Shanghai and Guangzhou have been the exception, leading by

**Emission Standards and Fuel Supply Quality in China and Europe**

| | Year | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| China HDV standards | | | | Euro I | | | | Euro II | | | | Euro III | | | | Euro IV | | |
| Diesel supply | China | 2000/5000/10000 | | | | | 2000 | | | | | | | | 350 | | | |
| | Beijing | 2000/5000/10000 | | | | 2000 | | 500 | | 350 | | | | 50 | | | | |
| | Shanghai | 2000/5000/10000 | | | | | 2000 | | | | | | | 50 | | | | |
| | Guangzhou | 2000/5000/10000 | | | | 2000 | | | 500 | | | 350 | | | 50 | | | |
| | Europe | 500 | | | 350 | | | | | 50 | | | | | 10 | | | |

*Source: Fung, Freda, et al., "Overview of China's Vehicle Emission Control Program: Past Successes and Future Prospects," International Council on Clean Transportation, April 2011*

59. Tian, Dongmei, et al., "Study on the Fuel Economy Standards of Passenger Vehicles in China," CATARC, 2007
60. "2010年汽车产销及经济运行情况信息发布稿" [Information released on the 2010 vehicle production and sale in China], CAAM, January 10, 2011, www.caam.org.cn
61. "商用车破冰中国制造国际化" [Commercial Vehicles Break the Ice as Chinese Manufacturing Goes Global], 21st Century Business Herald, September 25, 2009, www.21cbh.com
62. Wang, Zhao, "Fuel Economy Standards in China: Status and Challenges," CATARC, August 24, 2010, www.uncrd.or.jp
63. "环保部调整机动车国四标准实施日期" [MEP Adjusts China IV Implementation Date], 中国工业报, February 15, 2011

implementing emission standards ahead of schedule and offering diesel supply with 50 PPM sulfur content.[64]

### Trucks can benefit from basic improvements

Considering the near-term market challenges for adoption of advanced engine and exhaust technologies, simple, low-cost general vehicle improvements and driver training are a near-term priority. A recent World Bank and Clean Air Initiative (CAI)-Asia pilot program in Guangzhou showed promising results through the use of improved tire and aerodynamics equipment packages on long-haul, heavy-duty trucks.[65] The tire packages included aluminium wheels, low-rolling-resistance tires and tire pressure monitoring systems; the vehicle aerodynamic equipment consisted of simple vehicle fittings which included nosecones, cabin fairings and trailer skirts. The study suggested that that broader use of these basic solutions can deliver significant fuel and emission savings with a payback period of less than four years. CAI-Asia is now expanding the program nationwide.

Foreign engine and truck manufacturers are also developing their services in China. The portfolio is based on general vehicle improvements and driver training. Scania, for example, offers driver training services to fleet operators in China. Scania asserts that a brief training course can help drivers cut fuel consumption by 10%, with no investment needed in vehicle modifications.

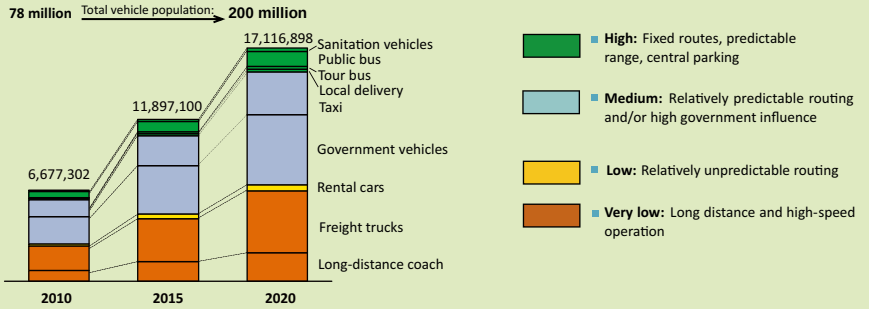
## Fleet Vehicle Electrification

### Opportunity Assessment Summary

**Electric vehicles (EVs) can offer more advantages to the fleet segment than the private consumer market, but China's fleet markets are too small and fragmented to meet 2020 EV policy targets.**

China's EV policy has centered on fleets from the beginning, with nearly all EVs currently deployed in China found in public sector fleets, such as buses and taxis. There are nearly 7 million fleet vehicles in China today, but fleet segments are fragmented and often lack characteristics that would make them likely to go electric. To achieve targets of 5 million new energy vehicles (NEVs) on the road by 2020, China will have to expand its efforts into the private consumer market and overcome obstacles, including high cost, unreliable battery technology, unclear business models for charging infrastructure, and protective subsidies.

**Fleet Vehicle Size and Likelihood of Electrification in China, million, 2010-2020**




*Notes: Assumes fleets will grow in proportion to China's total vehicle population, which MIIT predicts will reach 200 million by 2020; considers only grid-enabled EVs (PHEV and BEV), corresponding to vehicle deployment targets of 1 million in 2015 and 5 million in 2020.*

*Sources: "工信部预计2020年中国汽车保有量将超两亿辆" [MIIT Estimates China's Vehicle Population will Surpass 200 Million by 2020], Xinhua, September 5, 2010; China Statistical Yearbook 2010 (Beijing: National Bureau of Statistics, 2010); "政协委员：全国公务用车总量已达200多万" [CPPCC Official: Government vehicles nationwide exceed 2 million], Xinhua, March 9, 2011; "4月份全国机动车和驾驶人统计分析" [April Nationwide Motor Vehicles and Driver Statistical Analysis], Heilongjiang Traffic Police Net, May 13, 2011, www.hljjj.gov.cn; "At the wheel of Chinese car hire," Financial Times, April 12, 2011; "2.29b long-distance bus passengers during Spring Festival," Xinhua, March 11, 2011; CGTI analysis*

*64. Fung, Freda, et al., "Overview of China's Vehicle Emission Control Program: Past Successes and Future Prospects," International Council on Clean Transportation (ICCT), April 2011*

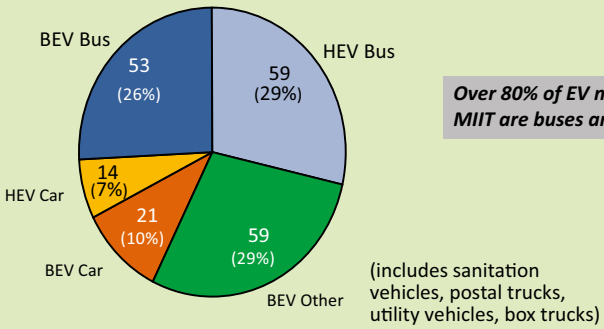
*65. "Guangzhou Green Trucks Pilot Project Final Report," Clean Air Initiative (CAI)-Asia Center, World Bank, June 2010, cleanairinitiative.org*

## Public sector fleets are leading China's EV and Natural Gas Vehicle (NGV) development

Policymakers in China recognized the advantages of fleets for EV and NGV development and expansion, and have designed EV and NGV initiatives focused on fleets in the public sector, primarily buses, taxis, municipal utility vehicles and other government-owned fleets. Aside from the inherent operational advantages over the private market, China's major consideration in targeting fleets is pragmatic, since public sector fleets are easiest for the government to manage.[66]

In 2009, the Tens of Cities, Thousands of Vehicles pilot program was launched in 13 cities and expanded to 25 cities by 2010, promoting EVs in public sector fleets and accounting for nearly all EVs currently on the road in China.[67] According to the Ministry of Industry and Information Technology (MIIT), of roughly 10,000 NEVs sold in 2010, only 800 were sold to individuals, while the remainder went to public sector demonstration fleets.[68] The program favors buses in particular, with central government subsidies of up to RMB 500,000 per bus, or upwards of RMB 1 million including matching local subsidies. By mid-2011, over 80% of MIIT approved EV models were buses and other fleet vehicles.[69]

**MIIT-Approved EV Models, 206 Total, June 2011**




***Over 80% of EV models approved by MIIT are buses and other fleet vehicles***

*Source: "Recommended Models for Energy-Saving and New Energy Vehicle Pilot Programs (Batches 1-21)," MIIT, June 2011*

## The vehicle fleet market is not uniformly suited to EV adoption

Of the 78 million vehicles on China's roads in 2010, 17.1 million (or 27%) could be classified as belonging to commercial and government fleets. The likelihood of EV adoption varies by segment and, of the 17.1 million, CGTI identified nearly 7 million fleet vehicles as potential targets for EV adoption.[70] The vehicle fleet market is highly fragmented and many fleet vehicles lack characteristics necessary for EV adoption.

- **Taxis:** China currently has over 1.2 million taxis, nearly ten times more than the roughly 150,000 taxis operating in the U.S.[71] In China, taxis are a large market and an easy target for government policy, since most taxi operators are either state-owned or licensed to operate only through close government connections.[72] From an operational standpoint, taxis are not ideal for electrification due to their unpredictable routing, long range, and nearly 24-hour operation from multiple shifts of drivers.

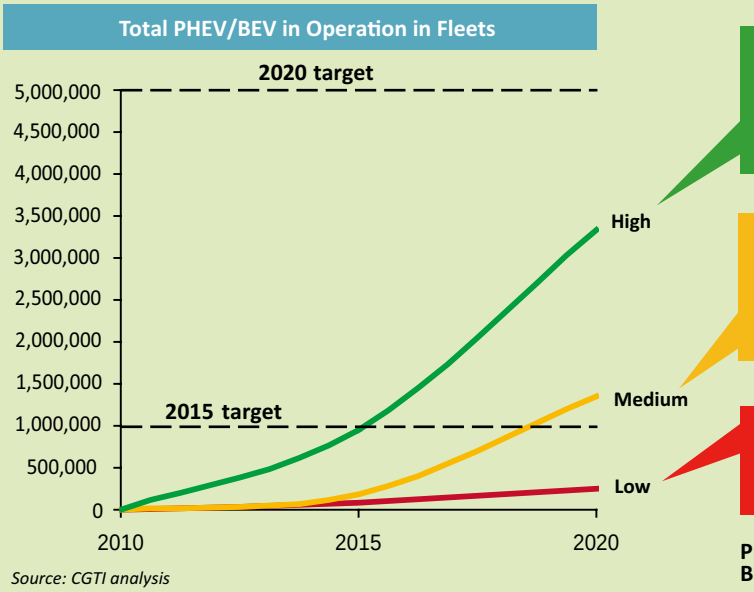


*66. CGTI analysis*
*67. "Electric Vehicles in the Context of Sustainable Development in China," U.N., May 2011*
*68. "私人购车800辆新能源车光靠补贴行不通" [800 EVs Sold to Private Consumers; New Energy Vehicle Subsidy Not Enough], Southern Metropolitan Daily, June 20, 2011, www.evtimes.cn*
*69. "Recommended Models for Energy-Saving and New Energy Vehicle Pilot Programs (Batches 1-21)," MIIT, June 2011*
*70. China Statistical Yearbook 2010 (Beijing: National Bureau of Statistics, 2010)*
*71. "4月份全国机动车和驾驶人统计分析" [April Nationwide Motor Vehicles and Driver Statistical Analysis], Heilongjiang Traffic Police Net, May 13, 2011, www.hljjj.gov.cn*
*72. CGTI interviews and analysis*

- **Government cars:** China has over 2 million government passenger vehicles, making this another easy target for policies to meet EV deployment goals.[73] However, these vehicles are most likely used as personal cars—including both commuting and general driving with no set hub—so operationally they are not very attractive for electrification that relies on centralized charging.
- **Rental cars:** The rental car market is a rapidly growing segment in China, but the top ten rental car companies only hold an 11% share of the fleet segment since the majority of rental car operators own a small number of vehicles.[74] This market is less attractive for EVs due to highly-variable routes and driver concerns about charging availability.
- **City buses, municipal sanitation vehicles and local delivery vans** are three classes of fleets in China that are most likely to go electric, due to their highly predictable routing and centralized overnight parking.

According to MIIT's Energy-Saving and New Energy Vehicle Industry Plan, China aims to have 5 million pure electric and plug-in hybrids on its roads by 2020.[75] Even under the most optimistic scenarios, however, China's current focus on public sector fleets is unlikely to be sufficient to meet this goal.

**China's Fleet Electrification Scenarios**




*Source: CGTI analysis*

- Near-term technology and business model breakthroughs allow substantial uptake in the next five years, continuing through 2020
- Government support pushes through moderate EV uptake by 2015
- By 2020, technology improvement allows commercialization
- With few breakthroughs, EVs continue to rely on relatively small-scale government policies

**PHEV:** Plug-in Hybrid Electric Vehicle
**BEV:** Battery Electric Vehicle

As technology matures and EV ownership costs grow more economical, fleets will likely be the first to benefit. Yet to achieve deployment of the scale envisioned by policymakers, China will need to address challenges that have thus far kept EVs limited to small-scale demonstration programs.[76]

## EVs are not yet economical, even for fleet owners

Cost is probably the most important factor preventing EVs from taking off in China. Fleet owners, which expect short payback periods on their investments, continue to report that costs are too high. Even with subsidies, the electric BYD taxis in Shenzhen cost 80% more than a conventional model.[77] And TNT Express estimates that for an

*73. "政协委员：全国公务用车总量已达200多万" [Chinese People's Political Consultative Conference (CPPCC) Official: Government vehicles nationwide exceed 2 million], Sina, March 9, 2011, news.sina.com.cn*
*74. Waldmeir, Patti and John Reed, "At the wheel of Chinese car hire," Financial Times, April 12, 2011, www.ft.com*
*75. "节能与新能源汽车产业规划 征求意见稿全文" [Energy-saving and New Energy Vehicle Industry Plan Draft for Public Comment, Full-Text], Netease Auto, September 21, 2010, auto.163.com*
*76. CGTI analysis*
*77. Yan, Fang and Don Durfee, "Electric Cars Remain Tough Sell in China," New York Times, July 3, 2011, www.nytimes.com*

ownership period of 5-6 years, total costs of ownership (TCO) for their electric Dongfeng delivery vans in Shanghai will be 70% higher than that of conventional alternatives. According to a recent World Bank report, the TCOs of EVs in China are not expected to become comparable with that of conventional vehicles until 2017.[78]

Aside from their cost, EV batteries continue to face reliability and safety issues. According to some reports, batteries in some of China's existing EV fleets, such as the Beijing Olympic buses and the Shenzhen taxis, only last two years before needing to be replaced.[79] Meanwhile, the electric taxi that caught fire in Hangzhou in April 2011 called attention to safety concerns that continue to negatively affect consumer confidence.

### Infrastructure is difficult to build, and operation models are still unclear

One unexpected challenge has been securing land for EV charging infrastructure. Industry players report that in developed urban areas, most available real estate is being reserved for high-end developments, while few decision-makers are willing to give up land for risky investments, such as charging stations.[80]

Meanwhile, proper operating models for EVs are still unclear. Both of China's grid companies are teaming up with battery swap service providers to build battery swap stations and standardize vehicle configurations. For instance, State Grid partnered with China National Offshore Oil Corporation (CNOOC) in March 2011 to develop battery swap station technology through its joint venture with Potevio, and China Southern Grid partnered with Better Place in April 2011.[81] Autos appear resistant to this model, however, preferring direct control over the battery, which currently accounts for half the cost of the vehicle and is the core determinant of its performance.

### Current government subsidy policy limits economies of scale

Government subsidies are the most powerful stimulus behind China's EV market, but limitations to the subsidy policy have hindered efficient market growth. To stimulate the local economy, many regional governments have limited their allocation of subsidies to purchases from local manufacturers only. For example, to receive a subsidy, a fleet buyer in Beijing must buy vehicles from a Beijing-based manufacturer.[82] This policy prevents regional industries from specializing, keeping production volumes low and costs high.

## Electric Vehicles (EVs) and Charging Infrastructure

### Opportunity Assessment Summary

**Many companies are poised to enter the charging market pending clarification of government vehicle and charging policies.**

In April 2011, the long-awaited Energy Saving and New Energy Vehicle (NEV) Development Plan (2011-2020), which envisions 5 million NEVs by 2020 and RMB 100 billion in investment, was submitted to the State Council for final approval. Formal release of the plan has been delayed by a year due to disagreements between the Ministry of Industry and Information Technology (MIIT) and the Ministry of Science and Technology (MOST). The government has pushed electrification of public vehicles, particularly transit buses, through its Tens of Cities, Thousands of Vehicles program, but the its impact is minor so far. As for the electrification of private vehicles, existing incentives have done little to convince private consumers to buy electric vehicles (EVs). Policies to encourage technology transfer from foreign to local carmakers have received

**Policies to encourage technology transfer from foreign to local carmakers have received mixed reactions.**

*78. "The China New Energy Vehicles Program: Challenges and Opportunities," World Bank and PRTM, April 2011, siteresources.worldbank.org*

*79. "北京试点电动汽车更换电池 标准统一成难题" [Beijing Pilot EVs Swap Batteries: Unification of Standards Poses Challenge], Xinhua, January 16, 2011, news.xinhuanet.com*

*80. CGTI Cleaner Transportation Working Session, June 27, 2011*

*81. "Better Place, China Southern Grid Sign Strategic Agreement Centered on Battery Switch Model," Better Place, April 27, 2011, www.betterplace.com; "State Grid Corp of China says to jointly tap EV market with China National Offshore Oil Corporation (CNOOC)," Reuters, March 22, 2011, www.reuters.com*

*82. CGTI interview*

mixed reactions. State Grid and Southern Grid have taken the lead in the development of the battery charging segment by building infrastructure across the country. Oil companies, original equipment manufacturers (OEMs), professional services companies and even real estate developers are interested in the charging market, but are cautiously awaiting the government's ruling regarding charging infrastructure.

### Differences within China's government delayed release of the NEV Development Plan

**The Chinese government will invest RMB 100 billion over the next 10 years to support NEV research, development and deployment to make China the world's leader.**

The NEV Development Plan drafted by MIIT outlines the government's strategy to invest in core technologies and to build a strong and competitive NEV industry. The government plans to invest around RMB 100 billion over the next 10 years to support NEV research, development and deployment to make China the world's leader in the field.[83] The investment funds are earmarked for research and development (R&D) and industrialization, pilot programs, hybrid electric vehicles (HEVs) and other energy-saving vehicles, EV core components, and pilot city infrastructure. Most investment funds will likely be allocated towards industrialization and R&D to address China's past weaknesses in terms of automation and new technology development.

In addition to expanding NEV sales, the plan targets reduced battery cost, increased battery energy density and expansion of pilot cities. By the end of the 12th Five-Year period in 2015, China intends to have an annual production capacity of 1 million NEVs, 50% of which will be plug-in electric vehicles (PEVs) and plug-in hybrid electric vehicles (PHEVs).[84]

MOST's 12th Five-Year Plan on Electric Vehicles had an understated launch in May 2011. It has a total funding of RMB 780 million and will focus on the development of the small EV industry.[85] The Plan's targets include 1 million EVs on the road by 2015, 70 EV demonstration cities by 2015, battery performance improvements, and 50% battery cost reductions by 2015 from current levels.

Classification of HEV as an NEV is currently being reviewed by MIIT. MIIT is considering reclassifying HEVs as energy-saving vehicles rather than new energy vehicles because of the relative maturity of the technology. Interviews with industry experts suggest that a change in definition might affect the amount of support and subsidies the HEV industry receives.

Private EV uptake has also been slow even though the government has offered subsidies and exemptions from vehicle tax and license plate lotteries. Interviews suggest that the low supply of EVs, lack of charging infrastructure and high costs are major obstacles preventing consumers from buying EVs.

### Technology transfer policies provoked mixed reactions, but production is rising

To enter China's EV market, foreign carmakers must share EV technologies with their Chinese partners and help them create local car brands. Domestically manufactured NEVs—including EVs, PHEVs and fuel-cell cars—qualify for national and municipal subsidies. Internationally-manufactured NEVs are not eligible for subsidies unless the producer has transferred important technologies to a joint venture in China. Foreign carmakers, such as GM and Nissan, responded by forming joint ventures with local carmakers, and Toyota has built a technical center in China in preparation for transfer of EV production.[86] However, foreign carmakers are still cautious with regard to the degree of technology they are willing to share.



*83. Li, Fangfang, "China plans to take lead in new-energy vehicles," China Daily, April 8, 2011, www.chinadaily.com.cn*
*84. Awater, Laurenz, "China's new-energy vehicle plan submitted for final approval," Xing, April 22, 2011, www.xing.com*
*85. Geng, Huili, "Science and Technology of electric cars 'second five' quietly began," The Economic Observer, May 20, 2011, www.eeo.com.cn*
*86. Shirouzu, Norihiko, "Toyota to Share Technology in China," The Wall Street Journal, October 23, 2011, online.wsj.com*

OEMs in China are starting to position their companies in the EV market. Major OEMs are offering different models to capture market share and are gradually increasing funding of their EV business segments to accelerate R&D and boost production capacity. Shanghai Automotive Industry Corporation (SAIC) and First Automobile Works (FAW) each plan to invest more than RMB 1 billion from now until 2015, while other OEMs have planned to invest around RMB 0.5 billion each during the same time period. Major Chinese battery makers, Lishen, Wanxiang and BYD, also unveiled their plans to invest around RMB 1-2 billion in 2012, mainly to increase their automotive battery production.[87]

## Companies are eager to build charging infrastructures despite the challenges

China's EV battery charging infrastructure is still in its early stage and faces a variety of economic, industrial, technology and regulatory issues. However, despite design, construction, operation and use challenges, grid and oil companies are keen to enter the market.

**State Grid plans to construct a total of 2,351 stations with 220,000 charging posts by 2015.**

State Grid and Southern Grid have drafted bold investment plans for the construction of battery charging and swapping stations. As of October 2011, State Grid has completed 87 stations with 7,031 charging posts.[88] State Grid plans to construct a total of 2,351 stations with 220,000 charging posts by 2015. Southern Grid has partnered with Better Place on an EV demonstration project in Guangzhou and built charging stations in Shenzhen for automaker BYD in 2011.[89] As of December 2011, Southern Grid has 14 charging stations in its network with 2,901 charging poles in operation.[90] Southern Grid plans to build stations in key cities until 2015 and expand to smaller areas depending on the development of the EV industry.[91]

Both CNOOC and Sinopec have made significant investments in EVs and related infrastructure. In 2010, CNOOC formed a joint venture with China Potevio to develop NEVs, batteries and supply systems.[92] It also invested in Tianjin Lishen Battery to manufacture lithium batteries for EVs and is planning to build charging stations. Sinopec formed a joint venture with a Beijing-based technology company to develop charging stations, and plans to invest RMB 875 million to build 175 petrol-EV charging multi-service stations across the country.[93] However, obtaining grid approvals for oil company projects in Beijing and Shenzhen have caused problems, prompting Sinopec to urge State Grid to do more to open the market.[94]

## Debate continues over the right charging model for EV infrastructure

The issue of which charging model to adopt—direct charging versus battery swap—remains unsettled. Supporters of each model have presented various arguments on the advantages and disadvantages of each. Grid companies tend to support the battery swap model, seeing it as a potential new source of revenue. In contrast, OEMs advocate the direct charging model, which enable them to retain control over the battery pack. Batteries are main determinants of an EV's performance, and there are fears that battery design might be taken on by grid companies if the battery swap model is implemented.

Some industry participants believe the models are complementary rather than mutually exclusive. Direct charging could be a primary charging option for private cars because they usually have sufficient parking time; battery swap can be a supplementary option if users need fully-charged batteries right away. Vehicles with fixed routes or



*87. "中外车企新能源车投资对比" [Comparison between the investment in new energy vehicle among international OEMs and domestic OEMs], Sohu Auto, auto.sohu.com, accessed on August 20, 2010*
*88. "电动汽车充电" [EV Charging], China Southern Power Grid, www.csg.cn, accessed on October 31, 2011*
*89. Bradsher, Keith, "In China, Power in Nascent Electric Car Industry," New York Times, December 26, 2011, www.nytimes.com*
*90. "China Southern Power Grid and Better Place open EV battery switch experience center in Guangzhou," Green Car Congress, December 12, 2011, www.greencarcongress.com*
*91. "Electric vehicles: Who will charge?" Global Auto Parts, October 25, 2011, www.oemol.com*
*92. Xiao, Wan, "Oil companies plan charging stations," China Daily, March 3, 2010, www.chinadaily.com.cn*
*93. "China Electric Vehicle Forum 2012," Pike Research, www.pikeresearch.com, accessed on February 7, 2012*
*94. CGTI CT and EPI Joint Working Session, November 7, 2011*

those in constant use, such as public buses and other public vehicles, may consider battery swap as a primary charging option, supplementing with direct charging once vehicles are parked in their garages.

**Direct Charging and Battery Swap Pros and Cons**

| Model | Charging Locations | Pros | Cons |
|---|---|---|---|
| **Direct Charging** | ▪ Charging spot (parking lot/or gas station)<br>▪ Home | ▪ Easy operation<br>▪ Stable and sufficient power supply<br>▪ Flexible charging locations | ▪ Long charging period required<br>▪ Shortened battery lifespan<br>▪ Demand pressure on grid<br>▪ Immaturity technology for fast charging<br>▪ Insufficient home power capacity |
| **Battery swap** | ▪ Battery swap station | ▪ Permits peak shaving<br>▪ Fast operation<br>▪ Battery as grid storage (V2G)<br>▪ Lower EV price for consumer<br>▪ Less harmful to battery lifespan | ▪ Complex operation<br>▪ Battery standardization<br>▪ More batteries and real estate needed |

*Source: "Business Models and Public Policies for EV Charging Stations in China," (Beijing, China: China Research Center for Public Policy, 2010)*

### State Grid's initial foray into vehicle-to-grid (V2G) technology

Though V2G technology at a pilot stage, grid companies are paying close attention to the topic. V2G is an integrated network between the grid and EVs. During hours of low power consumption, energy from the grid is stored in grid-connected batteries and vehicle owners are charged according to prevailing tariffs. When needed, electricity from the battery of parked, grid-connected cars flows back to the grid and vehicle owners are reimbursed accordingly.

**V2G technology is currently in its nascent stages and only a few countries, such as the U.S., China, Denmark and England, are actively engaged in research.**

V2G technology is currently in its nascent stages and only a few countries, such as the U.S., China, Denmark and England, are actively engaged in research. The research mainly includes the economics of grid access for EVs, distributor markets and support for renewable energy through V2G. The few pilot projects that exist around the world are mainly driven by government policy and the EV industry.

In China, State Grid's RMB 4 trillion Strong and Smart Grid investment plan could accelerate the V2G market in China. In 2010, State Grid demonstrated a V2G technology that enables an exchange of electricity between an EV and a charging stand,[95] onboard controller area network for car-charger-communication, and rapid charger that supports 30 kW DC, with 200-350V and up to 100A capacity.[96] An official affiliated with State Grid cautioned, however, that full-fledged introduction of V2G technology is dependent on the adoption of EVs.

## The Path Ahead

As the sector evolves, participants in the China Greentech Partner Program will continue to collaborate on additional opportunity areas. The first topic in 2012 covers the clean fuel sector, including biofuel for road transportation, alternative fuel application in fleets, and liquefied natural gas (LNG) use in heavy duty trucks and other commercial vehicles. Other topics may include EV battery technology, fuel efficiency and emission reduction solutions for commercial vehicles, light-duty electric vehicle (LDEV) development, HEV development, local EV markets and charging infrastructure. CGTI will also continue to track the overall evolution of China's Cleaner Transportation sector.

*95. "China: State Grid demonstrates Vehicle-to-Grid (V2G) tech," Telematics News, May 6, 2010, telematicsnews.info*
*96. Jing, Zhaoxia and Tongke Zhong, "V2G 研究综述" [Review of Research on V2G], School of Electric Power, South China University of Technology, July 19, 2011*

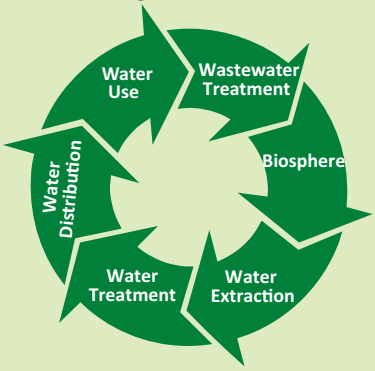
# Clean Water

**To address a dire water situation, which includes low water resources per capita, severe pollution and uneven distribution, China has set water protection as a priority over the next decade—driving strong private sector interest.**

China's water resources are scarce, poorly distributed and heavily polluted. In 2011, severe droughts and floods across China caused over RMB 230 billion in economic losses and led to hardship for 114 million people. Water scarcity alone costs China several hundred billion RMB every year. To respond to the country's water issues, in January 2011, the State Council announced a RMB 4 trillion water investment plan for the next decade, and the government's 12th Five-Year Plan introduced ambitious national targets on water efficiency and pollution control. Given government support, private equity and venture capital funds invested eight times more capital in the water sector in the first four months of 2011 than the whole of 2010.[1] State-owned enterprises (SOEs) and domestic companies raised capital and pursued acquisitions, while foreign firms faced a challenging environment locally. Policy trends and urgent needs are creating market opportunities for the private sector across the water value chain, including municipal and industrial wastewater treatment and sludge treatment and disposal.

## Clean Water Sector Definition

CGTI defines **Clean Water** as all activities within the economic water cycle: water extraction, treatment, distribution, use, and wastewater treatment and discharge. Clean Water technologies include those related to water quality measurement or monitoring, river basin management, water treatment and efficient point-of-use equipment.




- **Water Extraction:** Provision or extraction of water resources from the biosphere to original water rights holders
- **Water Treatment:** Treatment of raw water to meet potable or non-potable uses
- **Water Distribution:** Distribution of treated water to end users
- **Water Use:** Consumption of water by agricultural, industrial, commercial or residential users
- **Wastewater Treatment:** Collection of contaminated water discharged after use and treatment for secondary consumption or safe release into the environment

*Source: CGTI analysis*

*Senior Analyst Julien Bédin* (朱立安) *led the writing of this chapter with support from contributing writer Director of Research Analytics Anders Hove* (侯安德) *based on 2011 strategic research conducted by Analysts Amy Wan* (万婧), *Jing Wang* (王静) *and Manager Lixuan Zhou* (周丽璇).

1. *"清洁技术投资事件数据库" [Clean Technology Deals Database], PEdaily, zdb.pedaily.cn*

This chapter begins by providing an overview of Clean Water sector developments since the publication of the *China Greentech Report 2011*, and highlights a range of commercial opportunities for industry stakeholders. The chapter concludes by summarizing three Opportunity Assessments developed by the China Greentech Initiative (CGTI) in collaboration with Partner companies and organizations during 2011:

- Sludge Treatment and Disposal Markets in China
- Industrial Wastewater Treatment Opportunities in China
- Greywater System Adoption in China

These summaries represent high-level findings of the detailed proprietary research and analysis developed in collaboration with and for the organizations participating in the 2011 China Greentech Partner Program. The chapter concludes with an outlook on additional opportunities and issues in the Clean Water sector that CGTI plans to explore during 2012.

**Water disasters in China caused more than RMB 230 billion in economic losses for 114 million people in 2011.**

## Market Update

### China's dire water situation is worsening

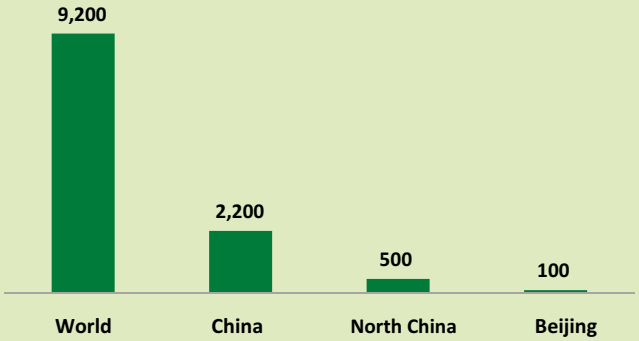
While severe floods were affecting parts of China from June to September 2011, the Yangtze River region suffered its worst drought in 50 years.[2] Floods across 12 provinces in central and south China caused direct economic losses exceeding RMB 43 billion by mid-year.[3] Summer droughts in the southwest cut off drinking water to 12 million people and affected 6 million hectares of farmland.[4] Overall, water disasters caused more than RMB 230 billion in economic losses and hardship for 114 million people in 2011.[5] Though floods and droughts are a common occurrence in China, the combination illustrates the phenomenal challenges the country must overcome.

China's per capita freshwater resources are scarce at around 2,200 cubic meters ($m^3$) per capita versus the world average of 9,200 $m^3$.[6] Water is also unevenly distributed with 80% of available resources located south of the Yangtze River.[7] To make matters worse, China's water is heavily polluted: one-fifth of the country's river water is unsuitable for any use.[8] Water scarcity is a national issue, yet local situations vary greatly. The Northern provinces—such as Beijing, Tianjin and Hebei—have the lowest water resources per capita.[9] Water resources per capita have decreased by roughly 60% over the past 50 years and are expected to decline another 10% by 2025.[10] Pollution from industrial and agricultural sources also reduces available resources for use: up to 42% of China's 140,000 kilometers of rivers are only suitable for industrial use and 22% are unsuitable for any use.[11]

*2. "Central China drought worst in more than 50 years: reports," The China Post, May 26, 2011, www.chinapost.com.tw; "Worst drought in 50 years plagues Yangtze River," China Daily, May 23, 2011, europe.chinadaily.com.cn*
*3. "China lost US$ 6.65 bn due to floods in 2011," Inewsone, June 30, 2011, www.inewsone.com*
*4. "Drought leaves over 12 million people short of drinking water in SW China," Xinhua, September 8, 2011, news.xinhuanet.com*
*5. Kang, Weixin, "2011年全国洪涝旱灾造成经济损失超2300亿" [The economic loss of droughts and floods in China in 2011 is over RMB 230 billion], China Value, February 5, 2012, www.chinavalue.net*
*6. McKee, Colin, "Investing in Asia's Water Sector: Turbulent Rush through Opening Floodgates," ASrIA, February 2007, p. 2*
*7. 80% refers to average annual internal renewable surface water resources as indicated in the United Nations Food and Agriculture Organization (U.N. FAO) Aquastat database, "China," 2010, www.fao.org.*
*8. "Industrial Pollution on The Rise in China: Minister," Institute of Public and Environmental Affairs, November 3, 2011, www.ipe.org.cn*
*9. "Severe water shortage hits China's capital," People's Daily, May 18, 2011, english.people.com.cn; Jiang, Liping, "How to combat water scarcity in China," China Daily, March 3, 2011, www.chinadaily.com.cn*
*10. Wright, Geoff, "Recent Advances in Water Resources Development and Management in Developing Countries in Asia," Asian Development Bank, Asian Water Development Outlook 2007 Discussion Paper, 2007*
*11. "Industrial Pollution on The Rise in China: Minister," Institute of Public and Environmental Affairs, November 3, 2011, www.ipe.org.cn*

## Water Scarcity in China

### Water Resources per Capita, m³, 2009



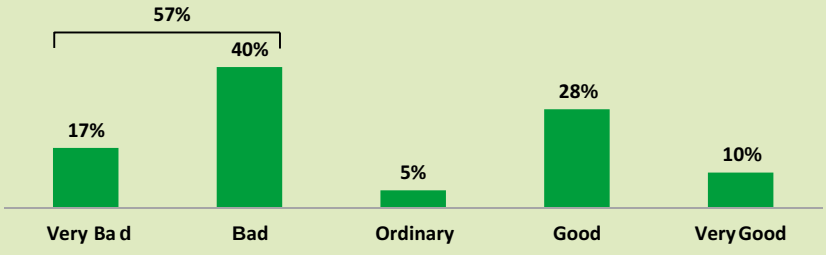

### Water Resources per Capita, m³, 2007


*Sources: China Statistical Yearbook 2010 (Beijing: National Bureau of Statistics, 2010); Carmody, Lucie, et al., Water In China, Issues for Responsible Investors: Water in China (Responsible Research, Feb. 16, 2010); Powell, Simon, et al., Falling up! Water pricing must meet true costs (CLSA University Blue Books, China Utility, May 15, 2010); "在"再生"中突破困局 北京"中水"发展调查" [Reuse as a solution to Beijing's severe water situation, survey on greywater development], Xinhua Net, November 3, 2011, news.xinhuanet.com; Browder, Greg, et al., Stepping up: Improving the performance of urban water utilities (World Bank, 2007, xix)*

The actual quality of China's water resources is a matter of uncertainty. In February 2010, regulators discovered that chemical oxygen demand (COD) levels—a measure of organic pollution in surface waters—were more than two times higher than previously measured due to the inclusion of pollution from agricultural use.[12] Results of the country's first national water census, involving over 800,000 surveyors, are expected to be publicly released in the second half of 2012.[13] Previous estimates from the Ministry of Land and Resources (MLR) in 2010 indicate that over half of the groundwater monitored in 183 major cities failed to meet standards for drinking water.[14]

**Over half of the groundwater monitored in 183 major cities in 2010 failed to meet for drinking water standards.**

### Underground Water Quality in 182 Major Chinese Cities, 2010




*Source: Ministry of Land Resources, 2010*

## State Council emphasized water issues in 2011

The State Council, the nation's highest policy body, emphasized the country's dire water situation in January 2011 by dedicating the Central Number One Document

*12. "China says water pollution double official figure," China Daily, February 10, 2010, www.chinadaily.com.cn*
*13. Liang, Chao, "China to launch first national water census," China Daily, March 18, 2011, www.chinadaily.com.cn; Jin, Zhu, "National Water Census Streams Into Action," China Daily, December 20, 2011, www.chinadaily.com.cn*
*14. Wang, Qian and Jian Li, "Groundwater gets worse, land agency says," China Daily, October 21, 2011, www.chinadaily.com.cn*

entirely to water issues.[15] More details were included in the Central Number Three Document released in January 2012.[16] These major policy documents describe a 670 billion $m^3$ cap on annual water consumption by 2020, and 700 billion $m^3$ by 2030, versus 599 billion $m^3$ used in 2010. Focus areas include water conservation, rural water access, water efficiency in industries, efficient crop irrigation, water reuse, droughts and flash-floods prevention. For instance, water consumption based on units of industrial output and units of GDP (per RMB 10,000) should both decrease by 30% between 2010 and 2015, and the former be contained to 65 $m^3$ by 2015 and 40 $m^3$ by 2020. The irrigation efficiency coefficient, a measure of the irrigation system's efficiency, is targeted to reach 0.53 by 2015, 0.55 by 2020 and 0.6 by 2030. The government will prevent the establishment of new agricultural and industrial projects in regions where local groundwater resources are overutilized. Water efficiency targets create demand for water pipeline leakage reduction, brackish water treatment, seawater desalination, rainwater collection and wastewater reuse. The government also calls for reforms to water prices for industrial, commercial and urban residential customers.

Two months later, the State Council and the National Development and Reform Commission (NDRC) released China's 12th Five-Year Plan, setting out national targets for water efficiency and pollution control from 2011 to 2015. The Plan calls for further reduction in COD by 8%—China achieved an actual reduction of 12.5% under the previous Plan—and introduces new targets for reducing ammonia nitrogen and industrial water use per unit GDP and industrial output.[17] Five heavy metals—arsenic, cadmium, chromium, lead and mercury—are targeted in the 12th Five-Year Plan for Integrated Control of Heavy Metal Pollution in an unprecedented blueprint to reduce water and soil pollution from industries.[18]

### Public and private capital is flowing into the sector

Central regulators announced in 2011 the largest ever investment allocations to the sector. In the same year, the Agricultural Development Bank of China (ADBC) increased lending to water projects. Financial investors also actively pursued investment opportunities in water companies and infrastructure projects.

The Central Number One Document allocated RMB 4 trillion to water resources conservation efforts over the next decade—on an annual basis, this is double the amount spent in 2010, and 15% more than in 2011.[19] Central and local governments and state-owned enterprises (SOEs) will supply 90% of funding, with the remainder provided by the private sector.[20] Water conservation projects, rural water access, efficient crop irrigation and water risk mitigation—including droughts and flash floods—will receive the bulk of investment. The policy's practical steps to finance water projects include requiring local governments to set aside a minimum of 10% of their revenue accrued from land sales for water resource protection projects. Some provinces are doing more: Shandong has announced plans to raise the allocation to 20%. Overall, Chinese media report that up to RMB 80 billion per year could be raised from this land transaction fee.[21]

**The Central Number One Document allocated RMB 4 trillion to water resources conservation efforts over the next decade.**

An October 2011 speech from Zhou Xuewen, Chief Planner at the Ministry of Water Resources (MWR), revealed more details about the Ministry's planned funding for the remainder of the 12th Five-Year Plan period. Out of the planned RMB 1.8 trillion budget, 38% is allocated to flood and drought prevention, 35% to water supply works, 20% to rural water and the remaining to soil conservation and eco-restoration. Total allocation to water conservancy projects in the previous Plan was only RMB 700 billion—or RMB 140 billion a year. The share of water resource works—including rural drinking



*15. "2011年中央一号文件(全文)" [State Council 2011 Central Number One Document], State Council, January 2011*
*16. "国发〔2012〕3号: 国务院关于实行最严格水资源管理制度的意见" [State Council 2012 Central Number Three Document: Opinion on Implementing the strictest Water Resources Management System], January 2012*
*17. "我国国民经济和社会发展十二五规划纲要 (全文)" [China's 12th Five-Year Plan for People's Economy and Social Development (Full Text)], State Council, National Development and Reform Commission (NDRC), March 17, 2011, news.sina.com.cn*
*18. "重金属污染综合防治规划(2010-2015年)" [China's 12th Five-Year Plan for Integrated Control of Heavy Metal Pollution (2011-2015)], Ministry of Environmental Protection (MEP), April 2011*
*19. Liang, Chao, "Government raises record funds to save water," China Daily, January 31, 2012, www.chinadaily.com.cn*
*20. China Greentech Initiative (CGTI) analysis and Partner interviews*
*21. Liang, Chao, "Government raises record funds to save water," China Daily, January 31, 2012, www.chinadaily.com.cn*

water, water diversion, small- to medium-sized reservoirs improvements, water-saving irrigation and solutions—increased to 55%, while the shares of hydropower and soil conservation projects decreased.[22]

**The initial public offering of county-level SOE Jiangsu Jiangnan Water in March 2011 attracted a total of RMB 1.1 billion in investments.**

Agricultural Development Bank of China (ADBC) increased its funding of water projects by 23% in 2011 to exceed RMB 30 billion. It financed the expansion of water storage capability by 1.2 billion $m^3$, the improvement of 1.5 million hectares of irrigated land, the excavation of 1,330 kilometers of rivers and the expansion of drinking water supply to 6 million more residents.[23] The bank plans to provide RMB 30-40 billion each year through 2015 to be used mainly for rural land remediation and water projects, farmland irrigation, flood prevention, drinking water resources management, soil and water conservation, and water use efficiency.[24]

Aside from increased public funding to water projects, private sector investments grew too. For instance, financial investors were very active in China's water sector in 2011. Private equity and venture capital (PE/VC) investments increased dramatically from US$ 50 million in 2010 to US$ 400 million in the first four months of 2011. In March, domestic fund CDH Investment announced plans to take Singapore-based membrane manufacturer and plant operator Sinomem Technology Ltd. private for US$ 280 million.[25] In May, Japanese financial group ORIX Corp. purchased a 14.5% stake in China Water Affairs Group, a water utility company, for US$ 103 million.[26] In August, U.S. private equity pioneer Kohlberg Kravis Roberts (KKR) invested US$ 114 million in convertible bonds issued by technology supplier and plant operator United Envirotech.[27] Private investors also participated through the domestic equity capital markets. The initial public offering (IPO) of county-level SOE Jiangsu Jiangnan Water Co., Ltd. in March 2011 attracted a total of RMB 1.1 billion investments indicating strong investor interest in the sector.[28] At least 30 other water companies have taken steps to go public; currently, there are 19 publicly-listed companies. As one provincial-level water utility manager noted, "A county-level water company can list on public markets, so why can't we?"[29]

After decades of underinvestment in China's water sector, these large allocations by both public and private sources are a positive trend to finance the protection and remediation of the country's water resources. Where in the past decade large foreign companies gained local market access by providing capital at levels unmatched by their local counterparts, China's water markets have become more competitive financially and operationally.

## Competition is increasing

China's water industry is increasingly becoming competitive with new entrants seeking profit opportunities created by strong government support. Established participants are expanding across the water value chain. SOEs have extended their market reach, partly via acquisitions. Domestic private companies are closing the technology gap and are benefiting from strong local market access; foreign entities are facing more challenges than in the prior decade.

In 2011, companies from various backgrounds announced plans to enter the water industry. For example, Joyoung, a household appliance company, purchased

*22. Zhao, Jianhua, "水利部：今后五年中国水利投资将达1.8万亿元" [Ministry of Water Resources (MWR): Water investment will reach RMB 1.8 trillion in next 5 years], China News, October 12, 2011, finance.qq.com; Liang, Chao, "Government raises record funds to save water," China Daily, January 31, 2012, www.chinadaily.com.cn; CGTI analysis*

*23. "Agricultural Development Bank of China (ADBC) Annual Report, 2010," ADBC, 2010; Huang, Zhaowu, "农民日报：农发行将发放290亿元信贷支持水利项目" [ADBC is about to lend RMB 29 billion to water projects], ADBC, November 29, 2011, www.adbc.com.cn*

*24. "ADBC lends RMB 15.5 billion to water facilities in H1," Xinhua, July 26, 2011, news.xinhuanet.com*

*25. Master, Farah and Samuel Shen, "Analysis - Investors chase big catch in China's muddy waters," Reuters, April 21, 2011, www.reuters.com*

*26. Kwok, Donny, "China Water Affairs sells 14.5 % stake to Orix at premium," Reuters, May 19, 2011, www.reuters.com*

*27. Aldred, Stephen, "KKR invests US$ 114 million in United Envirotech convertible bonds," Reuters, July 31, 2011, www.reuters.com*

*28. "Listings line-up," IFRAsia, IFR Asia 688, March 12, 2011, www.ifrasia.com; Master, Farah, "Chongqing Water makes a big splash on Shanghai debut," Reuters, March 29, 2010, www.reuters.com*

*29. "30家水企争上市：资本化幻梦商业模式创新拷问" [30 water companies compete for equity listing: Fantasy of capitalism or test of innovative privatization], Shanghai Securities Journal, December 13, 2011, news.chinaventure.com.cn*

intellectual property from domestic water appliance-maker Hai Lang Xing to establish its own water business.[30] A group of real estate developers led by Dalian Wanda Group Co., Ltd. and electronics giant Lenovo plan to invest RMB 11 billion in a 10 million $m^3$ mineral water project, the largest of its kind in China.[31] Chengdu Xingrong Investment, a chemical manufacturer, will commission its first sludge treatment plant early 2012 in Chengdu.[32] The emergence of new market players raise concerns given that plants run by companies with limited industry experience may have caused severe water pollution in the past.

SOEs have also expanded their market presence since the country's 2008-2009 RMB 4 trillion economic stimulus program.[33] In April 2011, Beijing Capital Co., Ltd., a Beijing municipality-owned enterprise with projects in 34 cities and daily treatment capacity of 12.3 million $m^3$, announced plans to invest up to US$ 38.5 million in New Environmental Energy Holdings Ltd.— a holding company with interests in waste treatment, waste-to-energy (WtE) operations and textile manufacturing. China Water Investment Group Corp. purchased a stake in Shanghai Environmental Protection Group Co., Ltd. (SEPG), which is involved in environmental projects, urban wastewater and urban solid waste treatment, and sewage pipeline design and installation.[34] However, SOEs also face limitations: according to a manager at a Beijing-based public sector consultancy, "Most of the managers in state-owned companies are former government officials with little experience in the water industry. This makes the water companies very inefficient in providing water services and improving transparency."[35]

Domestic private companies are increasingly becoming competitive. They benefited from the central government's push to involve the private sector in the country's infrastructure development, and they have more diverse funding sources for investing in technology or winning projects. A few, such as Origin Water, have even seen their market capitalizations exceed those of well-established water SOEs. 2011 also gave industry watchers a glimpse of their potential in international markets. Sound Global Ltd. signed its first international contract—valued at RMB 562 million—in early 2011 for the construction of a wastewater treatment plant in Saudi Arabia. In May, the company won a contract in Bangladesh following competition with 20 international firms. Tri-Tech Holding Inc. undertook several international projects, including a wastewater treatment plant in India and a seawater desalination plant in Qatar.[36]

Foreign investment and private sector participation in China's water industry began in the early 1990s, yet foreign firms still confront uncertainties surrounding market access and funding availability. Some local governments have been reluctant to grant contracts to foreign parties as domestic companies are showing improvements in their technical capabilities while still offering lower-cost alternatives. In the capital-intensive water sector, access to proper funding sources is critical. The economic challenges affecting foreign companies in other markets may limit their readiness to invest in Chinese projects. Overall, foreign firms have been less involved in plant operations where build-operate-transfer (BOT) models favor cash-rich domestic SOEs and large private companies. For instance, according to ChinaWaterNet, only two foreign-owned companies appeared on the list of China's top 10 most influential water companies in 2011. While foreign firms have historically dominated the rankings for

**Foreign firms participating in China's water industry still confront uncertainties surrounding market access, IP protection, and funding availability.**

*30. "九阳出资1亿进入水处理行业" [Joyoung invests 100 RMB to enter water treatment industry], Southern Daily, (quoted in Tencent), January 27, 2011, www.qq.com*

*31. "万达携手联想控股等4企110亿元投资矿泉水业" [Four group corporations will invest RMB 11 billion to build largest mineral water project in China], ChinaVenture, October 11, 2011, www.chinaventure.com.cn*

*32. "Accounting for the sludge factor in China," Global Water Intelligence, Volume 12, Issue 8, August 2011, www.globalwaterintel.com*

*33. "China's 4 trillion yuan stimulus to boost economy, domestic demand," Chinese government official website, November 9, 2008, english.gov.cn*

*34. "Accounting for the sludge factor in China," Global Water Intelligence, Volume 12, Issue 8, August 2011, www.globalwaterintel.com; "Beijing Capital To Buy Stake In New Environmental Energy Holdings Company," CapitalVue, March 30, 2011, www.capitalvue.com*

*35. Lu, Chang and Jing Yao, "Tapping into the future," China Daily, May 27, 2011, europe.chinadaily.com.cn*

*36. "What Chinese water company will enter the Top 25?" China Water Nexus, November 10, 2011, www.chinawaternexus.com; "Clarification Announcement in Relation to the Project in Saudi Arabia," Sound Global Corporate Press Release, February 24, 2011, soundglobal.listedcompany.com; "China's Sound Global expands abroad with EPC deal," Global Water Intelligence, May 19, 2011, www.globalwaterintel.com; "Tri-Tech bags EPC contract in India," Water Technology, November 14, 2011, www.water-technology.net; "Key Developments," Reuters, www.reuters.com, accessed on February 9, 2012*

water engineering and technology procurement projects, their influence appears to be decreasing—in 2010, six foreign companies or joint ventures (JV) ranked within the top 10, and by 2011, there were only four.[37]

China's dire water situation has a tremendous environmental and economic cost. In 2011, central regulators sent a clear message to the market with ambitious targets and strong financial support. In the years to come, the focus will likely be on local enforcement—an area of past weakness due to local conflicts of interest. Efficient use of water resources also requires simplification of China's fragmented regulatory framework—a gigantic task which has only just begun. Water pricing issues are likely to remain a short-term obstacle with local governments torn between the private sector's requests for price increases and the central regulators' concerns over inflation. Despite these challenges, a range of opportunities exist across the water sector, including water resources monitoring, floods and droughts prevention, wastewater treatment, and efficient water use, as will be explained in the following section.

**As much as 57% of China's underground water quality is classified as Bad or Very Bad.**

## Market Opportunities

China's water sector presents vast commercial opportunities along the water cycle, from supply to efficient use and wastewater discharge. At the local level though, the industry's segmentation, low water prices, market access issues and difficulties in dealing with local governments limit prospects. As a result, market opportunities for the private sector vary greatly across solutions, locations and nature of participants.

### Water resources quality monitoring and protection

China's push towards water resource protection creates many opportunities; the most attractive areas include water resources remediation, wastewater treatment and reuse, as well as water efficiency. Seizing opportunities may prove difficult, however, due to complex regulatory and industry structures. Market attractiveness varies considerably by region, sector and technology.

As much as 57% of China's underground water quality is classified as Bad or Very Bad according to a 2010 assessment led by the Ministry of Land and Resources (MLR) and a recently-approved National Groundwater Contamination Prevention and Remediation Plan (2011-2020).[38] The Remediation Plan's RMB 34.7 billion allocation for groundwater monitoring and remediation suggests strong prospects for technology providers.[39] The government also focuses on surface water monitoring and remediation. The introduction of ecological marine preservation zones along China's coastline creates opportunities for pollution prevention and remediation of both freshwater and seawater. For instance, following the recent oil spill at Dalian Xingang, authorities announced the creation of 12 national-level bases for offshore oil spill response.[40]

### Flood and drought prevention

Following severe droughts and floods in 2010 and 2011, China is investing in solutions to mitigate water-related disasters. A range of companies have been awarded contracts for flash-flood monitoring and prevention equipment, with more coming in the next two years or so. These may include improved weather forecasting software, measurement tools, diversion canals, emergency water storage tanks, reinforced irrigation channels and real-time remote communication equipment. Drought prevention requires holistic solutions ranging from expanded water supply infrastructure to monitoring systems and efficient water use equipment. Specific opportunities include seawater

*37. "2010年度水业十大优秀工程技术公司揭晓" [2010 water industry top 10 technology companies], ChinaWaterNet, 2011, www.h2o-china.com; Yu, Lin, "2011年度评选揭晓北控领衔十大影响力企业" [2011 water industry rankings - Beijing Enterprises Water Group leads top 10 most influential companies], ChinaWaterNet, February 3, 2012, www.h2o-china.com*

*38. "全国地下水污染防治规划 (2011—2020年)" [National Groundwater Contamination Prevention and Remediation Plan (2011-2020)], MEP, Ministry of Land and Resources (MLR), MWR, November 2011*

*39. "China sets ambitious plan for clean water," China Economic Net, October 29, 2011, en.ce.cn; "China introduces first national plan on groundwater pollution control: ministries," MWR, November 8, 2011, www.mwr.gov.cn*

*40. "中石油董事长因大连爆炸被警告事故损失超2亿" [The chairman in CNPC was warned because of Dalian explode event which caused direct loss over RMB 200 million], Sohu, November 25, 2011, news.sohu.com; "Oil spill response base network set to open," China Daily, December 21, 2011, www.china.org.cn*

desalination plants, membrane technology for wastewater reuse, emergency water storage, reservoir construction and water resource monitoring.

### Wastewater and sludge treatment

China has expanded its wastewater treatment infrastructure at a fast pace: the number of treatment plants increased by 25% annually since 2005 to exceed 3,000 facilities nationwide. The wastewater treatment rate in the urban area of the Beijing municipality is 94% and is targeted to reach 98% by 2015.[41] The market for new construction has shifted to smaller cities in less economically developed provinces inland. Due to local municipalities' lack of experience and limited financial resources, private participation models have good prospects. Inland provinces hold the most promise for new plant construction with daily capacity not exceeding 50,000 $m^3$ in second-, third- and fourth-tier cities.[42] The ongoing engineering work on the country's gigantic US$ 62 billion South-to-North Water Diversion Project (SNWD) also creates opportunities: 426 treatment plants will be built along the Eastern route of the project to treat heavily polluted waters between the Yangtze river and the city of Tianjin.[43] Retrofit opportunities to meet strict water quality standards or improve energy efficiency in older plants are mainly concentrated in industrialized coastal areas where pollution energy efficiency and reuse considerations are high on the agenda of local officials.

**The number of treatment plants in China increased by 25% annually since 2005 to exceed 3,000 facilities nationwide.**

Water reuse, or reclamation, will experience strong growth over the next 10 years. Beijing, which has out-paced other cities in building its wastewater treatment infrastructure, will upgrade all existing treatment plants into reclamation plants to reach a 75% reuse target by 2015.[44] Other cities in industrialized regions will follow now that their wastewater infrastructure is established. Water reuse in both municipal and industrial contexts will expand the membrane technology market, which is set to grow 30% annually for the next five years.[45]

### Water efficiency

National water consumption caps and water use efficiency targets are creating opportunities for water efficiency technologies.[46] These include water-efficient irrigation systems, water-free manufacturing systems, as well as low-flow fixtures, rainwater and greywater reuse in residential and commercial buildings. Markets for decentralized greywater systems are evaluated in more detail in the Opportunity Assessment section.

## Sludge Treatment and Disposal Markets in China

### Opportunity Assessment Summary

**Sludge treatment and disposal is a huge potential market opportunity, given the estimated 22 to 30 million tons discharged annually in China, but the lack of a comprehensive policy framework—including proper funding and inadequate enforcement—has held back the market.**

China's growing municipal wastewater treatment network has led to a rapid expansion of residual sludge. Sludge discharge has grown 5% annually over the past five years and is estimated to reach 22 to 30 million tons annually. Microorganisms and

*41. "北京：十二五污水处理率逾90% 污泥无害化处理率100%" [Beijing: Wastewater treatment rate to exceed 90%, sludge treatment to reach 100% under 12th Five-Year Plan], China Association for Environment Protection Industry, February 2, 2012, www.caepi.org.cn*

*42. CGTI analysis*

*43. Wong, Edward, "Plan for China's Water Crisis Spurs Concern," New York Times, June 6, 2011, www.nytimes.com*

*44. "京供水两成依靠再生水污水处理率达到98%" [Beijing water supply relies on reuse, wastewater treatment rate to reach 98%], People website, November 3, 2011, bj.people.com.cn*

*45. Master, Farah and Samuel Shen, "Analysis - Investors chase big catch in China's muddy waters," Reuters, April 21, 2011, www.reuters.com*

*46. "我国国民经济和社会发展十二五规划纲要 (全文)" [China's 12th Five-Year Plan for People's Economy and Social Development (Full Text)], State Council, NDRC, March 17, 2011, news.sina.com.cn; "2011年中央一号文件(全文)" [China's 2011 Central Number One Document], Xinhua News Agency, January 2011, bj.people.com.cn*

pathogens, unpleasant odors, emission of methane ($CH_4$) gases, and in some cases, heavy metal content make sludge a harmful by-product of wastewater treatment that requires proper treatment and disposal. Sludge regulation is highly fragmented and lacks a comprehensive framework—for example, there is no national standard sludge treatment fee. Due to inadequate incentives, the industry has continued with low-cost, potentially unsafe disposal methods in landfills—or worse, direct discharge into the environment—despite the existence of technologies to convert sludge into a valuable resource. Nevertheless, recent developments indicate growing private sector confidence in the sludge treatment market.

### Sludge output increases as wastewater treatment infrastructure espands

China's sludge output is growing rapidly due to the expansion of municipal wastewater treatment infrastructure. The number of municipal wastewater plants in China nearly quadrupled from 718 in 2005 to 2,823 in 2010. This figure is set to exceed 5,200 in 2012, representing an annual growth of 31%. China's Ministry of Housing and Urban-Rural Development (MOHURD) estimates 22 million tons of sludge is discharged annually across China, whereas some industry experts have quoted figures of up to 30 million tons.[47] How much sludge is that? 22 million tons would fill 1.6 million 14-ton trucks, or roughly 80% of China's total truck fleet.[48]

Which chinese provinces produce the most sludge? China's 12 coastal provinces account for the largest share of sludge discharge, or around 56% of China's wastewater output in 2010.[49] Guangdong, China's most populous province, produces the most sludge annually at an estimated 3 million tons, roughly 10-14% of total sludge output.[50]

How does China dispose of sludge now? Different sources offer conflicting sludge disposal estimates. Tsinghua estimates 48% is used as fertilizer, 34% is landfilled, 14% is discharged into the environment,[51] and the remaining 4% is incinerated or used in other ways. Water JV Sino-French Water, however, reports that 61% is landfilled.[52] In some areas, such as Guangdong, landfills account for 90% of sludge disposal.[53] Since 2007, China has not permitted sludge with over 60% water content in landfills—theoretically barring most wastewater treatment plants from discharging sludge without sufficient treatment.[54] Yet actual enforcement at the local level raises concerns.

### Improper sludge disposal is a growing hazard

In September 2009, a major sludge pollution trial opened in Beijing against five people accused of releasing at least 6,500 tons of municipal wastewater treatment sludge containing toxic heavy metals into the Mentougou water conservation district just west of Beijing. The dumping led to estimated economic losses of RMB 100 million. One of the accused, He Tao, explained that since starting his business in 2002, he either sold untreated sludge as fertilizer or discharged it directly on the banks of rivers. "In our industry, before 2008, most companies used to do exactly the same," he said.[55]

**In some areas, such as Guangdong, landfills account for 90% of sludge disposal.**

*47. Hornby, Lucy and Jane Lanhee Lee, "Analysis: Flood of money needed to fix China's water woes," Reuters, February 15, 2011, www.reuters.com; Wang, Hongchen, "中国水环境水源可持续利用" [China Sustainable Water Use], Da Yu Network, July 13, 2010, www.dy88com; "广东污泥问题令人忧专家建议因地制宜处理" [Guangdong sludge problem leaves people worried, experts suggest adopting local solutions], ChinaNews, October 14, 2011, www.chinanews.com*
*48. China Truck website, www.chinatruck.org, accessed on December 15, 2011; CGTI analysis*
*49. China Statistical Yearbook 2010 (Beijing: National Bureau of Statistics, 2010)*
*50. Ibid; CGTI analysis*
*51. Zuo, Jiane, "Status and Development of Sewage Sludge Treatment and Disposal in China," Tsinghua University, April 30, 2010, www.watersymposium.info*
*52. Ibid; "Sludge Disposal in China," Sino French Water Magazine, Issue 14, June 2011*
*53. Song, Yafen, "广东九成污泥填埋为害甚于污水行业标准混乱" [90% of sludge is improperly landfilled in Guangdong, as confusion surrounds industry standards], Nanfang Daily, October 14, 2011, www.nfdaily.cn*
*54. "Disposal of Sludge from Municipal Wastewater Treatment Plant: Sludge Quality for Co-landfill," National Standard, 2007*
*55. "污泥责任刑事诉讼警钟为谁而鸣?" [Sludge criminal lawsuit, for whom rings the alarm bell?], ChinaWaterNet, September 23, 2009, news.h2o-china.com*

The Mentougou case is hardly an isolated incident. In Guangdong, the province with the highest municipal wastewater discharge, the Nanfang Daily reported in 2009 that over 90% of sludge was improperly landfilled.[56] Improper sludge disposal can pollute soils, contaminate nearby water bodies and groundwater, and release methane. Improper sludge disposal not only threatens land, soil and water quality, but also means loss of potentially recoverable resources, but sludge is not inherently a useless waste.

**Sludge Composition: Shaanxi Yangling Treatment Plant Example, 2005**

| Content | Content (g/Kg) |
|---|---|
| Water | 90-99% |
| Organic Matter | 361-529 |
| Nitrogen (N) | 20-35 |
| Phosphor (P) | 3-7 |
| Potassium (K) | 9-12 |
| Heavy Metals (mg/kg): | |
| Cadmium (Cd) | 0.7-5 |
| Nickel (Ni) | 23-38 |
| Lead (Pb) | 29-76 |
| Zinc (Zn) | 297-313 |
| Copper (Cu) | 124-200 |
| Arsenic (As) | 6-16 |
| Mercury (Hg) | Not detectable |
| Chromium (Cr) | 43-255 |

*Source: "Components change of sewage sludge by month and land application in Shaanxi Yangling Sewage Treatment Plant," Journal of Northwest A&F University, Volume 35, Number 9, September 2007*

## Many challenges have hindered market development so far

China's sludge industry faces challenges ranging from lack of comprehensive policies to insufficient funding. Challenges related to the market and industry include:

- **Wide operating cost ranges:** The cost of handling, treating and disposing of sludge can range from as low as RMB 15/ton to over RMB 500/ton.
- **Lack of operational expertise:** Due to the recent and rapid increase in wastewater treatment infrastructure in China, few companies have developed China-specific operational and technical expertise, and lack a track-record of effective long-term plant management.
- **False marketing claims:** Some new market entrants have aggressively sought market share and make promises their technology cannot deliver.[57]

In addition, the industry faces a number of regulatory challenges, such as a lack of comprehensive national policies, enforcement and funding.

## Central government sludge treatment framework incomplete

The central government has issued a sludge treatment technology guide and has announced plans to spend RMB 60 billion on sludge treatment over the 12th Five-Year Plan period—or roughly the amount currently needed to meet treatment infrastructure capital needs. Sludge treatment is expensive and there is no national fee to compensate wastewater treatment plants for treatment costs.

*56. "广东九成污泥填埋为害甚于污水行业标准混乱" [90% of sludge is improperly landfilled in Guangdong, as confusion surrounds industry standards], Nanfang Daily, October 14, 2011, www.nfdaily.cn*
*57. Li, Jing, "国内污泥处理市场乱象丛生行业发展面临诸多障碍" [Domestic sludge treatment market is a mess], Economic Information Daily, October 11, 2011, www.jjckb.xinhua.org*

Since 2009, China has taken a number of important actions. In 2009, MOHURD and the Ministry of Environmental Protection (MEP) issued technology standards, including preferred technologies and restrictions on sludge transportation and storage. This measure was followed a year later by guidelines on technologies issued by the National Planning Commission (NPC). In November 2010, the central government released the Notice on Reinforcing Municipal Wastewater Treatment Plant Sludge Pollution Prevention and Control. The measure requires municipal wastewater treatment plants to install sludge treatment capacity within two years. In February 2011, the National Development and Reform Commission (NDRC) and MOHURD issued plans for setting up sludge treatment demonstration projects with advanced technologies, and urged provinces to set sludge treatment targets. Subsequently, in March, MOHURD and the NDRC issued a trial guideline on treatment technologies. Yet full standards and enforcement remain incomplete. As an executive from one of CGTI's Partner companies noted, "Only when the government imposed the strictest wastewater discharge standards—Grade IA—did the wastewater treatment market take off. I expect the same to be true for sludge treatment in China."[58]

The 12th Five-Year Plan sets ambitious targets for sludge treatment nationally—some provinces will see their rate for safe treatment and disposal rise from roughly 20% to 80%—and reiterates the 2010 requirement that all municipal wastewater treatment plants must install sludge treatment equipment by 2012. The Plan also sets investment plans of RMB 60 billion for sludge treatment infrastructure.[59]

**Capital costs to treat sludge can reach up to RMB 700,000 per ton per day of capacity.**

Though this investment plan sounds impressive, the funding may be barely enough to meet targets: capital costs to treat sludge can reach up to RMB 700,000 per ton per day of capacity depending on technology choice and location.[60] In other words, the required capital investment to treat China's 2011 sludge discharge could exceed RMB 57 billion—not accounting for operating costs financed by local governments.[61] Therefore, in the absence of a national sludge treatment fee included in water prices—and considering local governments' stretched budgets—funding remains an issue.

### Several provinces are taking the lead on targets, enforcement and funding

To address the lack of national targets and funding for sludge treatment, several municipalities and provinces have adopted their own plans, including Beijing, Guangdong, Hebei and Hubei.

Beijing promotes safe sludge treatment and disposal in its 12th Five-Year Plan for Water Resources Protection and Use released early February 2012. This plan includes a 100% treatment target by 2015 and the planned construction of eight facilities around the city.[62] Guangdong has set sludge treatment targets of 80% by 2012 and 100% by 2015. Hebei adopted strict regulations for sludge management, transportation, storage and disposal. The province plans to build a hazard-free sludge treatment infrastructure within three years.[63] Finally, Hubei set up sludge treatment and pilot programs in 2011, and plans to build a hazard-free sludge treatment infrastructure by 2013.[64]

Efforts by Jiangsu and Guangdong to add a sludge treatment surcharge to water prices could ease the financing needs of sludge treatment operations. In Guangdong, a provincial plan entitled Advice on Further Reinforcing Wastewater Plant Sludge Treatment and Disposal in Guangdong Province, calls for a surcharge of RMB 0.1/$m^3$

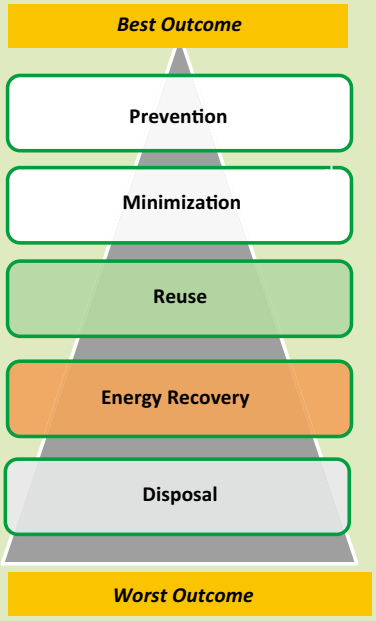
*58. CGTI Partner interview*
*59. "600亿投资推动'十二五'污泥处理处置市场" [RMB 600 billion promoted sludge treatment market during the 12th Five-Year Plan period], China National Materials Group Corporation Ltd. (Sinoma), September 6, 2011, www.sinoma.cn*
*60. "Analysis of Dalian Xiajiahe Sludge Anaerobic Treatment Project," Sina Blog, July 31, 2011, blog.sina.com.cn*
*61. CGTI analysis; based on 22 to 30 million tons of sludge discharged annually and various sludge treatment plant project profiles.*
*62. "北京：十二五污水处理率逾90% 污泥无害化处理率100%" [Beijing: Wastewater treatment rate to exceed 90%, sludge treatment to reach 100% under 12th Five-Year Plan], China Association for Environment Protection Industry, February 2, 2012, www.caepi.org.cn*
*63. "河北省规定到2013年底各市污水处理率超90%" [Hebei Target of 90% Wastewater Treatment Rate by 2013], ChinaWaterNet, March 27, 2011, news.h2o-china.com*
*64. Hu, Guiyu, "湖北谋划2015污泥处理全部达标" [Hubei Plans to Reach Sludge Treatment Standards by 2015], ChinaWaterNet, January 1, 2011, news.h2o-china.com*

on wastewater fees to cover sludge treatment costs.[65] In Jiangsu, the province plans to increase wastewater fees by RMB 0.1-0.2/$m^3$.[66] However, industry experts have suggested that average wastewater treatment fees would have to rise by RMB 0.4-0.6/$m^3$ to cover sludge treatment costs.[67] Thus, currently proposed fees in Jiangsu and Guangdong may still be insufficient.

### Sludge can be a resource depending on the disposal method

The economics of sludge treatment are complex: the process can involve a number of stages, including thickening, stabilization and dewatering to remove pathogens, pollutants and surplus water. The wide range of sludge treatment and disposal methods leads to a variety of environmental outcomes. The most cost-effective and environmentally-friendly method is to avoid or minimize sludge discharge in the first place through advanced wastewater treatment technologies. Sludge treatment can, however, generate additional revenues from value recovery, with fertilizer and biogas fuel the most promising outputs.

**Sludge Disposal Alternatives**




| | |
|---|---|
| Prevent or Minimize | ▪ Best alternative to sludge treatment is reducing sludge output during the wastewater treatment process |
| Building Material | ▪ Technologies exist to turn dry sludge into building materials<br>▪ Provides new revenues or reduce costs |
| Fertilizer | ▪ Increased focus on processing sludge to extract nutrients<br>▪ New revenues via agricultural and city gardening use |
| Biogas-Natural gas | ▪ Biogas can be used internally to generate part of plant's energy needs; or turned into natural gas |
| Incineration | ▪ Incineration can be used for district heating or power generation<br>▪ Ashes used to make bricks or activated carbon adsorbents |
| Landfill | ▪ Stabilization and dewatering is necessary for proper disposal<br>▪ Lowest cost approach for sludge disposal |

*Source: CGTI analysis and Partners interviews*

There are a number of ways to dispose of sludge that can generate revenues:

- **Convert into construction materials:** Sludge can be turned into construction materials—cement, bricks or ceramic cubes. However, sludge-derived building materials in China have yet to overcome quality barriers. The recent example of Beijing Cement's sludge-to-cement project illustrates how technology plays an important role in producing quality materials—the plant has been an economic failure, as discussed further below.[68] In addition, building material processes require dry sludge, increasing initial investment and operating costs associated with dewatering and drying equipment.



*65. Huang, Huicheng, "广东：污泥处理也要收费" [Guangdong: Sludge Treatment Should Charge], ChinaWaterNet, December 17, 2010, news.h2o-china.com*
*66. "江苏拟出污泥处置新规定" [Jiangsu Province Plans on New Sludge Treatment Policy], ChinaWaterNet, December 4, 2008, news.h2o-china.com; CGTI analysis*
*67. "三部门明确污水处理费应包括污泥处理成本" [Three Ministry Agreed Wastewater Treatment Fee Should Include Sludge Treatment Cost], ChinaWaterNet, March 4, 2009, news.h2o-china.com; CGTI analysis*
*68. Zhang, Qi, "Sludge Solution," China Daily, March 31, 2008, www.chinadaily.com.cn*

- **Turn into fertilizer:** Sludge can be turned into fertilizer for agricultural or garden use. Sludge-turned-fertilizer represents an economic way to dispose of sludge and reuse precious nutrients, such as phosphorous and nitrogen. However, if treated or handled improperly, sludge-based fertilizer risks soil pollution via infiltration.
- **Use by treatment plants:** Biogas or natural gas derived from sludge can be used by treatment plants to meet internal energy needs, or can be sold to local users. If anaerobic fermentation were used to treat all 30 million tons of sewage sludge generated by China annually, in theory it could generate 2.5 billion $m^3$ of methane gas, which could in turn generate 4 billion kWh of electricity and reduce carbon emissions by 15 million tons annually.[69] However, the process is not without problems: sludge can be difficult to degrade, and it takes time. Varying levels of organic content may affect biogas output volume and quality, reducing the potential for power or heat generation.[70]
- **Incinerate for power:** Incineration can produce district heating or electricity, and ash output can be turned into bricks or activated-carbon absorbents. Incineration is sometimes considered a quick fix for China due to low cost and technology maturity. However, incineration has low energy efficiency due to sludge's low calorific content and requires dry sludge, increasing pre-incineration treatment costs. Furthermore, incineration raises air pollution concerns for nearby populations.[71]

**If anaerobic fermentation treated all of the sewage sludge generated by China annually, it could generate 2.5 billion $m^3$ of methane gas, which could generate 4 billion kWh of electricity and reduce carbon emissions by 15 million tons.**

Landfilling is in most respects the least attractive option for sludge disposal given its health and environmental costs, yet economic considerations and process simplicity make landfilling a widespread method in China. Sludge is considered a hazardous waste. When untreated, sludge is disposed in landfills wherein it can infiltrate soil, pollute groundwater and release methane into the atmosphere. Transporting this heavy waste to landfills also creates additional air pollution. Beside environmental and health concerns, landfilled sludge takes valuable land—particularly in large cities—and discards content that could be reused.[72]

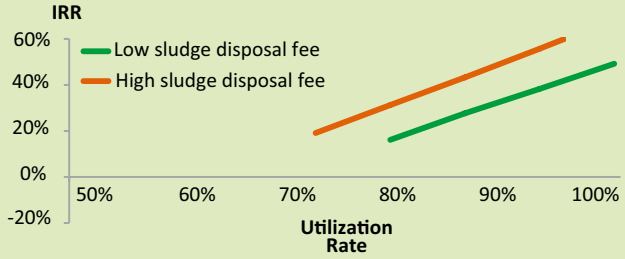
### With high utilization and collection fees, plant economics are attractive

A CGTI sensitivity analysis of an advanced anaerobic sludge treatment plant in Dalian sows that sludge treatment may offer attractive returns. Capital cost, utilization and sludge treatment fees are the most important variables.

The Dalian Dongtai Xiajiahe anaerobic sludge treatment project was included in the 2010 Top 10 Sludge Treatment Projects according to the website ChinaWaterNet.[73] The Dalian plant began operations in April 2009 and is operated by the Dalian Dongtai Industry Waste Management Company.[74] The plant has a 600 ton daily sludge treatment design capacity, but now operates at only 25%. The plant initially received an RMB 135/ton sludge disposal fee, which the government raised to RMB 170/ton starting in 2011 to compensate for low utilization. The plant uses roughly 30% of its biogas output for its own energy consumption while the remainder is turned into natural gas and sold to local utilities at RMB 2.4/$m^3$. On a daily basis, the plant's operations consume 70 $m^3$ of drinking water, 400 $m^3$ of recycled water from a nearby wastewater treatment plant, and 15,000 to 18,000 kWh of electricity. The plant cost roughly RMB 150 million, paid through a 6% 20-year loan.[75]

*69. Liu, Yongli, "厌氧消化应成为污泥处理主要技术?" [Will anaerobic fermentation become the main technology in sludge treatment?], ChinaWaterNet, April 23, 2010, news.h2o-china.com*
*70. CGTI analysis and Partner interviews*
*71. Zhang, Qi, "Sludge Solution," China Daily, March 31, 2008, www.chinadaily.com.cn*
*72. Ding, Isabelle, "Dirty Business," China International Business, October 2009, www.cibmagazine.com.cn; CGTI analysis and Partner interviews*
*73. Liu, Yongli, "污泥最佳适用技术案例比选结果揭晓" [Best Examples of Sludge Treatment Technology Utilization], ChinaWaterNet, August 31, 2010, news.h2o-china.com*
*74. Liu, Dong-Hai, et al., "大连市夏家河污泥处理厂工艺设计与运行经验介绍" [Introduction to the Dalian City Xiajiahe Sludge Treatment Plant Technology Design and Operating Experience], China Water and Wastewater Magazine, December 2010, www.cnki.net*
*75. Li, Zhihong, "夏家河污泥处理厂每天 '消化' 污泥达600吨" [Xiajiahe Sludge Treatment Plant to Digest 600 Tons of Sludge Per Day], Dalian Daily, May 27, 2010, www.daliandaily.com.cn*

**Dalian Dongtai Xiajiahe Sludge Treatment Plant Economics: Internal Rate of Return (IRR) Sensitivity to Utilization Rate**




*Notes: 2010 low sludge disposal fee is RMB 135/ton; 2010 high sludge disposal fee is RMB 170/ton; assuming RMB 150 million investment, 20-year lifespan, O&M costs (electricity, chemicals, maintenance, HR expenses and water consumption), 20% equity, 6% interest, 25% corporate tax, 365 days a year.*

*Sources: "2010 Top 10 Sludge Treatment Projects in China," ChinaWaterNet, October 2010, www.h2o-china.com; Chen, Hai, "大连市夏家河污泥处理厂工艺设计与运行经验介绍" [Introduction to Dalian city Xiajiahe sludge treatment plant technology design and operating experience], China Water and Wastewater magazine, December 2010; "这里的污泥源源不断地变成燃气" [The sludge continuously changes into gas], Liaoning Daily, December 22, 2009; Li, Zhihong, "夏家河污泥处理厂每天"消化"污泥达600吨" [Xiajiahe Sludge Treatment Plant to Digest 600 Tons of Sludge/Day], Dalian Daily, May 27, 2010, www.daliandaily.com.cn*

Not surprisingly, low utilization is the main factor affecting the plant's economics. Based on a simple cash flow analysis, it is estimated that the utilization rates must reach roughly 70% to make the project's internal rate of return (IRR) economical given the sludge disposal fee level of RMB 135/ton. With a more attractive RMB 170/ton disposal fee, the required utilization rate would fall to roughly 60%, which is still far higher than the plant has experienced. A 75% utilization rate offers an IRR of 16% at the lower fee level. Several factors explain the attractiveness of this project under a high utilization scenario. First, the plant's capital cost was low compared to other similar plants—roughly RMB 250,000 per ton per day versus RMB 412,000 per ton per day for similiar sludge treatment facilities of the Qingdao Maidao wastewater treatment plant.[76] Second, biogas generation reduces the plant's electricity needs, which typically account for the largest part of total operations and maintenance (O&M) costs. Third, the sludge disposal fee was increased to RMB 170/ton in 2011 to compensate for the money-losing operations during the first year of operation, and could be reduced if the utilization rate increases.

As the Dalian plant case shows, high-technology sludge treatment has the potential to be economical, but actual operations impact viability. Another example, the Beijing Cement Plant Sludge Treatment Project is currently producing below capacity and running at a loss. The plant was intended to make sludge into cement, but this plan has been hampered by technical complexity, cement quality issues and a difficult operating environment.[77] Similarly, the Shanghai Shidongkou Sludge Treatment Project was the first Chinese sludge drying and incineration project to use imported technology and equipment, but initially operated at less than half its design capacity. In 2006, plant operators allegedly dumped untreated sludge into the river. Its main operational problems include under-sized incineration capacity and higher-than-expected percentage of sand in sludge, resulting in higher maintenance costs.[78] As these cases demonstrate, proper capacity design and cost estimation are critical elements to project success.

Sludge treatment and disposal markets are still at the very early stage in China, yet offer attractive prospects over the next decade. Their development will likely compare to that of industrial wastewater treatment, which experienced rapid development with strong government support—though local-level enforcement remains an issue.



*76. Chen, Raohua, "青岛麦岛污水处理厂污泥消化及热电联产" [Qingdao Maidao Wastewater Treatment Plant Sludge Digestion and Heat-Power Combined Generation], Presentation at 2nd Shanghai Water Specialized Conference, August 2010; Wang, Fuzhi, "青岛麦岛污水处理厂介绍" [Qingdao Maidao Wastewater Treatment Plant], Presentation at Qingdao Sludge Treatment Seminar, May 2011*

*77. "误区还是方向－北京水泥厂污泥处置项目的成本剖析" [Cost analysis Beijing Cement Factory Sludge Project], BaiduWenku, December 4, 2011*

*78. "污泥处理处置技术分析" [Technical analysis of sludge treatment and disposal], Sina Blog, October 27, 2011, blog.home.news.cn*

# Industrial Wastewater Treatment Opportunities in China

## Opportunity Assessment Summary

**Industrial users are a major source of water pollution in China and have fallen under regulator's scrutiny.**

**The government has made industrial wastewater treatment a priority in the 12th Five-Year Plan, but investment opportunities vary considerably by industry and region.**

In May 2011, Zijin Mining, a large domestic gold producer, was fined RMB 30 million for a copper leak into the Ting River the previous year. Five of its employees were sentenced to jail for three or more years. Such severe penalties highlight a positive trend in China's industrial wastewater sector: improvements in local enforcement of the country's strict discharge standards. Indeed, industrial users are a major source of water pollution in China and have fallen under regulator's scrutiny. The 12th Five-Year Plan calls for large reductions in chemical oxygen demand (COD), ammonia nitrogen, heavy metals and water consumption per unit of GDP. Meeting targets will create opportunities for industrial wastewater treatment and reuse technologies. Many industrial markets appear attractive, including pharmaceuticals, beverages, paper and pulp, raw chemicals, textiles, food processing, and ore mining, mainly in industrialized coastal provinces. Finally, centralized treatment plants in industrial parks offer attractive prospects under strong government support.

### Central-level regulators increase scrutiny over industrial polluters

Major policy documents released in 2011 emphasize mitigating water pollution from industrial sources. China's 12th Five-Year Plan specifically includes:

- Reduction of 30% in water intensity per unit of GDP and industrial output.[79]
- Emphasis on lifecycle management of water pollution sources rather than China's traditional end-of-pipe or point-of-use approaches.
- 15% discharge reduction goals for five major heavy metals, based on 2007 levels, including arsenic, cadmium, chromium, lead and mercury, identified in the 12th Five-Year Plan for Integrated Control of Heavy Metal Pollution.[80]
- Policies to tighten pollution control over major river watersheds and coastal marine areas.
- Identification of nine target industries for promoting industrial wastewater treatment, including paper and pulp, raw chemicals, petroleum refining, textiles, dyeing, pharmaceuticals, ferrous metal processing, food processing, and power and heat generation.[81]

While enforcement for industrial wastewater treatment at the local level has been improving, the gap between central government targets and local implementation has limited progress in industrial pollution mitigation. Many local monitoring and enforcement offices are constrained by inadequate budgets. Local officials are forced to a balancing act between promoting local industrial growth and enforcing strict water quality standards. However, the government has lifted maximum limits on water pollution fines and introduced key performance indicators (KPIs) to evaluate and promote government officials—these are encouraging improvements, though some regions have previously ignored KPIs when they conflict with local economic interests.[82]



*79. "水利部：万元工业增加值用水降30%是约束性指标" [MWR: Reduction of 30% of water intensity per unit of GDP and per unit of RMB 10,000 industrial product is a binding target], 163, October 12, 2012, money.163.com*
*80. Wu, Fei, "Anticipating new policies. Seeking out advantageous enterprises," CITICS Spring Strategy Forum, March 2011*
*81. Hu, Meidong and Peng Yinning, "12th Five-Year Plan targets polluted water," China Daily, November 6, 2010, www.chinadaily.com.cn*
*82. Carmody, Lucie, et al., "Water In China, Issues for Responsible Investors: Water in China," Responsible Research, February 2010, p. 16*

### Industry segment attractiveness for treatment solutions varies

Most industries present attractive market prospects for wastewater treatment; some, such as petrochemicals and pharmaceuticals, appear more attractive based on CGTI's evaluation criteria. Regionally, heavily industrialized coastal provinces remain most attractive. Centralized wastewater treatment plants—where a treatment plant (typically located in or near an industrial park) collects and treats wastewater streams from multiple nearby factories—will particularly benefit from central-level investments in such plants.

CGTI analyzed 38 industries to determine wastewater treatment attractiveness based on four criteria:[83]

- **Water pollution levels:** The 12th Five-Year Plan sets new targets to reduce COD discharges by 8%, ammonia nitrogen discharges by 10% and overall discharge volume. Industries with high COD and ammonia nitrogen levels and large discharge volumes are under stricter oversight, and thus appear more attractive.
- **Economic criteria:** Industries with higher profit margins have greater flexibility to adopt and properly maintain wastewater treatment systems. State-owned enterprises (SOEs) that benefit from strong financial backing tend to be more strictly monitored by regulators, and may therefore offer more opportunities.
- **Treatment difficulty:** Specific treatment requirements and process complexity drive innovation opportunities, particularly for leading foreign companies, and contribute to market attractiveness.
- **Target industries:** The 12th Five-Year Plan identifies nine highly-polluting industries that are expected to receive more attention from central-level regulators. Greater focus by the government increases attractiveness.

Using these criteria, the most attractive industries are pharmaceuticals, beverages, paper and pulp, raw chemicals (including coal chemicals), textiles, agricultural food processing, and coal mining and washing. Each of these industries ranked in the top ten for industrial COD/ammonia nitrogen and total volume discharges.[84] Moderately attractive industries include ferrous metal processing (including iron and steel), petroleum products refining, tobacco, food manufacturing and chemical fibers. For the iron and steel industry, new discharge standards will likely spur more investment in wastewater treatment, which may make this market more attractive over time. The remaining 25 industries appear less attractive due to limited discharge volumes, low profitability, lower treatment difficulty, market fragmentation or lack of government focus in the 12th Five-Year Plan.[85]

CGTI used a similar approach to identify regional opportunities by examining discharge volumes, investment, COD/ammonia nitrogen levels and pricing. The six provinces discharging almost half of China's total industrial wastewater volumes are located in heavily industrialized coastal zones, starting with Jiangsu, followed by Zhejiang, Guangdong, Shandong, Guangxi and Fujian.[86] In terms of investment in industrial wastewater infrastructure by regional governments, overall investment has increased from RMB 17.4 billion in 2001 to RMB 44.3 billion in 2009, an annual growth rate of 9.4%. Investments are projected to reach RMB 125 billion during the 12th Five-Year Plan.[87] At the provincial level, Shanxi, Hubei, Jiangsu and Guangdong provinces currently account for nearly 40% of China's total regional investments.[88]

**Investment in industrial wastewater infrastructure by regional governments increased from RMB 17.4 billion in 2001 to RMB 44.3 billion in 2009, an annual growth rate of 9.4%.**



*83. China Statistical Yearbook 2010 (Beijing: National Bureau of Statistics, 2010)*
*84. Ibid.*
*85. CGTI analysis and Partner interviews*
*86. China Statistical Yearbook 2010 (Beijing: National Bureau of Statistics, 2010)*
*87. Ke, Kendra, "China Needs RMB 3.4 trillion for Environmental Protection Projects for Next 5 Years," Business China, December 22, 2011, en.21cbh.com*
*88. China Statistical Yearbook 2010 (Beijing: National Bureau of Statistics, 2010)*

**Centralizing wastewater treatment transfers the responsibility for waste disposal from individual industrial plants to local water utilities and to private companies.**

### Centralized wastewater treatment presents a number of advantages

Central and local governments favor centralized wastewater treatment.[89] In this model, industrial wastewater is collected from various industrial users and transferred to a central plant for treatment. Treated wastewater is subsequently either discharged or reused in industrial or municipal settings, including cleaning, cooling, landscaping, car-washing or residential non-potable uses. Centralizing wastewater treatment transfers the responsibility for waste disposal from individual industrial plants to local water utilities and, in some cases, to private companies through public-private partnerships (PPPs). Additional benefits include increased efficiency for nutrient recovery, sludge treatment and water reuse, as well as improved local-government monitoring and enforcement of discharge standards.

Drawbacks of centralized wastewater treatment raised by CGTI's Partner companies include increased costs for water pipeline network extensions required to connect various industrial users to centralized plants. These higher costs reflect pipeline construction, higher energy consumption, water loss due to pipeline leakage, and the need for dedicated pipelines or road transportation for reused water. Moreover, in diversified industrial parks, managing the variety of pollutants discharged from various users can make the treatment process more complex and onerous.

### Technology adoption depends on industry-specific treatment needs

Treatment technology adoption varies across industries and processes. Heavy metals, organic matter and chemical particle proportions differ between and within the mining, food processing and textile industries to name a few. Therefore, treating industrial wastewater streams requires different technologies, potentially including clarification, granular filtration, carbon adsorption, ion exchange, ozone generators and disinfection (chemical or ultraviolet) and membrane technologies, such as reverse osmosis, nano-filtration, ultra-filtration and microfiltration.

Water reuse appears promising over the next few years. Considering China's severe water scarcity issues, such technology, to some extent, can isolate industrial users from both water access limitations and water price increases. To alleviate water scarcity, the central government has promoted water reuse since issuing the Revised Water Resources Law in 2002, which contained an initial focus on municipal water infrastructure.[90] Now that the country initially focused on raising quality requirements for industrial wastewater discharge, the quality gap between treated wastewater and water qualifying for reuse is narrowing, improving incentives for water recycling. Other external drivers include rising industrial water tariffs—9% annual increases over the past decade—and the 12th Five-Year Plan's 30% water-intensity reduction targets for industrial output based on 2010 levels.[91] Internal considerations include a company's financial position, operational needs and corporate values.

Illustrative examples of water reuse in industrial contexts can be found in the power generation sector, where reusing water for cooling and cleaning will help reduce water consumption. Water quality requirements across various industrial processes mainly determine the potential for water reuse. Building on our example of the power generation industry, cooling represents a good fit for water reuse since quality requirements are not as high as for contact uses. With the worsening of China's water situation, reuse is a promising development to follow closely.



*89. CGTI analysis and Partner interviews*
*90. "中华人民共和国水法(2002修订)" [Water Law of the People's Republic of China(2002 Revision)], National People's Congress, October 1, 2002*
*91. China's 12th Five-Year Plan*

# Greywater System Adoption in China

## Opportunity Assessment Summary

**Although China has started to promote greywater recycling, the market is still in its early stages. Major challenges remain, including lack of infrastructure, misalignment of incentives, lagging policies and low water prices.**

Non-industrial buildings account for only 12% of China's water consumption, yet they discharge 60% of all wastewater.[92] Over half of all building wastewater could be classified as greywater—slightly polluted wastewater from sources including laundry, showers and hand-basins. While treating grey and blackwater (wastewater from toilet flushing) separately has been shown to be more efficient due to greywater's low treatment requirements, a dual plumbing system is required, which has thus far inhibited wide-spread adoption.[93] Regulators are focused on building large-scale centralized wastewater treatment and reclamation plants rather than decentralized greywater systems. Low residential water prices are also an issue. Due to these challenges, the market remains at an early stage, despite the potential for greywater systems to help achieve China's water policy goals while offering attractive economic returns.

### Regulators show mixed signals over greywater system promotion

Central government policies on greywater have moved slowly since 1995. In that year, Ministry of Housing and Urban-Rural Development (MOHURD) adopted a greywater definition and identified three categories of buildings which should install greywater systems: commercial and residential buildings larger than 20,000 square meters ($m^2$), public buildings larger than 30,000 $m^2$, and residential communities with populations over 30,000 (or recycled water use over 750 $m^3$ per day). In 2003, MOHURD established national water quality standards for greywater systems.[94]

More recently, regulators have started promoting water reuse as an alternative to tap water, especially in urban areas. In 2006, MOHURD and the Ministry of Science and Technology (MOST) adopted targets of 10-15% urban wastewater recycling in Northern cities by 2010 and 20-25% by 2015. Southern city targets were set at 5-10% for 2010 and 10-15% for 2015.[95] Released in early 2011, the 12th Five-Year Plan sets a wastewater reuse target of 10% nationwide. The National Development and Reform Commission (NDRC), MOHURD and the Ministry of Environmental Protection (MEP) have completed in November 2011 the Plan on Urban Wastewater Treatment and Reuse Facility Construction, 2011-2015.[96] Although promoting water reuse can encourage greywater system adoption, regulators have tended to focus on centralized wastewater treatment and reclamation to meet reuse targets.

At the local level, Beijing has pioneered greywater systems in China, beginning with a 1987 pilot scheme defining greywater and appropriate types of buildings for installations. In 2001, Beijing announced it would penalize building owners with non-operating greywater systems and require installation for commercial buildings with over 20,000 $m^2$, public buildings over 30,000 $m^2$, and residential buildings over 50,000 $m^2$. In 2004, the city included water reuse as part of its annual water resource allocation plan and established an RMB 1/$m^3$ charge for greywater. Beijing now boasts the most greywater recycling facilities in the country, with over 400 units in operation.[97] Consumption of recycled water in Beijing reached 680 million $m^3$ in 2010, or 19% of the

**Non-industrial buildings account for only 12% of China's water consumption, yet they discharge 60% of all wastewater.**

*92. China Statistical Yearbook 2010 (Beijing: National Bureau of Statistics, 2010)*

*93. Allen, Lucy, et al., "Overview of Greywater Reuse: The Potential of Greywater Systems to Aid Sustainable Water Management," Pacific Institute, November 2010, www.pacinst.org*

*94. "建设部关于发布《城市中水设施管理暂行办法》的通知" [Interim Measures on Urban Greywater Recycling Facilities Management], Ministry of Housing and Urban-Rural Development (MOHURD), December 8, 1995; "建筑中水设计规范" [Codes for Design of Building Greywater Recycling Systems], MOHURD, January 10, 2003*

*95. "关于印发《城市污水再生利用技术政策》的通知" [Notice on Urban Wastewater Recycling Technology Regulations], MOHURD and Ministry of Science and Technology (MOST), April 25, 2006*

*96. "污水处理及再生利用设施建设规划将出台" [Wastewater treatment and reuse facility construction plan near release], 163, November 1, 2011, money.163.com; "发改委官员：多项水处理规划正编制" [NDRC official: several water policy documents under preparation], 163, October 28, 2011, money.163.com*

*97. Weng, Jianwu and Yuansheng Chen, "Suitability Evaluation for the Construction of Decentralized Wastewater Reclamation Facilities in Beijing," Journal of Resources and Ecology, Volume 1, Issue 3, September 3, 2010, www.jorae.cn*

city's annual supply, up from 8% in 2005.[98] A number of other cities have followed by adopting policies that promote greywater recycling systems, such as Tianjin, Kunming, Shenzhen, Harbin, Dalian and Qingdao.

**A 2004-2005 study of 48 greywater systems in Beijing and Tianjin showed that fewer than half such systems were operating consistently.**

While the list of targets and standards shows progress, limitations remain. A comprehensive policy framework for greywater recycling has yet to be enacted. Furthermore, the government has focused on system installation rather than operation. A 2004-2005 study of 48 greywater systems in Beijing and Tianjin showed that fewer than half such systems were operating consistently.[99] Better pricing and incentives would encourage proper system installation, operation and maintenance.

## Greywater recycling technology is ready, and China's booming construction makes it attractive

The primary market drivers for greywater system adoption include decreasing availability of water resources and consumption limitations, improved economics following water price increases, technology improvements, and increased focus on building sustainability in high-end real estate.

China represents an attractive target for greywater systems for the following reasons:

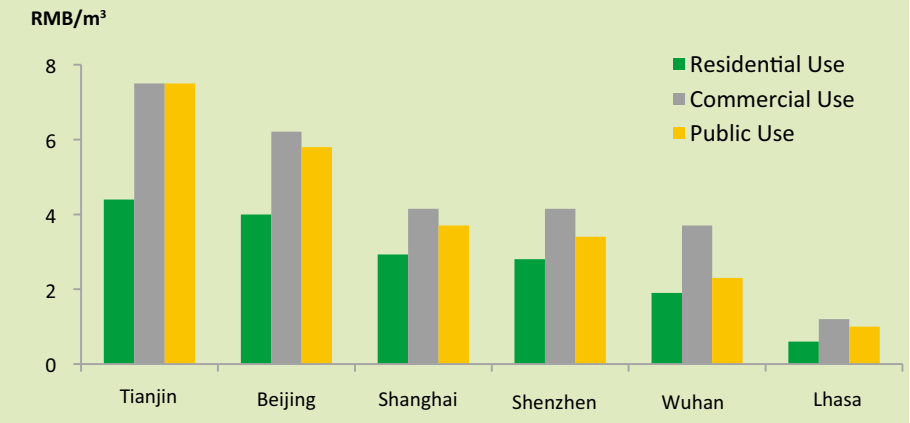
- **Ample new construction:** China has the world's largest construction market, adding over 3 billion $m^2$ of buildings annually.[100] Project economics for new construction are more attractive compared with existing buildings requiring complex retrofits of water pipe networks.
- **Growth in green buildings:** Both the Leadership in Energy Efficiency Design (LEED) and China's domestic 3-Star systems reward water efficiency initiatives, including greywater recycling. The number of LEED and 3-Star certified buildings has grown five-fold in just the last two years, with prospects for further expansion given government focus on energy and water efficiency.[101]
- **Cost-effective technologies:** Systems range from simple low-cost diversion devices for direct reuse to complex treatment and storage with sedimentation tanks, bioreactors, filters, pumps and disinfection. In China, grey and blackwater are often treated as one wastewater stream, with membrane bioreactors (MBRs) offering cost effective treatment solutions.[102]
- **Contribution to water reuse goals:** Building water consumption is expected to reach 89.2 billion $m^3$ by 2015.[103] Given that between 50% to 70% of building wastewater can be classified as greywater, recycling could go a long way to help address China's urban water supply bottlenecks.

## Municipal water prices are generally higher than greywater system operating costs

As an alternative to tap water, greywater's recycling attractiveness mainly depends on local municipal water prices. In China, water prices vary greatly across cities and user types, with spas, golf clubs and car washing at the high end and residential compounds at the low end. Water prices have risen 250% in the last 15 years, yet they are still low by world standards—water accounts for just 1-2% of household budgets compared to 2-3% worldwide, and well below 3-4% under a World Bank recommendation for promoting conservation.[104]

*98. "京再生水用量达6.8亿立方米占供水比例19%" [Beijing recycled water consumption reaches 680 million $m^3$, a 19% share of total supply], People's Daily, May 26, 2011, scitech.people.com.cn*
*99. "京津地区建筑中水设施调研报告" [Research Report on Greywater Systems in Buildings in the Beijing Tianjin Area], Water Works and Hydroenergy Planning Institute and Beijing Ecojoy Water Technology Company Ltd., 2005*
*100. China Statistical Yearbook 2010 (Beijing: National Bureau of Statistics, 2010)*
*101. "LEED Projects & Case Studies Directory," U.S. Green Building Council, www.usgbc.org, accessed on March 31, 2011; Mo, Kevin, "China Launches National Green Building Label Campaign," Switchboard, June 25, 2009, switchboard.nrdc.org*
*102. Allen, Lucy, et al., "Overview of Greywater Reuse: The Potential of Greywater Systems to Aid Sustainable Water Management," Pacific Institute, November 2010, www.pacinst.org*
*103. China Statistical Yearbook 2010 (Beijing: National Bureau of Statistics, 2010)*
*104. Powell, Simon, et al., "Falling Up! Water pricing must reflect true costs," CLSA University Blue Books, May 2010*

**Water Price in Selected Chinese Cities, per m³, 2011**




*Source: "National Water Prices," ChinaWaterNet, accessed on August 15, 2011*

Yet data on greywater system operating costs suggest that low water prices are not an insurmountable economic barrier: in many Chinese cities, operating costs are low enough to make greywater recycling attractive compared to tap water. Average costs of RMB 3.3/m³ and in some cases as low as RMB 1-1.5/m³ (for aerobic biological fluidized beds, biological aerated filters or MBRs) make greywater systems economically attractive.[105] This is especially true in the Northern cities of Beijing and Tianjin, which have the highest municipal water prices.

### Despite attractive economics, greywater system adoption has been slow

Despite attractive economics and policies for promoting greywater systems, major obstacles impede large-scale adoption. As a system provider executive from a CGTI Partner company noted, "I am rather pessimistic about the market. Though distributed greywater systems do not face technology obstacles, there is an issue of public awareness and government attitudes." Specific obstacles for the greywater market include:

**In many Chinese cities, operating costs are low enough to make greywater recycling economical compared to tap water.**

- **Fragmented greywater market:** Low barriers to entry and market fragmentation result in varying levels of equipment quality and service, lowering market confidence. Low-end systems reduce lifecycle economics and hinder long-term market acceptance.
- **Confusing greywater government oversight:** Overlapping responsibilities of major government agencies present further obstacles. The NDRC, MEP, MOHURD, the Ministry of Water Resources (MWR), their provincial- and local-level bureaus, and municipal urban planning commissions are all somewhat involved in project approval and regulation.
- **Misaligned interests:** Especially vexing is the misalignment of incentives between solution providers, building developers and owners, and water users. Greywater systems adoption is facilitated where a single entity controls initial investment decisions, system operation and maintenance, which is less frequent in the residential building segment.
- **Focus on large-scale infrastructure:** Local officials, whose careers heavily depend on local economic performance and infrastructure spending, have focused on centralized reclamation plants—or wastewater treatment plants built or retrofitted for the purpose of providing reclaimed or recycled water. For example, the Beijing Jingcheng Reclaimed Water Company supplies reclaimed

*105. "National Water Prices," ChinaWaterNet, www.h20-china.com, accessed on August 15, 2011; "京津地区建筑中水设施调研报告" [Report on distributed greywater systems for buildings in Beijing and Tianjin], MWR and Ecojoy Water Technology, 2005; CGTI analysis and Partner interviews*

water at RMB 1/$m^3$, lower than most greywater system's operating cost levels.[106]

- **Public attitudes:** As incomes rise, residents become more attuned toward water quality, which may paradoxically work against the acceptance of greywater recycling. For example, one executive from a CGTI Partner company pointed out that in Inner Mongolia payback periods for greywater systems can be as short as two years, yet many building owners are reluctant to install them because of public concerns over water quality.

## The Path Ahead

This chapter provides an update of China's Clean Water sector and three Opportunity Assessments prioritized by the CGTI research team, Partners and Advisors in 2011. As the sector evolves, participants in the China Greentech Partner Program will continue to collaborate on additional opportunities areas. The next area for research will be water efficiency in industrial processes—an increasingly important aspect for water-intensive industries facing water shortages and supply restrictions. Other research areas in 2012 may include market prospects for seawater desalination, membrane technology, and water efficiency in the oil and gas industry. Water-saving solutions for sustainable agriculture also offer strong market potential and attract interest from corporate and financial investors. CGTI will also continue to track the overall evolution of China's Clean Water sector.

Jim Gourley



106. *"京津地区建筑中水设施调研报告" [Report on distributed greywater systems for buildings in Beijing and Tianjin], MWR and Ecojoy Water Technology, 2005*

# RESEARCH METHODOLOGY

*Bruce Wu*

The *China Greentech Report 2012* is based upon consulting-style studies developed as part of the China Greentech Initiative's 2011 Partner Program. CGTI leverages an open collaborative approach to develop market insights, combining the expertise and experiences of hundreds of experts from more than 100 Partners, Advisors and Supporting Organizations, with CGTI's dedicated strategic research team. Through this unique combination of industry and functional expertise, we deliver fact-based insights and analysis beyond what any single organization could on their own.

CGTI's sector teams typically used a five-step approach to develop market insights in collaboration with Partners, Advisors and Supporting Organizations:

- **Secondary Research:** Define questions and issues to be researched, determine domestic and foreign information sources, gather and analyze information, list unanswered questions to explore via field interviews, and identify key industry experts.
- **Field Interviews:** Conduct expert interviews, test and validate preliminary findings, and integrate insights into deliverables.
- **Analyses:** Perform in-depth analysis of research, translating collected data into meaningful and actionable insights.
- **Working Sessions:** Present, discuss, refine and validate findings in interactive sector Working Sessions of 30-40 industry experts in each session.
- **Opportunity Assessments:** Incorporate sector Working Session insights and perspectives into final detailed 50-100 page studies.

Organizations involved in the China Greentech Partner Program were provided with in-depth, consulting-style Opportunity Assessments for the sectors in which they participate. This Report provides high-level summaries of these findings.

For the convenience of readers, some figures in the Report are provided in Chinese RMB and U.S. dollars, using an assumed exchange rate of RMB 6.3 per U.S. dollar, which was the approximate exchange rate as of March 2012.

Jim Gourley

# GLOSSARY

| Term | Definition |
|---|---|
| **Activated-carbon absorbents** | Form of carbon that has been processed to make it extremely porous and thus to have a very large surface area available for adsorption or chemical reactions. Due to its high degree of microporosity, just 1 gram of activated carbon has a surface area in excess of 500 $m^2$. Sufficient activation for useful applications may come solely from the high surface area, though further chemical treatment often enhances the adsorbing properties of the material. Activated carbon is usually derived from charcoal. It is also referred to as activated charcoal, activated coal or carbo activatus. |
| **Advanced meter infrastructure (AMI)** | An AMI system typically consists of three components: a "smart meter" at the customer's premise, a communications network between the smart meter and the utility, and a "meter data management application" (MDMA) at the utility. |
| **Agricultural Development Bank of China (ADBC)** | The ADBC is a Chinese Policy Bank under the People's Central Bank of China (PBOC). As such, is responsible for funding projects related to China's economic growth. |
| **Alternative fuels** | Any materials or substances that can be used as fuels, other than conventional fuels. Some well known alternative fuels include biodiesel, bioalcohol and hydrogen. Also known as non-conventional or advanced fuels. |
| **Ammonia** | Ammonia is a compound of nitrogen and hydrogen with the formula $NH_3$. It is a colourless gas with a characteristic pungent odor. Ammonia contributes significantly to the nutritional needs of terrestrial organisms by serving as a precursor to food and fertilizers. |
| **Arsenic** | Arsenic occurs in many minerals, usually in conjunction with sulfur and metals, and also as a pure elemental crystal. Arsenic is notoriously poisonous to multicellular life, although a few species of bacteria are able to use arsenic compounds as respiratory metabolites. Arsenic contamination of groundwater is a problem that affects millions of people across the world. |
| **Automatic meter reading (AMR)** | The technology of automatically collecting consumption, diagnostic, and status data from energy metering devices (water, gas and electric) and transferring that data to a central database for billing, troubleshooting and analyzing. The advantages include saving utility providers the expense of periodic trips to each physical location to read a meter, and billing based on near real time consumption rather than on estimates. |
| **Barrel** | A volume unit. A barrel of oil is defined as 42 US gallons or approximately 59 liters. |
| **Battery electric vehicle (BEV)** | Use a battery to store the electric energy that powers the motor; batteries are charged by plugging the vehicle into an electric power source. Also known as: All-electric vehicles or EV. |
| **Battery management system (BMS)** | Any electronic device that manages a rechargeable battery (cell or battery pack), such as by monitoring its state, calculating secondary data, reporting that data, protecting it, controlling its environment, and balancing it. |
| **Biodiesel** | Non-petroleum-based diesel fuel that utilizes either vegetable oil or animal fat. |

**Biogas**

Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Organic waste, such as dead plant and animal material, animal dung and kitchen waste, can be converted into a gaseous fuel called biogas. Biogas originates from biogenic material and is a type of biofuel. Biogas is produced by the anaerobic digestion or fermentation of biodegradable materials such as biomass, manure, sewage, municipal waste, green waste, plant material, and crops. Biogas comprises primarily methane ($CH_4$) and carbon dioxide ($CO_2$) and may have small amounts of hydrogen sulphide ($H_2S$), moisture and siloxanes.

**Biogas digester**

A piece of equipment which can turn organic waste into usable fuel. In addition to providing a source of renewable fuel, biogas digesters also provide low-cost fuel to people in poverty.

**Black carbon**

A climate forcing agent formed through the incomplete combustion of fossil fuels, biofuel, and biomass, and is emitted in both human activities and naturally occurring soot. Black carbon warms the Earth by absorbing heat in the atmosphere. It stays in the atmosphere for only several days to weeks.

**Blackwater**

Wastewater generated from toilet flushing which is designated sewage or blackwater to indicate it contains human waste.

**British thermal unit (Btu)**

Amount of heat required to raise the temperature of one pound of water (at or near 39.2 degrees Fahrenheit) by one degree Fahrenheit. One Btu is equal to about 252 small calories or approximately 0.3 kilocalories or 1055.1 joules. Used also as a unit of measurement for natural gas prices (1,034 Btu = 1 cubic foot of natural gas).

**Build-operate-transfer (BOT)**

Arrangement wherein the government awards a franchise license to a private sector company (including foreign companies) for a certain period of time. This in turn permits the construction and operation of a specific public infrastructure project, which is eventually transferred to the government free of charge when the concession period expires. Also known as: build-own-operate-transfer (BOOT).

**Building energy intensity**

Measurement of a building's energy efficiency calculated as units of energy per square meter.

**Building integrated photovoltaics (BIPV)**

Application of solar photovoltaic materials, whether crystalline or thin-film, into actual building structures. This normally replaces conventional building materials in parts of the building envelope, such as the roof, skylights or facades.

**Cadmium**

Cadmium occurs as a minor component in most zinc ores and therefore is a byproduct of zinc production. It was used for a long time as a pigment and for corrosion resistant plating on steel while cadmium compounds were used to stabilize plastic. With the exception of its use in nickel-cadmium batteries and cadmium telluride solar panels, the use of cadmium is generally decreasing.

**Cap-and-trade**

An environmental policy tool that constrains the aggregate emissions of regulated sources by creating a limited number of tradable emission allowances, which emission sources must secure and surrender in number equal to their emissions.

**Capacity factor**

The ratio of the actual output of a power plant over a period of time and its output if it had operated at full nameplate capacity the entire time. Capacity factors vary greatly depending on the type of fuel that is used and the design of the plant.

**Carbon capture and storage (CCS)**

A system that captures carbon dioxide from fossil fuel, either prior to or after combustion, and sequesters it for long-term storage.

**Carbon intensity**

The average emission rate of carbon dioxide from a given source relative to the intensity of a specific activity, such as per unit GDP.

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| **Carbon pricing** | A critical policy tool for achieving carbon reductions by trying to put a price on carbon through either subsidies, a carbon tax, or an emissions trading ("cap-and-trade") system. |
| **Carbon tax** | An environmental tax that is levied on the carbon content of fuels. It can be implemented by taxing the burning of fossil fuels in proportion to their carbon content. Accordingly, a carbon tax increases the competitiveness of non-carbon technologies compared to the traditional burning of fossil fuels, thus helping to protect the environment while raising revenues. |
| **Central heating systems** | Provides warmth to the whole interior of a building (or portion of a building) from one place, such as a furnace room in a house or a mechanical room in a large building, to multiple rooms. |
| **Central Number One Document** | First policy document released at the beginning of the year. This document usually highlights the main priorities for the country. |
| **Chemical oxygen demand (COD)** | A measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals, such as ammonia and nitrite. COD tests are commonly used to indirectly measure the amount of organic compounds in water. |
| **China Electricity Council (CEC)** | Founded with the approval of the State Council in 1988, China Electricity Council (CEC) is a consolidated organization of all China's power enterprises and institutions, which is also a non-profit social and economic organization operating under the supervision of the State Electricity Regulatory Commission (SERC). |
| **Chromium** | Chromium is a steely-gray, lustrous, hard metal that takes a high polish and has a high melting point. Steel can be made highly resistant to corrosion and discoloration by adding chromium to form stainless steel. This application, along with chrome plating (electroplating with chromium) are currently the highest-volume uses of the metal. |
| **Circular economy** | A model for economic growth which aims at environmental protection, pollution prevention and sustainable development. Under this model, resources are used with higher efficiency and reused and recycled when possible, so that pollution is minimized and waste is reduced as much as possible. It also involves the transformation of industrial organization and allocation, urban infrastructure, environmental protection, technological paradigms, and social welfare distribution. |
| **Cleaner rail** | Solutions that increase energy efficiency, reduce emissions and improve resource utilization in rail transportation, such as electrification of railways and low-emissions locomotives, including high-speed rail. |
| **Cleaner transportation** | Solutions that increase energy efficiency, reduce emissions and improve resource utilization to minimize negative impact of transportation on the environment; includes efficient engines, cleaner fuels, electric vehicles and road networks, and electrification of railways and low-emissions locomotives, including high-speed rail. |
| **Coal-bed methane (CBM)** | Methane originating in coal seams in a near liquid state that is drained from surface boreholes before mining takes place. |
| **Coal blending** | Process of combining various types of pulverized coal to take advantage of their different combustion and emission properties. |
| **Coal-mine methane (CMM)** | Methane contained in gases captured in a working coal mine by methane drainage systems. |
| **Coal screening and scrubbing** | Process that reduces impurities, such as ash or sulfur, contained in coal prior to burning, normally at or close to the coal mine. |
| **Coal-to-gas (CTG)** | A type of syngas produced from coal, a mixture of carbon monoxide (CO) and hydrogen ($H_2$) gas. |

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| **Coal-to-liquids (CTL)** | A process referred to as coal liquefaction – allows coal to be utilized as an alternative to oil. |
| **Combined Cooling, Heat and Power (CCHP)** | The simultaneous generation of electricity, useful heating and useful cooling from the same original heat source, such as fuel or solar energy. |
| **Combined heat and power (CHP)** | System that simultaneously generates electricity and usable heat by capturing heat that would normally be lost. |
| **Compact fluorescent lamp (CFL)** | Lamps that combine the energy efficiency of fluorescent lighting with the convenience and popularity of incandescent fixtures. Synonyms: compact fluorescent light, energy saving light, and compact fluorescent tube. |
| **Compressed air energy storage (CAES)** | During nightime and off-peak hours, a CAES systems compresses air on the surface and then pumps the air underground to a cavern or former mine. There, it is stored as an energy source. During the day and at peak times, air is released and heated using a small amount of natural gas. The heated air flows through a turbine generator to produce electricity. In conventional gas-turbine power generation, the air that drives the turbine is compressed and heated using natural gas. CAES technology needs less gas to produce power during periods of peak demand because it uses air that has already been compressed and stored underground. |
| **Compressed natural gas (CNG)** | Fossil fuel substitute for gasoline, diesel or propane made by compressing natural gas and stored in special compressed gas cylinders. |
| **Concentrated solar power (CSP)** | The type of solar energy which is created by concentrating sunlight onto a small area using mirrors and reflectors, thus creating intense light and heat, which in turn generates power and electricity. |
| **Crystalline silicon photovoltaic (PV) modules** | A packaged interconnected assembly of solar cells, which are made from a single crystal or a polycrystalline slice of silicon. It can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. |
| **Demand response management systems** | Control, operate and monitor remote assets employing open standards based systems, managing millions of endpoints, 2-way communications and verification and integrating the AMI/Smart Grid network and the utility back office systems. |
| **Demand-side management** | The implementation of policies and measures which serve to control, influence and generally reduce end users' energy demand, aiming to improve final energy systems, reduce consumption, while preserving the same level of service and comfort. |
| **Denitrification (De-$NO_x$)** | System that removes nitrogen oxides from flue gas. |
| **Desulfurization (De-$SO_x$)** | System that removes sulfur oxides from flue gas. |
| **Desalination** | Water treatment process that removes salts from water producing fresh water from brackish or seawater. |
| **Dimethyl ether (DME)** | Considered a clean burning hydrocarbon fuel, structural formula: $CH_3OCH_3$, produced by the gasification of coal or natural gas. Considered to have potential as a synthetic biofuel. |
| **Direct current line (DC line)** | Long distance transmission usually utilizes direct current (DC), because DC power travels with much less loss of energy than AC power, big DC transmission is cheaper to build than complicated AC and only DC connections can link non-synchronous systems. However, conversion costs AC-DC-AC are high. |
| **Dispatch** | Power transmission and distribution. |
| **Distribution automation** | Key component of smart grid, and can yield significant cost savings through measurable improvements to operational efficiency, reliability, service quality and energy conservation. |

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| **District heating** | A system for distributing heat generated in a centralized location for residential and commercial heating requirements, such as space heating and water heating. The heat is often obtained from a cogeneration plant burning fossil fuels but increasingly biomass, geothermal heating and central solar heating are also used. District heating plants can provide higher efficiencies and better pollution control than localized boilers. |
| **District heating systems** | District heating uses a single boiler to provide heat for a number of properties. |
| **Eco-city** | A city designed with consideration of environmental impact, inhabited by people dedicated to minimization of required inputs of energy, water and food, and waste output of heat, air pollution, and water pollution. Also known as a sustainable city. |
| **Electric vehicle (EV)** | EVs are propelled by an electric motor (or motors) powered by rechargeable battery packs. Advantages over internal combustion engines (ICEs) include higher energy efficiency, less pollution, higher performance, and reduction of energy dependence. |
| **Electrochemical battery** | Energy storage system that can generate an electromotive force (voltage) and current from chemical reactions, or the reverse, induce a chemical reaction by a flow of current. The current is caused by the reactions releasing and accepting electrons at the different ends of a conductor. A typical example of such device is a standard 1.5-volt battery. For large-scale energy storage different chemical compositions can be used, including lead-acid, lithium, vanadium and sodium sulfur. |
| **Electrolytes** | Any substance containing free ions that make the substance electrically conductive. The most typical form is an ionic solution, but molten electrolytes and solid electrolytes are also possible. |
| **Energy density (in batteries)** | Watt-hour per kilogram. |
| **Energy intensity** | A measure of the energy efficiency of a nation's economy. It is calculated as units of energy per unit of GDP. |
| **Energy management contracting (EMC)** | Outsourcing contract arrangement for energy services. |
| **Energy management solutions (EMS)** | A customizable portfolio of new and existing hardware, software and services to help improve energy efficiency and reduce greenhouse gas (GHG) emissions. |
| **Energy performance contract (EPC)** | Agreement between a building owner (or facilities manager) and a private energy services company (ESCO) to improve the energy efficiency of a building, with a savings guarantee. The ESCO is paid from these savings for the term of the contract. If none are achieved, the energy services company is not paid. Once the work is completed and the contract has ended, the full savings revert to the building owner. |
| **Energy service company (ESCO)** | A specialized commercial business providing energy efficiency solutions to industrial or commercial clients on a risk-reward basis over a specified payback period. |
| **Enhanced oil recovery (EOR)** | Solutions that increase the amount of extractable crude oil from an oil field, such as gas injection, chemical injection, ultrasonic stimulation, microbial injection or thermal recovery. |
| **Environmental tax** | A tax whose tax base is a physical unit (or a proxy of it) that has a proven specific negative impact on the environment. Four subsets of environmental taxes are distinguished: energy taxes, transport taxes, pollution taxes and resources taxes. |
| **Euro III standard** | European Union emission standard for heavy-duty vehicles as per Directive 1999/96/EC implemented in 2000 (now obsolete). |
| **Euro IV standard** | European Union emission standard for heavy-duty vehicles, as defined by Directives 2005/55/EC and Directive 2005/78/EC implemented in 2005 (now obsolete). |

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| **Feed-in tariff** | A policy mechanism designed to encourage the adoption of renewable energy sources and to help accelerate the move toward grid parity. Under a feed-in tariff, eligible renewable electricity generators are paid a premium price for any renewable electricity they produce. Typically regional or national electric grid utilities are obligated to take the electricity and pay them. |
| **Fiber optic power line connection** | A system for carrying data on a conductor also used for electric power transmission. A wide range of technologies are needed for different applications, ranging from home automation to Internet access. Also referred to as broadband over power line (BPL), power line communication (PLC), power line digital subscriber line (PDSL), mains communication, power line telecom (PLT), and power line networking (PLN). |
| **First-tier cities** | Shanghai, Beijing, Guangzhou and Shenzhen. |
| **Flexible alternating current transmission solutions (FACTS)** | The term FACTS refers to a number of technologies that enhance the security, capacity and flexibility of power transmission systems. FACTS solutions enable power grid owners to increase existing transmission network capacity while maintaining or improving the operating margins necessary for grid stability. As a result, more power can reach consumers with a minimum impact on the environment, after substantially shorter project implementation times, and at lower investment costs - all compared to the alternative of building new transmission lines or power generation facilities. |
| **Fly-ash** | Fly ash is the solid, particulate residue generated during combustion that rises with flue gas due to its high degree of fineness. |
| **Flywheel energy storage (FES)** | These systems work by accelerating a rotor (flywheel) to a very high speed and maintaining the energy in the system as rotational energy. When energy is extracted from the system, the flywheel's rotational speed is reduced as a consequence of the principle of conservation of energy; adding energy to the system correspondingly results in an increase in the speed of the flywheel. Most FES systems use electricity to accelerate and decelerate the flywheel, but devices that directly use mechanical energy are being developed. |
| **Fuel cell** | Device that generates electricity by a chemical reaction using hydrogen as basic fuel. |
| **Gasification** | Method that extracts energy from organic materials. Carbon-based matter (e.g. coal) reacts at high temperatures with oxygen producing synthesis gas. Process can be more efficient than direct combustion of carbon material and is considered to be more environmentally sound. |
| **Greywater** | Greywater is lightly-contamined wastewater generated from domestic activities such as laundry, dishwashing, and bathing, which can be recycled on-site for potable and most often non-potable uses, such as toilet flushing, landscape irrigation or street cleaning. |
| **Grid connection** | Physical connection between the power generation utility and the grid. |
| **Grid connectivity** | Qualitative connection of power generation utility to the grid. |
| **GW** | Equivalent to one billion (109) watts or 1,000 megawatts. |
| **Heating, ventilation and air conditioning (HVAC)** | Climate control system of buildings; it ensures that room temperature, humidity and air flow are adequate to sustain a comfortable living environment. |
| **High-speed electric vehicles** | Vehicles that travels at speeds of more than 100 km/hour. |
| **High-speed magnetic-levitation (Maglev)** | A system of transportation that suspends, guides and propels vehicles, predominantly trains, using magnetic levitation from a very large number of magnets for lift and propulsion. This method has the potential to be faster, quieter and smoother than wheeled mass transit systems. |

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| **High-speed rail (HSR)** | A type of passenger rail transport that operates significantly faster than the normal speed of rail traffic. In China, it refers to any commercial train service with an average speed of 200 km/h (120 mph) or higher. |
| **Hybrid electric vehicles (HEVs)** | Powered by conventional or alternative fuels as well as electric power stored in a battery. HEVs use regenerative braking and the internal combustion engine (ICE) to charge. |
| **Hybridization** | The extent to which electricity power plays a role in the low-speed driving course of vehicles. |
| **Indoor air quality (IAQ)** | Refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants. It is impacted by indoor pollution sources that release gases or particles into the air, inadequate ventilation, high temperature and humidity levels. |
| **Integrated gasification combined cycle (IGCC)** | System that turns coal into synthesis gas and removes impurities before combusting it in gas turbines; the waste heat is captured and passed to a steam turbine system for energy recovery. |
| **Intellectual property (IP)** | Creations of the mind: inventions, literary and artistic works, and symbols, names, images, and designs used in commerce. Common types of intellectual property include copyrights, trademarks, patents, industrial design rights and trade secrets in some jurisdictions. |
| **Intermittent power** | Non-continuous power production by solar and wind. Also known as variability. |
| **International Electrotechnical Commission (IEC)** | Founded in 1906, the IEC is the world's leading organization for the preparation and publication of International Standards for all electrical, electronic and related technologies. These are known collectively as "electrotechnology". IEC provides a platform to companies, industries and governments for meeting, discussing and developing the International Standards they require, on a consensus basis. |
| **Inverter** | An electrical device that converts direct current to alternating current. |
| **Landfill** | A landfill is a site for the disposal of waste materials by burial and is the oldest form of waste treatment. Historically, landfills have been the most common methods of organized waste disposal and remain so in many places around the world. Many landfills are also used for waste management purposes, such as the temporary storage, consolidation and transfer, or processing of waste material (sorting, treatment or recycling). |
| **Lead** | Lead is a soft, malleable poor metal used in building construction, lead-acid batteries, bullets and shots, weights, as part of solders, pewters, fusible alloys and as a radiation shield. Lead, at certain exposure levels, is considered a poisonous substance. |
| **Lease contract** | Short-term contract where private partner pays a fee to the government for asset operation. |
| **Lifecycle analysis (LCA)** | A technique to assess the environmental aspects and potential impacts associated with a product, process, or service from-cradle-to-grave. |
| **Light-emitting diode (LED) lamp** | Lamp based on electroluminescence through light-emitting-diodes (LEDs). The LEDs involved may be conventional semiconductor light-emitting diodes, to organic LEDs (OLED), or polymer light-emitting diodes (PLED) devices. |
| **Liquefied natural gas (LNG)** | Natural gas temporarily converted into liquid form in order to ensure ease of storage and transport. The reduction in volume is accomplished by cooling the gas until it becomes liquid. |

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| **Liquid propane gas (LPG)** | Mixture of hydrocarbon gases (typically propane) that are synthesized from petroleum. It is a low-carbon emitting fuel source for powering appliances and vehicles. |
| **Lithium-ion battery** | Known for their use in consumer electronics, as well as increasingly being used in pure electric vehicles applications. Compared to nickel-metal hydride batteries, Li-Ion batteries enjoy a higher energy density, longer life cycle, more rapid charge and perform better in colder weather. |
| **Loss reduction** | Reduction of energy loss through resistance in the transmission line. |
| **Low-flow fixtures** | Refers to plumbing and point-of-use solutions or fixtures which deliver an equivalent level of service while using fewer volumes of water compared to traditional fixtures. These can include water-efficient urinals, toilets, showers and hand basins. |
| **Low-speed electric vehicle (LSEV)** | Vehicles that travel at a maximum speed of 40 km/hour. LSEVs are best suited for short, intra-city trips or short trips in rural areas, may be suited for limited travel within urban areas. Also known as neighborhood electric vehicles. |
| **Low-voltage ride-through (LVRT)** | Technology that improves connectivity by allowing wind and solar farms to remain connected to the grid when voltage drops off, in turn protecting turbines against grid disturbances. |
| **Mechanically switched capacitors (MSC)** | The capacitor is an example of static var compensator (SVC). It is switched by circuit-breaker, usually only a few times a day, and aims at compensating steady state reactive power. |
| **Membrane technology** | Covers all process engineering measures for the transport of substances between two fractions with the help of permeable membranes. About half of the market has applications in medicine. The importance of membrane technology is growing in the field of environmental protection. In the water industry membranes have applications for drinking water treatment, seawater desalination and wastewater treatment and reuse. Common technologies adopted include reverse osmosis (RO), micro-filtration (MF), ultra-filtration (UF), and multiple-effect distillation (MED). |
| **Mercury** | Mercury is the only metal that is liquid at standard conditions for temperature and pressure. Mercury poisoning can result from exposure to water-soluble forms of mercury, inhalation of mercury vapor, or eating seafood contaminated with mercury. Mercury is used in thermometers, barometers, manometers, float valves, some electrical switches and lighting, among others. |
| **Ministry of Environmental Protection (MEP)** | Cabinet-level ministry replacing the State Environmental Protection Administration (SEPA) since 2008. The Ministry is the nation's environmental protection department charged with the task of protecting China's air, water and land from pollution and contamination. Directly under the State Council, it is empowered and required by law to implement environmental policies and enforce environmental laws and regulations. Complementing its regulatory role, it funds and organizes research and development. MEP also serves as China's nuclear safety agency. |
| **Ministry of Housing and Urban-Rural Development (MOHURD)** | Ministry under the jurisdiction of the State Council of China. It provides housing and regulates the state construction activities in the country. It was formerly known as the Ministry of Construction. |
| **Ministry of Industry and Information Technology (MIIT)** | The Ministry responsible for regulation and development of the postal service, Internet, wireless, broadcasting, communications, production of electronic and information goods, software industry and the promotion of the national knowledge economy. It is not responsible for the regulation of content for the media industry, which is instead administered by the State Administration of Radio, Film and Television. |

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| **Ministry of Land and Resources (MLR)** | The Ministry under the jurisdiction of the State Council of China. It is responsible for the regulation, management, preservation and exploitation of natural resources, such as land, mines and oceans. |
| **Ministry of Water Resources (MWR)** | The Ministry under the jurisdiction of the State Council of China. It is responsible for the regulation, management, preservation and exploitation of the country's surface and underground water resources. Previously the Ministry of Water Resources and Electric Power. |
| **Municipal solid waste (MSW)** | A combination of residential waste (including food scraps, packaging plastics, paper, electronics), commercial waste from offices, restaurants (including waste cooking oil), and non-process waste from industry. |
| **National Development and Reform Commission (NDRC)** | The Macroeconomic management agency under the Chinese State Council, which has broad administrative and planning control over the Chinese economy. NDRC studies and formulate policies for economic and social development, maintains the balance of economic development, and guides the restructuring of China's economic system. Formerly the State Planning Commission and State Development Planning Commission. |
| **National Planning Commission (NPC)** | Predecessor of National Development and Reform Commission (NDRC). It was established in 1952 and was reorganized in 2008 during the 11th National People's Congress to form the actual NDRC. |
| **Natural gas combined cycle (NGCC)** | Systems that generate electricity using gas turbines, which then capture waste heat to generate steam and additional electricity using a steam turbine. |
| **New energy vehicle (NEV)** | NEV is defined by the Ministry of Industry and Information Technology (MIIT) as vehicles that use unconventional fuel power as their power source (or use conventional fuels with a new drive system) integrated with advanced drive and control technologies to form a new technology platform and vehicle system. |
| **Oil sands** | A type of unconventional petroleum deposit. The sands contain naturally occurring mixtures of sand, clay, water, and a dense and extremely viscous form of petroleum. Oil sands are found in large amounts in many countries throughout the world, but are found in extremely large quantities in Canada and Venezuela. |
| **Operating reserves** | Provide the power difference between supply and demand in lag period by instantaneous regulation and manage unplanned outages (or failures) of generating capacity and transmission lines and/or unexpected surges in electricity demand. |
| **Photocatalyst systems** | Systems which employ photocatalysis, catalysed photolysis, which is the degradation of chemical compounds by absorption of UV-light. Applications include water treatment and water splitting. |
| **Plug-in hybrid electric vehicle (PHEV)** | Hybrid with an extension cord that can be plugged in to any 120-volt outlet to recharged. |
| **Polygeneration** | Polygeneration involves the gasification (or conversion) of coal to produce synthesis gas (syngas) that can be simultaneously used for the generation of electricity and in the manufacture of chemicals and liquid fuels. |
| **Powertrain** | A group of components that generate power which is delivered to the road surface, water or air. Powertrains include the engine, transmission, driveshafts, differentials, and the final drive. |
| **Prediction technology** | Includes weather and wind prediction methods, such as drawing on meteorological data from the upper air, and topographical and land use data. |
| **Premise** | In this report premise refers to demand-side solutions for end users. |
| **Public-private partnership (PPP)** | Government service or private business venture which is funded and operated through a partnership of government and one or more private sector companies. |

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| **Pumped-storage hydroelectricity** | Pumped-storage hydroelectricity refers to a method where energy is stored in the form of water, pumped from a lower elevation reservoir to a higher elevation. Low-cost off-peak electric power is used to run the pumps. During periods of high electrical demand, the stored water is released through turbines to produce electric power. Pumped storage is the largest-capacity form of grid energy storage available worldwide. |
| **Renewable energy** | Energy produced from sources that are naturally replenishing, such as sunlight, wind, waves, underground heat, surface water flows and biomass. |
| **Renewable energy surcharge** | Surcharge collected from a majority of electricity end users to compensate grid companies for higher feed-in tariff paid for renewable energy source than coal-fired power plants. |
| **Resource tax** | A kind of tax to help ensure the long run sustainability to make people be more aware of natural resource consumption. These taxes can be levied on volume or price. |
| **Second-tier cities** | Secondary provincial capitals. |
| **Selective catalyst reduction (SCR)** | Post combustion nitrogen oxides ($NO_x$) control technology capable of achieving $NO_x$ reduction in excess of 95% by converting $NO_x$ into less harmful compounds such as diatomic nitrogen, $N_2$, and water, $H_2O$. A gaseous reductant, typically anhydrous ammonia, aqueous ammonia or urea, is added to a stream of flue or exhaust gas and is absorbed onto a catalyst. |
| **Separator** | A separator is a porous membrane placed between electrodes of opposite polarity, that is permeable to ionic flow, but prevents electric contact of the electrodes. |
| **Series compensation (SC)** | In series compensation, the flexible alternating current transmission (FACTS) is connected in series with the power system. It works as a controllable voltage source. Series inductance exists in all AC transmission lines. On long lines, when a large current flows, this causes a large voltage drop. To compensate, series capacitors are connected, decreasing the effect of the inductance. |
| **Shale Gas** | Natural gas that is trapped within shale formations. |
| **Sludge treatment** | Processes used to manage and dispose of sludge produced during sewage treatment. |
| **Smart appliance** | Smart appliances include various types of digital devices typically deployed in the home and supporting automatic or pre-determined adjustments enabled by a home network supporting two-way communication flows. An example of smart appliance is a washing machine programmed to run during off-peak hours and communicate with the home meter to determine when the next off-peak period starts. The machine would then automatically start without requiring manual intervention. |
| **Smart dispatch supporting systems** | Provides a better holistic and forward-looking view of system conditions and generation patterns, e.g. by incorporating renewable forecasts (wind and sun), demand response capabilities, carbon constraints, estimates for distributed generation and storage. These systems also allow for quick compliance and adaptation to changes in local electricity regulations. |
| **Smart grid** | Networks supported by digital technology capable of exerting "smart control" over all aspects of the electric power sector (including generation, transmission, distribution, customer service and power dispatch at all voltage levels). They deliver power in an efficient manner and can better integrate power from renewable sources. |
| **Smart lighting** | Lighting systems with adaptive and controllable properties, such as spectral content, emission pattern, polarization, color temperature and intensity, which simultaneously supply data to audio/visual and computing devices, and optically sense environment for harmful biological or chemical agents. |

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| **Smart meter** | Electricity monitoring devices with two-way communication capabilities, allowing utilities and customers to analyze energy use. China's definition includes both automatic meter reading (AMR) and advanced meter infrastructure (AMI). |
| **Smart substation** | The concept of a smart substation has been introduced using intelligent and ubiquitous IT techniques for more efficient and economical management of substations. Smart substations include hardware, functions and communication interfaces to allow substations to operate to some degree of automation and remoteness. |
| **Spin-off** | The common definition of spin-out is when a division of a company or organization becomes an independent business. The "spin-out" or "spin-off" company takes assets, intellectual property, technology, and/or existing products from the parent organization. Shareholders of the parent company receive equivalent shares in the new company in order to compensate for the loss of equity in the original stocks; thus, at the moment of spin-off, the ownership of the original and spun-off companies are identical. |
| **Solar photovoltaics (PV)** | Devices that convert light into direct current using the photoelectric effect. Solar PVs are the main technology used in China for the generation of electric solar power. |
| **South-to-North Water Diversion Project (SNWD)** | Planned for completion in 2050, the project involves drawing water from Southern rivers and supplying it to the dry north via three diversion routes, stretching south-to-north across the Eastern, Central and Western parts of the country. When finished, the work will link China's four main rivers – the Yangtze, Yellow River, Huaihe and Haihe. |
| **State Council (SC)** | The chief administrative authority of China. It is chaired by the Premier and includes the heads of each governmental department and agency. Currently, the council has 35 members: the premier, one executive vice premier, three vice premiers, five state councilors (of whom two are also ministers), and 25 additional ministers and chairs of major agencies. The State Council directly oversees the various subordinate People's Governments in the provinces, and in practice maintains an interlocking membership with the top levels of the Communist Party of China creating a fused center of power. |
| **State Electricity Regulation Commission (SERC)** | Government agency responsible for administration and regulation the electricity and power industry. This includes regulating the development of electricity markets, setting tariffs, transmission, distribution, safety standards, technical standards, business licenses, environmental laws and development of the industry. |
| **Strategic emerging industry (SEI)** | Seven industries that receive special support in the 12th Five-year plan period: energy saving and environment protection, new energy, new energy vehicles, new materials, high-end equipment manufacturing, next generation IT, and biotechnology. |
| **Static var compensator (SVC)** | Electrical device for providing fast-acting reactive power on high-voltage electricity transmission networks. SVCs are part of the flexible AC transmission system device family, regulating voltage and stabilizing the system. The term "static" refers to the fact that the SVC has no moving parts (other than circuit breakers and disconnects, which do not move under normal SVC operation). The SVC is an automated impedance matching device, designed to bring the system closer to unity power factor. SVCs are used in two main situations: connection to the power system, to regulate the transmission voltage ("transmission SVC") and connection near large industrial loads to improve power quality ("industrial SVC"). |
| **Smart substation** | Encompasses entire lifecycle of substation infrastructure not only facilitating the transformation of voltage levels and distribution of electrical power, but also providing services, such as security, monitoring, peak load management, feeder outage management, data access and integration automation. |

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| **Strong and Smart Grid** | Official name of China's electric power infrastructure development plan announced in 2009 with a view to build a reliable, extensive and smart grid. The plan extends from 2009 to 2020 and consists of three phases: Pilot, Construction and Industrialization. The plan notably includes ambitious targets for development of ultra-high voltage (UHV) lines across the country, emphasis on renewable energy storage and improved connectivity with the grid, as well as demand-side solutions such as electric vehicle charging infrastructure, smart meters and intelligent communities. |
| **Sulfur scrubbing** | An action of removing harmful gas sulfur dioxide from the exhaust flue gases of fossil fuel power plants. |
| **Supply-chain operations reference (SCOR) model** | A process reference model that has been developed and endorsed by the Supply Chain Council as the cross-industry standard diagnostic tool for supply chain management. |
| **Sustainable indoor environment (SIE)** | Sustainable indoor environments promote daylighting, natural ventilation, and interiors that are free of toxins. The result is an interior environment that safeguards occupant health and reduces operating costs. |
| **Tens of Cities, Thousands of Vehicles Program** | 13 pilot cities (25 as of 2010) promoted a certain number of electric vehicles ranging from 1,000 to 9,000 in the public sector by 2012. The central government pledged subsidies of up to RMB 420,000 (US$ 64,615) per hybrid bus, RMB 500,000 (US$ 76,923) per fully electric bus and RMB 600,000 (US$ 92,307) per fuel cell bus. |
| **Terawatt hours (TWh)** | A unit for a large amount of electricity. 1 TWh equals 109 kWh. |
| **Third-tier cities** | Prefecture or county-level city capitals. |
| **Tiered pricing** | In the case of electricity prices, tiered pricing is a mechanism which sets different prices for different levels of consumption, usually with a higher rate for electricity consumption exceeding a predetermined threshold. |
| **Time-of-use pricing** | Refers to different levels of pricing charged depending on a time element. It usually includes a lower rate for off-peak hours and a higher rate for peak-hours when demand is highest. |
| **Tons of coal equivalent (TCE)** | Unit representing energy generated by burning one metric ton (1,000 kilograms or 2,204.7 pounds) of coal, equivalent to the energy obtained from burning 5.2 barrels (700 kilograms) of oil or 890 cubic meters of natural gas. The energy generated is equivalent to 29.4 gigajoules (GJ), 27.8 million Btu (MMBtu), or 8.1 megawatt hours (MWh). |
| **Ultra-high voltage (UHV) transmission** | Voltages of 1,000 kV AC or higher and 800 kV DC or higher. UHV enables the delivery of large quantities of power over very long distances with very little loss of power. Higher voltage means lower current on the transmission line and therefore lower loss. |
| **Vehicle-to-grid Technology (V2G)** | An integrated network between the grid and EVs. During hours of low power consumption, energy from the grid is stored in grid-connected batteries and vehicle owners are charged according to prevailing tariffs. |
| **Voltage-source converter (VSC)** | These may be installed in existing AC grids for their role in stabilizing power flow without the additional short-circuit current that would be produced by an additional AC transmission line. There are several different variants of VSC technology: most "HVDC Light" installations use pulse width modulation but the most recent installations, along with "HVDC PLUS" and "HVDC MaxSine," are based on multilevel switching. Multilevel switching has the advantage in that it allows the harmonic filtering equipment to be reduced or eliminated altogether. |
| **Waste-to-energy (WtE)** | The process of creating energy in the form of electricity or heat from the incineration of waste source. |
| **Wastewater treatment** | Collection and treatment of water discharged after consumption for either secondary consumption or release into the environment. |

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|---|---|
| **Water distribution** | Transportation of water to end users. |
| **Water extraction** | Provision or extraction of water resources from the biosphere to original water rights holders. |
| **Water reclamation** | Process by which wastewater from residential, commercial and industrial users is treated to be reused in commercial or environmental remediation projects. Also referred to as water reuse. |
| **Water treatment** | Processes by which raw water is made ready for use. |
| **Watt peak (Wp)** | A measure of the nominal power of a photovoltaic solar energy device under laboratory illumination conditions. The nominal power of the module in "Wp" is the maximum power measured. |

*Steve Bale*

# ACRONYMS

Bruce Wu

| Term | Definition |
|---|---|
| **AC** | Alternating current |
| **ADB** | Asian Development Bank |
| **ADBC** | Agricultural Development Bank of China |
| **AMI** | Advanced metering infrastructure |
| **AMR** | Automatic meter reading |
| **AQI** | Air quality index |
| **ASP** | Average selling price |
| **B-CHP** | Building cooling, heating and power |
| **BIPV** | Building-integrated photovoltaic |
| **BOT** | Build-operate-transfer |
| **Btu** | British thermal units |
| **CAAM** | China Association of Automobile Manufacturers |
| **CADB** | China Agricultural Development Bank |
| **CAI** | Clean Air Initiative |
| **CAS** | Chinese Academy of Sciences |
| **CATARC** | China Automotive Technology and Research Center |
| **CCHP** | Combined cooling, heating and power |
| **CEC** | China Electricity Council |
| **CEPRI** | China Electric Power Research Institute |

| Term | Definition |
|---|---|
| **CER** | Certified emission reduction |
| **CET** | China Electric Power Equipment and Technology Co., Ltd. |
| **CFL** | Compact fluorescent lamp |
| **CGTI** | China Greentech Initiative |
| **$CH_4$** | Methane gas |
| **CIAE** | China Institute of Atomic Energy |
| **CIC** | China Investment Corporation |
| **CNEC** | China Nuclear Engineering Corporation |
| **CNG** | Compressed natural gas |
| **CNNC** | China National Nuclear Corporation |
| **CNOOC** | China National Offshore Oil Corporation |
| **CNPC** | China National Petroleum Corporation |
| **CO** | Carbon monoxide |
| **$CO_2$** | Carbon dioxide |
| **COD** | Chemical oxygen demand |
| **COSTIND** | Commission of Science, Technology, and Industry for National Defense |
| **CPPCC** | Chinese People's Political Consultative Conference |
| **CREIA** | China Renewable Energy Industries Association |
| **CSP** | Concentrated solar power |

| Term | Definition |
|---|---|
| **CTG** | Coal-to-gas |
| **CTL** | Coal-to-liquids |
| **CTM** | Coal-to-methanol |
| **CTO** | Coal-to-olefin |
| **CUCBM** | China United Coal-Bed Methane Corporation |
| **CVT** | Continuously variable transmission |
| **DC** | Direct current |
| **De-$NO_x$** | Denitrification |
| **De-$SO_x$** | Desulfurization |
| **DME** | Dimethyl ether |
| **DOE** | (U.S.) Department of Energy |
| **DRC** | Development Research Center |
| **E10** | Mixture of 10% ethanol and 90% gasoline |
| **E&P** | Exploration and production |
| **EDP** | Eletricidad de Portugal |
| **EER** | Energy efficiency rate |
| **EIA** | (U.S.) Energy Information Administration |
| **EMCA** | Energy Management Company Association |
| **EPA** | (U.S.) Environmental Protection Agency |
| **EPB** | Environmental Protection Bureau |
| **EPC** | Engineering, procurement and construction |
| **EPIA** | European Photovoltaic Industry Association |
| **EPS** | Expandable polystyrene |
| **ESCO** | Energy service company |
| **EV** | Electric vehicle |
| **FACTS** | Flexible alternating current transmission solutions |

| Term | Definition |
|---|---|
| **FAO** | (U.N.) Food and Agriculture Organization |
| **FAW** | First Automobile Works |
| **FDI** | Foreign direct investment |
| **FiT** | Feed-in tariff |
| **GDI** | Gasoline direct injection |
| **GDP** | Gross domestic product |
| **GTZ** | German Technical Cooperation |
| **GW** | Gigawatt |
| **HCP-B** | Heating, cooling and power for buildings |
| **HEV** | Hybrid electric vehicle |
| **HVAC** | Heating, ventilation and air conditioning |
| **ICCT** | International Council on Clean Transportation |
| **ICE** | Internal combustion engine |
| **IEA** | International Energy Agency |
| **IEC** | International Electrotechnical Commission |
| **IEEE** | Institute of Electrical and Electronics Engineers |
| **IEEJ** | Institute of Energy Economics, Japan |
| **IFC** | International Finance Corporation |
| **IGCC** | Integrated gasification combined cycle |
| **IMF** | International Monetary Fund |
| **IP** | Intellectual property |
| **IPO** | Initial public offering |
| **IRR** | Internal rate of return |
| **ITC** | (U.S.) International Trade Commission |
| **JV** | Joint venture |
| **KKR** | Kohlberg Kravis Roberts |

| Term | Definition |
|---|---|
| **KPI** | Key performance indicator |
| **kWh** | Kilowatt hour |
| **kWp** | Kilowatt peak |
| **LDEV** | Light-duty electric vehicle |
| **LDI** | Local design institute |
| **LDV** | Light-duty vehicle |
| **LED** | Light-emitting diode |
| **LEED** | Leadership in Energy and Environmental Design |
| **LEV** | Light-duty vehicle |
| **$LiCoO_2$** | Lithium cobalt oxide |
| **$LiFePO_4$** | Lithium iron phosphate |
| **Li-ion** | Lithium ion |
| **$LiMnO_2$** | Lithium manganese oxide |
| **$LiPF_6$** | Hexafluorophosphate |
| **LNB** | Low-$NO_x$ burners |
| **LNG** | Liquefied natural gas |
| **LPG** | Liquefied petroleum gas |
| **LVRT** | Low-voltage ride-through |
| **M&A** | Mergers and acquisitions |
| **MBR** | Membrane bioreactor |
| **MEP** | Ministry of Environmental Protection |
| **MIIT** | Ministry of Industry and Information Technology |
| **MLR** | Ministry of Land and Resources |
| **MOF** | Ministry of Finance |
| **MOFCOM** | Ministry of Commerce |
| **MOHURD** | Ministry of Housing and Urban-Rural Development |

| Term | Definition |
|---|---|
| **MOST** | Ministry of Science and Technology |
| **MSC** | Mechanically switched capacitors |
| **MSW** | Municipal solid waste |
| **MTO** | Methanol-to-olefin |
| **MW** | Megawatt |
| **MWR** | Ministry of Water Resources |
| **$N_2O$** | Nitrous oxide |
| **NaS** | Sodium sulfur |
| **NDRC** | National Development and Reform Commission |
| **NEA** | National Energy Administration |
| **NEV** | New energy vehicle |
| **NGCC** | Natural gas combined cycle |
| **NNSA** | National Nuclear Safety Administration |
| **$NO_x$** | Oxides of nitrogen |
| **NPC** | National Planning Commission |
| **O&M** | Operations and maintenance |
| **ODI** | Outbound direct investment |
| **ODP** | Overall development plan |
| **OEM** | Original equipment manufacturer |
| **OPLC** | Optical power line communication |
| **PE** | Private equity |
| **PEV** | Plug-in electric vehicle |
| **PE/VC** | Private equity and venture capital |
| **PHEV** | Plug-in hybrid electric vehicle |
| **PIFC** | Platform of investment and financing company |
| **PM2.5** | Particulate matter smaller than 2.5 micrometers |

| Term | Definition |
|---|---|
| **PM10** | Particulate matter smaller than 10 micrometers |
| **PPM** | Parts-per-million |
| **PPP** | Public-private partnership |
| **PSC** | Production sharing contract |
| **PU** | Polyurethane |
| **PV** | Photovoltaic |
| **R&D** | Research and development |
| **REN** | Redes Energéticas Nacionais |
| **RIET** | Research Institute of Economics and Technology |
| **SAIC** | Shanghai Automotive Industry Corporation |
| **SAT** | State Administration of Taxation |
| **SC** | Series compensation |
| **SCR** | Selective catalyst reduction |
| **SDIC** | State Development & Investment Corporation |
| **SEI** | Strategic emerging industry |
| **SEIA** | Solar Energy Industries Association |
| **SEPG** | Shanghai Environmental Protection Group |
| **SERC** | State Electricity Regulatory Commission |
| **SEU** | Sustainable energy utility |
| **SNCR** | Selective non-catalytic reduction |
| **SNWD** | South-to-North Water Diversion Project |
| **$SO_2$** | Sulfur dioxide |
| **SOE** | State-owned enterprise |
| **SVR** | Static var compensator |
| **tcf** | Trillion cubic feet |
| **TCO** | Total cost of ownership |
| **TWh** | Terawatt-hours |
| **UHV** | Ultra-high voltage |
| **UHVDC** | UHV direct current |
| **USGBC** | U.S. Green Building Council |
| **UV** | Ultraviolet |
| **V2G** | Vehicle-to-grid |
| **VAT** | Value-added tax |
| **VC** | Venture capital |
| **VECC** | Vehicle Emission Control Center |
| **VOC** | Volatile organic compounds |
| **VRB** | Vanadium redox battery |
| **VSC** | Voltage-source converter |
| **VVT/L** | Variable valve timing and lift |
| **WHO** | World Health Organization |
| **WtE** | Waste-to-energy |

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Steve Bale

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# ABOUT THE CHINA GREENTECH INITIATIVE

Jim Gourley

中国绿色科技
China Greentech Initiative
Strategic Insights, Industry Collaboration, Market Acceleration

The China Greentech Initiative (CGTI) accelerates the success of our Chinese and international Partner companies in China's greentech markets. Leveraging our insight-enabled platform, we help our Partners:

- Make informed decisions on emerging market opportunities
- Develop commercial partnerships based on meaningful industry and policy maker relationships
- Position themselves as thought leaders and educate stakeholders with the co-branded *China Greentech Report* and other publications

CGTI integrates commercial and policy organizations with strategic capabilities to create a one-of-a-kind, insight-enabled platform focused on accelerating China's greentech markets. The CGTI platform includes the China Greentech Partner Program and Partner-specific Advisory Services.

Now in its fifth year, the China Greentech Partner Program consists of more than 500 senior decision makers coming from 100+ commercial and policy organizations. Partnering organizations include technology buyers and sellers, service providers, investors and policymakers. Partners (the participants) in CGTI's Partner Program are empowered by CGTI's strategic research, ecosystem development, partner services, online services and market promotion.

Guided by the China Greentech Council, a leadership group within the Partner Program, the 2012 Partner Program agenda focuses on five priority market plays: next generation energy value chain; energy, water and waste in the built environment; electric vehicles; low carbon zones; and sustainability. By investing in these five market plays, CGTI will enable cross-sector ecosystems to help China achieve and exceed 2015 targets, and increase the commercial success of our Partners.

CGTI's Advisory Services provide Partner companies and organizations with tailored projects to meet specific needs that are beyond the scope of what the Partner Program provides. CGTI's Advisory Services include custom strategic market studies, Partner matchmaking, custom thought leadership and education products and services.

Organizations pay an annual fee to participate in the Partner Program. Advisory Services, which are only provided to clients who are part of the Partner Program, are project-based. For more information about the China Greentech Initiative please visit www.china-greentech.com or contact cgti@china-greentech.com.

CGTI is an offering of Greentech Networks Limited, a Hong Kong based company, operating in China through its Wholly Owned Foreign Enterprise Greentech Networks Advisory (Beijing) Limited (绿科创合咨询顾问（北京）有限公司).

Chelsea Eakin

# PARTNERS, SUPPORTING ORGANIZATIONS AND ADVISORS

## Strategic Partner

### PwC

## Profile

**PwC** firms help organizations and individuals create the value they're looking for. We're a network of firms in 158 countries with close to 169,000 people who are committed to delivering quality in assurance, tax and advisory services. "PwC" is the brand under which member firms of PricewaterhouseCoopers International Limited (PwCIL) operate and provide services. Together, these firms form the PwC network. Each firm in the network is a separate legal entity and does not act as agent of PwCIL or any other member firm. PwCIL does not provide any services to clients. PwCIL is not responsible or liable for the acts or omissions of any of its member firms nor can it control the exercise of their professional judgment or bind them in any way.
Website: www.pwc.com

## Major Partners

### HAO Capital

**HAO Capital** is a China focused Private Equity firm based in Beijing and Hong Kong, providing growth capital to Chinese companies. Founded in 2005 by three seasoned investment professionals, we currently manage total assets of US$ 500 million across two funds. We are biased for investments in Consumer, Healthcare and Light Industrial, including Clean/Greentech.
Website: www.HAOcapital.com

### APCO Worldwide

**APCO Worldwide** is a global consulting firm and a leading provider of government relations, strategic communication, corporate responsibility and corporate advisory services in China. We have been serving clients' interests in China since 1989. Today, our China team includes more than 100 professionals from a diverse range of backgrounds, including business, government, journalism, academic and civil society. We are based in Beijing, Shanghai, Guangzhou and Hong Kong.
Website: www.apcoworldwide.com

### BP

**BP** is one of the world's largest energy companies, providing its customers with fuel for transportation, energy for heat and light, retail services and petrochemicals. BP has transformed from a local oil company into a global energy group; employing over 80,000 people and operating in over 100 countries worldwide.
Website: www.bp.com.cn

### Dorsey & Whitney LLP

Clients have relied on **Dorsey & Whitney LLP** as a valued business partner since 1912. Our Cleantech Industry Group has the privilege of serving hundreds of cleantech companies and investors across the globe, including many of the sector's most promising early and late stage technology companies. Our group integrates over 70 lawyers located across offices in the United States, Canada, Europe, Asia and Australia, and practicing in a variety of specialty areas, including corporate finance, private equity, project finance, energy regulatory, tax, intellectual property, advocacy and others. This broad array of specialty practices allows the group to offer clients seamless service throughout their life cycle – from assistance with early stage venture financings, intellectual property counseling and patent procurement to mid-stage project financings and later stage capital markets and merger and acquisition transactions.
Website: www.dorsey.com

**GE**

**GE** (NYSE: GE) works on things that matter. The best people and the best technologies taking on the toughest challenges. Finding solutions in energy, health and home, transportation and finance. Building, powering, moving and curing the world. Not just imagining. Doing. GE works.
Website: www.ge.com

**Holcim**

**Holcim** is one of the world's largest suppliers of cement, aggregates and ready-mix concrete. With 100 years' development, today the Group holds operations in 70 countries on all continents. Holcim is recognised as a pioneer in sustainable development and has been the leading building material company in the Dow Jones Sustainability Index for the last 8 years. Holcim has 20 years experience in the China building materials industry, working in cooperation with Huaxin Cement.
Website: www.holcim.cn

**HSBC**

**HSBC Bank** (China) Company Ltd. started operations on April 2, 2007 as a locally incorporated foreign bank. It is wholly owned by its parent, The Hongkong and Shanghai Banking Corporation Limited, which is based in the Hong Kong Special Administrative Region. HSBC China incorporated the previous Mainland offices of its parent, which retains a branch in Shanghai that conducts foreign currency wholesale banking. Established in Hong Kong and Shanghai in 1865, The Hongkong and Shanghai Banking Corporation Limited has had a continuous presence in mainland China for 146 years. It is the founding and a principal member of the HSBC Group, which has around 7,500 offices in more than 80 countries and territories, making it one of the world's largest banking and financial services organisations. Update to February 2012, the Bank has a branch network across 31 cities, having the largest number of outlets and the widest geographical reach of any foreign bank in mainland China.
Website: www.hsbc.com.cn

**KPCB**

**Kleiner Perkins Caufield & Byers (KPCB),** since 1972 has backed hundreds of entrepreneurs in building over 600 ventures, including such major names as AOL, Amazon.com, Bloom Energy, Compaq Computer, Electronic Arts, Genentech, Google, Netscape, Sun Microsystems, and Zynga. By forming partnership with TDF Capital, KPCB officially launched operation in China with offices in Beijing and Shanghai in 2007. KPCB China team has backed successful ventures such as 360buy, Alibaba, Baidu, Focus Media, A8.com, Sungrow, Autonavi, Kanghui and CAR. KPCB China manages two USD funds, one RMB fund and together with KPCB US manage over US$3.5 billion of funds. KPCB China is well positioned to assist Chinese entrepreneurs and to promote innovation in high-growth industries, including Greentech, TMT, and Life Sciences.
Website: www.kpcb.com

**OgilvyEarth**

**OgilvyEarth** is a global sustainability practice that helps brands harness the power of sustainability through strategic planning and communications. OgilvyEarth works with visionary companies that are looking to make sustainability a growth driver for both their business and the communities they serve. OgilvyEarth is a unit of Ogilvy & Mather, a WPP company (NASDAQ: WPPGY), one of the world's largest communications services groups.
Website: www.ogilvyearth.com and www.ogilvy.com

**Qiming Venture Partners**

**Qiming Venture Partners** is an early to growth stage venture capital firm with offices in Shanghai, Beijing, and Hong Kong. Managing 4 funds with over US$ 1 billion assets with a focus on the China market from its debut in February 2006, Qiming has established itself as one of the leading investment firms in China. Qiming has over 20 investment professionals, and its partners are proven business leaders with strong operational experience and successful investment track records including many successful IPOs and merger and acquisition transactions in both the U.S. and China. Qiming's portfolio includes over 60 investments, and most of them are sector leaders in China distributed among its targeted sectors in the Information Technology, Consumer and Internet, Healthcare, and Cleantech sectors. We are very committed to helping our companies succeed. Our entrepreneurs can get access to and benefit from our portfolio of companies and our global network. While striving to be the investor of choice, Qiming will work closely with other leading venture capital firms in China to deliver the investor value that young Chinese companies require.
Website: www.qimingvc.com

**Solutia Inc.**

**Solutia** is a market-leading performance materials and specialty chemicals company. The company focuses on providing solutions for a better life through a range of products, including: Saflex® polyvinyl butyral interlayers for glass lamination and for photovoltaic module encapsulation and VISTASOLAR® ethylene vinyl acetate films for photovoltaic module encapsulation; LLumar®, Vista™, EnerLogic™, FormulaOne™, Gila®, V-KOOL®, Hüper Optik®, IQue™, Sun-X® and nanoLux® aftermarket performance films for automotive and architectural applications; Flexvue™ advanced film component solutions for solar and electronic technologies; and technical specialties products including Crystex® insoluble sulfur, Santoflex® PPD antidegradants, Therminol® heat transfer fluids and Skydrol® aviation hydraulic fluids. Solutia's businesses are world leaders in each of their market segments. With its headquarters in St. Louis, Missouri, USA, the company operates globally with approximately 3,300 employees in more than 50 worldwide locations. More than 75% of our sales come from outside the U.S., including 30% of revenue from Asia Pacific in 2011. With a global reach and a focus on the future, Solutia continues to make products people use more durable, more energy efficient and more reliable.
Website: www.solutia.com

**Tsing Capital**

Established in 2001, **Tsing Capital** is the pioneering and leading cleantech venture capital firm in China with a distinguished track record and international recognition. Through its China Environment Fund and Yiyun Cleantech Fund series, Tsing Capital works intimately with its portfolio companies across China in areas of renewable energy, energy efficiency, environmental protection, new materials, sustainable transportation, smart grids, sustainable agriculture and cleaner production. Tsing Capital champions the "Triple Bottom Line" investment practice and its own "Doing Well by Doing Good ©" investment philosophy in China, which has won itself the 2008 Corporate Citizenship Award by the 21st Century News Group. In 2010, Tsing Capital was selected as 1 of the 10 "Companies That Will Shape the World in 2020" in Aron Cramer's new book Sustainable Excellence. In 2011, Tsing Capital won "Responsible Investor of the Year in Asia" Award by PE Asia, the first of its kind awarded to Chinese VC/PE community.
Website: www.tsingcapital.com

## General Partners

### Alstom

**Alstom** is a global leader in the world of rail infrastructure, power generation and electricity transmission and sets the benchmark for innovative and environmentally friendly technologies. Present in more than 70 countries and regions, the Group employs 96,000 people and had orders of €19.7 billion in 2009-2010. Alstom takes the lead in high-speed, very high-speed and urban transport, provides turnkey integrated power plant solutions, equipment and associated services for a wide variety of energy sources, including hydro, nuclear, gas, coal and wind. Alstom have experience in electrical grids with expertise in power electronics, ultra high voltage, direct current interconnections, integration of renewables into the grid and network management solutions.
Website: www.alstom.com

### ASB Biodiesel

**ASB Biodiesel (Hong Kong) Ltd**. is building a 100,000 tpa advanced multi-feedstock biodiesel factory in Hong Kong scheduled to come on line in 2013. The plant will produce clean sustainably certified low-carbon transport fuel from recovered and recycled oils including used cooking oil, grease trap oil, waste animal fat and vegetable oil refinery waste.
Website: www. asb-biodiesel.com

### Atkins

**Atkins** is one of the world's leading engineering and design consultancies. Whether it's the concept for a new skyscraper, the upgrade of a rail network, the modelling of a flood defence system or the improvement of a management process, we plan, design and enable solutions. Our skills lie in the expansive area of infrastructure – the wiring of society – encompassing buildings, transport and utilities (including energy and water) as well as work for national and local governments and other industrial clients. The social and environmental framework is crucial and we view all our projects in the context of the communities and in which they will be undertaken. The Group employs over 20,000 staff and operates in 200 offices throughout the world. In China, Atkins has 1,000 staff based in Beijing, Shanghai, Shenzhen, Chengdu, Chongqing, and Hong Kong.
Website: www.atkinsglobal.com

### Bayer

**Bayer** is a global enterprise with core competencies in the fields of health care, nutrition and high-tech materials. The company's products and services are designed to benefit people and improve their quality of life. At the same time Bayer creates value through innovation, growth and high earning power. The Group is committed to the principles of sustainable development and to its role as a socially and ethically responsible corporate citizen. Economy, ecology and social responsibility are corporate policy objectives of equal rank. In fiscal 2010, Bayer employed 111,400 people and had sales of €35.1 billion. Capital expenditures amounted to €1.6 billion, R&D expenses to €3.1 billion.
Website: www.bayer.com

### Carrier Corporation

**Carrier Corporation** is the world's largest provider of heating, air conditioning and refrigeration solutions and a global leader in energy management and sustainable building services, with operations in more than 170 countries. Ever since Dr. Willis Carrier, founder of Carrier Corporation, invented modern air conditioning in 1902, Carrier has been at the forefront of the air-conditioning industry. Regarded as the leader and expert in air conditioning, Carrier has several thousand patents and 11 lead design centers worldwide, including one in China. Carrier has more than 2,500 employees in China and a network of more than 60 sales and service offices.
Website: www.carrier.com

**Cummins Inc.**

**Cummins Inc.**, a global power leader, is a corporation of complementary business units that design, manufacture, distribute and service engines and related technologies, including fuel systems, controls, air handling, filtration, emission solutions and electrical power generation systems. Cummins serves customers in more than 190 countries through its network of over 600 company-owned and independent distributor facilities and more than 6500 dealer locations. Cummins reported consolidated sales of US$ 18 billion in 2011. Cummins' investment in China currently exceeds US$ 310 million. As the largest foreign investor in the Chinese diesel engine industry, the Company's business connection to the country date back to 1975. After more than 30 years of development, Cummins now has significant ownership in 15 factories producing fourteen of the twenty-three Cummins engine families, turbochargers, filters, exhaust systems, fuel systems, alternators and gensets. In the aftermarket support area, Cummins has 12 regional service centers, more than 30 Customer Service Platform and over 1000 authorized dealers across the country.
Website: www.cummins.com

**The Dow Chemical Company**

**Dow** combines the power of science and technology to passionately innovate what is essential to human progress. The Company connects chemistry and innovation with the principles of sustainability to help address many of the world's most challenging problems such as the need for clean water, renewable energy generation and conservation, and increasing agricultural productivity. Dow's diversified industry-leading portfolio of specialty chemical, advanced materials, agrosciences, and plastics businesses delivers a broad range of technology-based products and solutions to customers in approximately 160 countries and in high growth sectors such as electronics, water, energy, coatings and agriculture. In 2011, Dow had annual sales of US$ 60 billion and employed approximately 52,000 people worldwide. The Company's more than 5,000 products are manufactured at 197 sites in 36 countries across the globe. Dow entered China as early as the 1930s. Since that time, the Company has invested US$ 1.2 billion in the Greater China region, with annual sales of more than US$ 4.45 billion in 2011, which makes it the second largest international market for Dow globally.
Website: www.dow.com

**DP CleanTech**

Founded in 2004 and having already established a reference list of over 50 biomass power plants around the world, **DP CleanTech** has quickly risen to become a world leader in providing biomass power plant solutions in the rapidly growing renewable energy industry. DP CleanTech delivers a complete range of solutions that converts waste residues into steam for the production of power and heat. Our unique technology, based on high pressure, high temperature systems, was originally developed in Denmark and is continually being refined and upgraded to broaden the range of fuels that can be burned efficiently.
Website: www.dpcleantech.com

**Duke Energy**

**Duke Energy** is one of the largest utilities in the United States, supplying and delivering energy to approximately 4 million U.S. customers. We have approximately 35,000 megawatts of electric generating capacity (regulated) in the Carolinas and the Midwest, and natural gas distribution services in Ohio and Kentucky. Our commercial and international businesses own and operate diverse power generation assets in North America and Latin America, including a portfolio of renewable energy assets. Headquartered in Charlotte, N.C., Duke Energy is a Fortune 500 company with over one hundred years of history.
Website: www.duke-energy.com

**General Motors Company**

**General Motors Co.** (NYSE: GM, TSX: GMM) and its partners produce vehicles in 30 countries, and the company has leadership positions in the world's largest and fastest-growing automotive markets. GM's brands include Chevrolet and Cadillac, as well as Baojun, Buick, GMC, Holden, Isuzu, Jiefang, Opel, Vauxhall and Wuling. More information on the company and its subsidiaries, including OnStar, a global leader in vehicle safety, security and information services, can be found at www.gm.com.
Website: www.gm.com

**Haworth**

**Haworth** is a global leader in the design and manufacture of office furniture and organic workspaces. Serving markets in more than 120 countries, Haworth brings together workplace knowledge and combines it with our global capabilities to create high-performance environments that support truly successful organizations.
Website: www.haworth-asia.com

**Honeywell International**

**Honeywell International** is a Fortune 100 diversified technology and manufacturing leader, serving customers worldwide with aerospace products and services; control technologies for buildings, homes and industry; automotive products; turbochargers; and specialty materials. Based in Morris Township, N.J., Honeywell's shares are traded on the New York, London and Chicago Stock Exchanges. All of Honeywell's four Strategic Business Groups are represented in China. As of today, Honeywell has invested US$ 600 million in China and employs over 11,000 people.
Website: www.honeywell.com

**Huaneng Invesco WLR**

**Huaneng Invesco WLR Investment Consulting Company** ("HIWLR") is a joint venture between Huaneng Capital, financial services platform of China Huaneng Group and Invesco with its private equity arm WL Ross & Co. HIWLR takes advantage of the unique combination of strengths of Huaneng as the largest power company in China, and Invesco's global reach in capital markets as well as WLR's rich private equity experience to provide advice on energy related investment in China. HIWLR focuses on opportunities in cleaner traditional energy, new energy, energy logistics, smart grid, energy storage and conservation and other related areas.
Website: www.huanenginvescowlr.com

**IQwind**

**IQwind** - The innovator of a variable gearbox technology (IQgearTM) that significantly reduces the cost of wind generated energy. This mechanical gear converts variable wind energy to constant frequency of the grid without power electronics or energy conversions. IQturbineTM Multi MW design leveraging the IQgearTM technology, enables up to 20% cost of energy reduction achieved by improved efficiency and elimination of power electronics. IQwind's initial product, upgrade to existing older fixed speed turbines replaces original gearboxes with the IQgearboxTM retrofit solution improving turbine energy production by up to 20%. IQwind is actively seeking Chinese manufacturing and OEM partners.
Website: www.iqwind.com

**Johnson Controls**

**Johnson Controls** is a global diversified technology and industrial leader serving customers in more than 150 countries. Our 162,000 employees create quality products, services and solutions to optimize energy and operational efficiencies of buildings; lead-acid automotive batteries and advanced batteries for hybrid and electric vehicles; and interior systems for automobiles. Our commitment to sustainability dates back to our roots in 1885, with the invention of the first electric room thermostat. Through our growth strategies and by increasing market share we are committed to delivering value to shareholders and making our customers successful. In 2011, Corporate Responsibility Magazine recognized Johnson Controls as the #1 company in its annual "100 Best Corporate Citizens" list.
Website: www.johnsoncontrols.com

## Jones Lang LaSalle

**Jones Lang LaSalle** (NYSE: JLL) is a financial and professional services firm specializing in real estate. The firm offers integrated services delivered by expert teams worldwide to clients seeking increased value by owning, occupying or investing in real estate. With 2011 global revenue of US$ 3.6 billion, Jones Lang LaSalle serves clients in 70 countries from more than 1,000 locations worldwide, including 200 corporate offices. The firm is an industry leader in property and corporate facility management services, with a portfolio of approximately 2.1 billion square feet worldwide. LaSalle Investment Management, the company's investment management business, is one of the world's largest and most diverse in real estate with approximately US$ 47.7 billion of assets under management.
Website: www.joneslanglasalle.com.cn

## Liaoning Huafu Group

Established in 1994, **Liaoning Huafu Group** is engaged in technical consulting, fabrication, EPC, BOT and capital operation from oil production, environmental, energy conservation and NG processing industries. The Group is a private hi-tech enterprise evaluated by National Science & Technology Ministry with12 domestic and overseas subsidiaries and offices, and also possesses its own Consulting and R & D Institute, manufacturing and chemical factory and several professional companies.
Website: huafugroup.com.cn

## LP Amina

**LP Amina** is a US based energy and environmental company with a focus on sustainable coal utilization for power generation and chemical production.
Website: www.lpamina.com

## MAN

The **MAN Group** is one of Europe's leading manufacturers of commercial vehicles, engines and mechanical engineering equipment with annual revenue of approximately €16.5 billion and around 52,500 employees worldwide. MAN supplies trucks, buses, diesel engines and turbomachinery as well as turnkey power plants. MAN's divisions hold leading positions in their respective markets. MAN is at the leading edge of developing green solutions such as for cleaner transportation, efficiency, cleaner coal utilization and renewable energy. Munich-based MAN SE is one of the 30 leading companies in Germany's DAX equity index.
Website: www.man.eu

## Pentair Water

**Pentair** is a global diversified industrial company headquartered in Minneapolis, Minnesota. Its Water Group is a global leader in providing innovative products and systems used worldwide in the movement, treatment, storage and enjoyment of water. Pentair Water business covers flow technologies, process technologies, aquatic system, and water purification. They serve multi markets, such as industry, residential, commercial, infrastructure, municipal, and agriculture etc. Water Group sales accounted for 69% of Pentair sales. Pentair's Technical Products Group is a leader in the global enclosures and thermal management markets, designing and manufacturing thermal management products and standard, modified, and custom enclosures that protect sensitive electronics and the people that use them. With 2011 revenues of US$ 3.5 billion, Pentair employs over 15,000 people worldwide.
Website: www.pentairwater.com.cn

## PepsiCo

At **PepsiCo**, "Performance with Purpose" means delivering sustainable growth by investing in a healthier future for people and our planet. As a global food and beverage company with brands that stand for quality and are respected household names - Quaker Oats, Tropicana, Gatorade, Frito-Lay and Pepsi-Cola, to name a few - we are an industry leader in finding innovative ways to reduce the use of energy, water and packaging. Additionally, we respect, support and invest in the local communities where we operate by hiring local people, creating products that suit local tastes, and partnering with local farmers, governments and community groups. This is our promise.
Website: www.pepsico.com.cn

**Philips**

**Royal Philips Electronics of the Netherlands** (NYSE: PHG, AEX: PHI) is a diversified health and well-being company, focused on improving people's lives through timely innovations. As a world leader in healthcare, lifestyle and lighting, Philips integrates technologies and design into people-centric solutions, based on fundamental customer insights and the brand promise of "sense and simplicity." Headquartered in the Netherlands, Philips employs approximately 122,000 employees with sales and services in more than 100 countries worldwide. With sales of EUR 22.6 billion in 2011, the company is a market leader in cardiac care, acute care and home healthcare, energy efficient lighting solutions and new lighting applications, as well as lifestyle products for personal well-being and pleasure with strong leadership positions in male shaving and grooming, portable entertainment and oral healthcare. News from Philips is located at www.philips.com/newscenter.
Website: www.philips.com.cn

**Pinnacle Engines**

**Pinnacle Engines** is a global high-efficiency engine company. Pinnacle has developed an ultra-efficient engine design based on a four-stroke, spark-ignited (SI) opposed-piston sleeve-valve architecture using conventional engine manufacturing technology. The efficiency gains have been independently verified by FEV, and demonstrate 30 – 50% drive cycle fuel economy improvements. The result is a power train system that provides dramatic reductions in both fuel consumption and greenhouse gas emissions without increasing the vehicle cost, while meeting existing and projected emissions standards. Pinnacle is commercializing the technology now, and will be launching our first products in conjunction with a major Asian vehicle OEM in 2013.
Website: www.pinnacle-engines.com

**Scania**

**Scania** is one of the world's leading manufacturers of trucks and buses for heavy transport applications, and of industrial and marine engines. A growing proportion of the company's operations consists of products and services in the financial and service sectors, assuring Scania customers of cost-effective transport solutions and maximum uptime. Founded in 1891, legendary Scania has been enjoying a great reputation in the industry as "King of the Road". Employing some 37,500 people, Scania operates in about 100 countries. Research and development activities are concentrated in Sweden, while production takes place in Europe and South America, with facilities for global interchange of both components and complete vehicles.
Website: www.scania.com.cn

**Tesco Property Limited**

**Tesco Property Ltd.**, a subsidiary of Tesco, is mainly responsible for purchasing, developing and operating commercial properties, especially Lifespace shopping malls in China, as well as sourcing and acquiring space for Tesco Legou hypermarkets. Tesco is a leading retailer in the UK and one of the top three retailers in the world. Tesco operates over 5380 stores, and is ranked 61 among Global Fortune 500 companies in 2011. Up to February 2011, Tesco has 107 hypermarkets, 1 Tesco Extra Store, 14 trial express stores and 7 Lifespace malls in China.
Website: www.lifespace-mall.com

**UPC Renewables**

**UPC Renewables** is a global renewable energy developer. As developer, owner, and operator of wind farms and solar facilities, UPC Renewables strives for long-term partnerships with communities in which its projects operate, while providing a range of benefits for local economies. UPC Renewables represents a globally diversified and privately owned franchise in the renewables industry.
Website: www.UPCrenewables.com

**Uponor**

**Uponor** is a leading international provider of plumbing and indoor climate solutions for the residential and commercial building markets across Europe and North America. In Northern Europe, Uponor is also a prominent supplier of infrastructure pipe systems. Uponor offers its customers solutions that are technically advanced, ecologically sustainable, and safe and reliable to own and operate. In 2011, Uponor's net sales totaled €806.4.million. Uponor Corporation is listed on the NASDAQ OMX Helsinki Ltd., Finland.
Website: www.uponor.cn

**Vecor**

**Vecor** technologies offer a comprehensive solution for reducing the solid waste liability of thermal power generators. Vecor proprietary processes and equipment convert fly ash destined for landfill into high-value, high-demand industrial minerals and resource-efficient raw materials.
Website: www.vecor.com and www.vecorchina.com

**Volkswagen Group China**

**Volkswagen Group** is the largest and most successful international partner of China's automobile industry, whereby the initial contact between the company and China already dated back in 1978. In 1984, Shanghai Volkswagen Corporation Ltd. was established as the first joint venture of Volkswagen Group in China, followed by FAW-Volkswagen Corporation Ltd. in 1991 as the second joint venture. In 2011, Volkswagen Group China delivered more than 2 million vehicles to customers in mainland China and Hong Kong. Volkswagen Group is to invest 10.6 billion Euros in China from 2011 to 2015, which is the biggest automotive investment in China ever.
Website: www.volkswagen.com.cn

**XPV Capital Corporation**

**XPV Capital Corporation** is a Toronto-based investment firm that has been focused on making a difference in water since 2005. By combining water entrepreneurs with investment professionals, XPV considers itself a value added financial partner for both investors and companies aiming to capitalize on the sweeping transformation taking place in the global water industry. XPV uses its industry insight and focused approach to invest in rapidly growing water enterprises. They put their water and investment resources to work by helping portfolio companies expand their strategic networks and execute market-driven milestones. XPV invests at all stages of a company's growth cycle and seeks potential investments throughout the global water community.
Website: www.xpvcapital.com

## Supporting Organizations:

AmCham Shanghai
Beijing Capital Co., Ltd.
Beijing Shougang International Engineering Technology Co., Ltd.
CBEEX
CEC China Entrepreneur Club
CEETA (China Energy Environment Technology Association)
China Datang Technologies & Engineering Group
China Environment Chamber of Commerce (CECC)
CULCEC
Shanghai University, MBA Center
SPRIE (Stanford Program on Regions of Innovation and Entrepreneurship)
Tsinghua University
UN Global Compact
UNIDO-ITPO
US DOE
US FCS

## Advisors:

ACORE
Asia Society
Australia Trade Commission
Clean Air Task Force
Cleantech Switzerland
CoreNet Global
Econet, German Industry & Commerce
Embassy of the Kingdom of the Netherlands
Embassy of Sweden Center for Environmental Technology (CENTEC)
iCET
IsCham Beijing
NRDC (Natural Resources Defense Council)
Spanish Economic & Commercial Office
State Grid National Bio Energy Co., Ltd.
USITO

www.china-greentech.com