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China Greentech Initiative
Strategic Insights, Industry Collaboration, Market Acceleration

THE CHINA GREENTECH REPORT™ 2011

China's Emergence as a Global Greentech Market Leader

BY THE CHINA GREENTECH INITIATIVE

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Founded in 2008, The China Greentech Initiative has grown rapidly to become the only China-international collaboration platform of over 100 organizations focused on identifying, developing and promoting green technology solutions in China. Partnering organizations include technology buyers and sellers, service providers, investors and policy makers. Strategic market research and a network of over 200 industry experts shape the foundation of the CGTI Partner Program, allowing it to provide participating organizations with world-class market insights and partnering opportunities.

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Photography: All rights reserved. Steve Bale, Jim Gourley and
Photo & Video White Balance
Printed by: PORO Marketing and Design Solutions
(北京般若企业策划有限公司), Beijing, China
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THE CHINA GREENTECH REPORT™ 2011

CHINA'S EMERGENCE AS A GLOBAL GREENTECH LEADER

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

MangoStrategy

Navigation Guide

The China Greentech Report™ 2011 is organized into four sections in order to help readers access and use the findings easily.

Executive Summary
Succinctly summarizes the entire Report's findings.

China's Evolving Greentech Markets
Outlines how China is emerging as a global greentech leader, reviewing five key developments that cut across China's greentech markets.

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 2010. Each sector chapter includes:

- **Market Update**
  Insights on how each sector has evolved and where it is going, including analysis of market attractiveness for selected areas.
- **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 2010 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, definitions of acronyms, and an extensive bibliography of sources used.

***The China Greentech Report 2011* Structure**

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PREFACE

Steve Bale

Dear Reader,

We are delighted to provide you with *The China Greentech Report 2011*, the latest public deliverable of the China Greentech Initiative. This Report builds upon *The China Greentech Report 2009*, which has become widely recognized as the primer for understanding China's greentech markets. The 2011 edition provides an updated view of the world's fastest growing greentech markets, explaining how China has emerged as a global greentech leader over the past several years.

When we first conceptualized the China Greentech Initiative in 2008, we never expected the tremendous support the Initiative would receive from organizations and people in China and the rest of the world. Support for the Initiative has continued to grow dramatically over the past two years, thanks to over 100 partners and advisors who, in addition to financial support, provide time, expertise, information, valuable introductions and access to other resources.

As shown on the front and inside covers of the Report, we have been extraordinarily fortunate in both the number and quality of partners, supporting organizations and advisors who have been involved in the creation of this Report. They represent a cross section of the global community, with approximately one-third Chinese, one-third American and one-third other international organizations. Indeed, this inspiring mix of leading organizations from around the world is in itself a reflection of China's emergence as a global greentech leader.

Based on our thousands of interactions with leaders of major Chinese enterprises, foreign companies, entrepreneurs, investors, government, NGOs and policy advisors, we see clearly that we stand at a unique moment in time. Greentech solutions are poised to play a fundamental role in shaping China's future and improving the lives of the Chinese people. The 12th Five-Year Plan underscores China's intent to advance greentech to the forefront of the nation's economic and social development agenda, with far reaching implications for China and the world.

This Report is the culmination of an open source, collaborative research process, which has involved literally thousands of people in China and around the world. This process combined a dedicated strategic research team with ongoing insights from the Initiative's partners and advisors during the past year. In addition, certain insights in this report were shaped by our deepening collaboration with various government organizations at the central and local levels.

In 2010, the Initiative hosted 18 sector working sessions—three sessions for each of six sectors—involving senior executives and industry experts from our partners and advisors. These working sessions provided a powerful forum to frame and debate issues, test preliminary insights, and validate the findings highlighted in this Report. Each session generally involved 30-40 senior participants, lasted four hours, and was hosted simultaneously from PwC's Beijing and Shanghai conference facilities, connected via videoconferencing and simultaneously translated between Chinese and English.

With over 100 organizations and hundreds of people involved, we are unable to name everyone who has participated in this effort. However, we would like to mention a few partners explicitly. Our strategic partner PwC has supported the Initiative for the past three years in multiple critical ways, including providing guidance, financial support, working session facilities, marketing support and much more. Hao Capital has graciously opened up its Beijing offices, which has become the home for the Initiative's growing team. APCO Worldwide provided government relations support which proved invaluable for the Initiative's government outreach efforts. The China Entrepreneur's Club partnered with the Initiative to launch this Report at the Annual Summit of Green Companies in Qingdao, Shandong. A complete list of all partners, supporting organizations and advisors is included on the inside back cover of the report, while a list of individuals who supported the creation of this report is included in the Acknowledgments chapter.

We hope *The China Greentech Report 2011* will continue to help a broad group of stakeholders, including greentech solution adopters, solution providers, financers, investors, regulators, policy advisors and others, in their quest to uncover, develop and accelerate greentech opportunities in China. Given the scale, complexity and dynamic nature of China, we recognize that we have not been able to cover everything, and that what we do cover will continue to evolve rapidly. For example, in the days preceding the publication of the report the team worked hard to incorporate the impact of recent developments related to the 12th Five-Year Plan and Japan's unfolding nuclear crisis.

China's journey towards a low-carbon, sustainable future presents both enormous opportunities and daunting challenges. While many government actors will play a leading role in driving necessary changes, we believe it remains largely up to the commercial sector to provide the myriad greentech solutions and new innovations that China needs to translate its impressive ambitions into reality. We hope the China Greentech Initiative can serve as an example of the collaboration that will be needed between diverse stakeholders—both government and commercial—to accelerate our common goal of an environmentally sustainable future for China and the world.

We look forward to continuing to collaborate with our partners, advisors and others involved in the China greentech market through our 2011 Partner Program. To that end, please visit the China Greentech Initiative at www.china-greentech.com to join in the discussion and learn more. We also welcome your input at CGTI@china-greentech.com.

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

Managing Directors,
The China Greentech Initiative
April 2011

EXECUTIVE SUMMARY

The China Greentech Report 2011 **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 2010 Partner Program. These organizations commit their expertise, time and funding to the China Greentech Initiative to address the many on-going opportunities and challenges facing those seeking to accelerate China's complex, rapidly-changing greentech markets.**

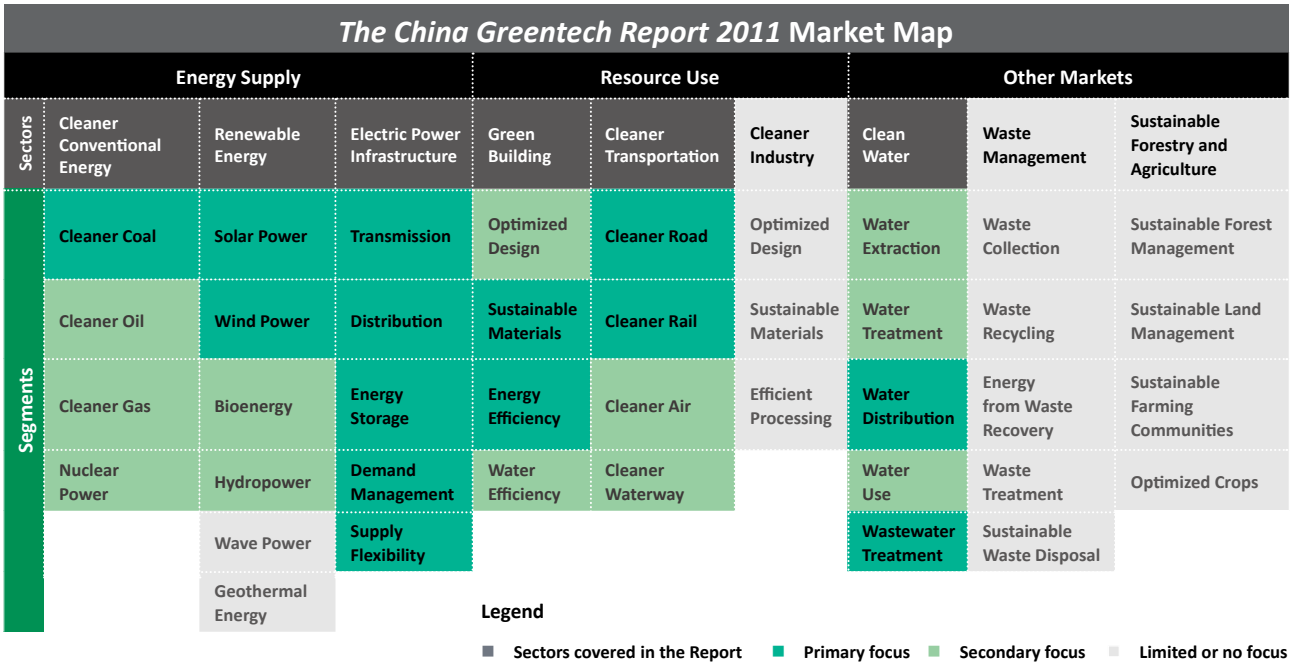
This Report builds upon the first edition of *The China Greentech Report*, which the China Greentech Initiative launched at the World Economic Forum in Dalian, China in 2009. With over 50,000 copies downloaded, the 2009 edition is commonly referred to as the primer by which to understand China's greentech markets. This edition provides an updated view on the world's fastest growing sector in the world's fastest growing market, with a focus on three main themes:

- Why China is emerging as a global greentech leader
- How each of the six sectors on which the China Greentech Initiative focused in 2010 are evolving
- What prioritized greentech opportunities exist within each of these sectors

This Report summarizes the detailed proprietary analysis provided to the China Greentech Initiative's partners and advisors who participated in the 2010 Partner Program. This Report should be viewed as a complement to the 2009 edition. Whereas the 2009 edition focused on defining the China greentech landscape and solutions, the 2011 Report provides deeper analysis on some of the most important greentech opportunities in China today.

Defining China's Greentech Markets

The term 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: China Greentech Initiative analysis

China's Evolving Greentech Markets

Within just a few years, China has emerged as a global greentech leader. As we predicted in *The China Greentech Report 2009*, China is now a greentech leader by a number of indicators, but more importantly, China stands at the center of almost every greentech market. No greentech investor or company can ignore China. Here are five reasons why:

- **Astonishing Growth in China's Greentech Markets**
  Propelled by China's economic expansion and ambitious policies, greentech markets in China have grown swiftly, showing no signs of slowing. In the last two years China's greentech markets have advanced across every sector, from wind and solar power to emissions control and wastewater treatment. For example, by the end of 2010 China had become the world's largest investor in clean energy at RMB 354 billion (US$54.4 billion),[1] installed 44.7 GW of wind power,[2] and built 8,358 kilometers of high-speed rail.[3] The 12th Five-Year Plan (2011-2015) and other policies will propel further expansion in coming years.

- **Urgent Needs Drive Greentech Growth**
  Government policies respond pragmatically to China's urgent needs in energy security, food and water supply, and pollution. The scale of the country's energy- and environmental-related needs is just as immense as everything else in today's rapidly-growing China. Consider some of the most pressing needs pushing China ahead on greentech policies and spending: China imports over 50% of its oil, per capita water supply is only one quarter of the world average and decreasing, and indoor and outdoor air pollution cause up to 1.3 million deaths per year.[4] In each area, significant change and implementation of new solutions are essential to prevent major negative consequences for China and its people.

1. Pew Charitable Trusts, Who's Winning the Clean Energy Race? (Washington, D.C.: Pew Charitable Trusts, 2011)
2. "China adds 18.9 GW of new wind power capacity in 2010," Global Wind Energy Council, Apr. 6, 2011, www.gwec.net
3. "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, Mar. 4, 2011, www.news.163.com
4. "China Energy Data, Statistics, and Analysis," U.S. Energy Information Administration, www.eia.doe.gov, accessed on Nov. 2010; 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); "Environment problems pose health risk for China: Lancet," The Independent, Mar. 26, 2010, www.independent.co.uk

- **Continuing Urbanization and the Growth of Eco-Cities**
  Immense resource demands brought about by China's continuing historic urbanization compel policymakers to make existing cities more sustainable and establish new eco-city projects. China's population shift from rural to urban areas represents the largest migration in human history. In 1980, a mere 20% of the population was urban, but by 2010 this rate had risen to 47% with no signs of slowing.[5] However, this has occurred without emphasis on sustainability. Policymakers recognize that achieving national goals on energy efficiency and carbon emissions will depend upon the progress made by cities, reflected in China's growing number of eco-cities and policies for building and heating efficiency. For example, cutting carbon emissions of existing eco-cities by 20% would equal 32 million tons of carbon annually, equivalent to the emissions of New Zealand.[6]

- **China Becoming a Player in International Energy and Environmental Issues**
  As China's energy demands and greentech policies have expanded, so has its role on the international stage. China's energy demands and environmental impact are vast and growing, with two distinct forces combining to expand China's international role. First, rising energy demand may triple by 2035, giving China a greater stake in the world energy and resource economy.[7] This has profound effects on geopolitics, world commodity markets and international business. Second, China's greentech market growth has helped change China's image from that of a laggard on the environment to a position of leadership in many instances.

- **Seeking to Capture Domestic and Global Greentech Markets**
  China's industrial policy promotes the domestic greentech industry to ensure China's energy security. National industrial policy is a central driver of China's greentech markets. The country's booming greentech markets represent a huge social and technological shift, and have real potential to solve serious energy and environmental problems. Because of the scale of China's energy needs, the government has made it a priority to ensure the country and its businesses capture these new markets. One of the ways they are doing this is by emphasizing domestic research capabilities: R&D spending rose by 20% annually between 1995 and 2005 and China is now home to some of the world's largest greentech manufacturing companies.[8]

While these five reasons apply to all of China's greentech markets, the specifics differ within each greentech sector. For each of the China Greentech Initiative's six sectors we reviewed recent major developments and summarized the key findings of specific Opportunity Assessments completed during 2010.

5. Goldman Sachs, Hukou Reform: A Mid To Long Term Goal, Picking Up Pace (U.S.: Goldman Sachs, 2011)
6. China Greentech Initiative analysis
7. International Energy Agency, 2010 World Energy Outlook (Paris, France: International Energy Agency, 2010)
8. Steinfeld, Edward S., Playing Our Game: Why China's Rise Doesn't Threaten the West (U. S.: Oxford University Press, 2010)

Cleaner Conventional Energy

China's energy and environmental problems cannot be solved without Cleaner Conventional Energy. The government has implemented a range of policies within the last 18 months to encourage the development of greentech solutions.

Cleaner Conventional Energy—energy derived from fossil fuels in ways that minimize their negative impact on the natural environment—is a focal point for government and industry. Achieving government targets for reducing carbon intensity by 40-45% by 2020 will require dramatic increases in natural gas and nuclear power consumption as well as an emphasis on cleaner coal. The government established the National Energy Commission (NEC) in 2010 to overcome competing interests and ensure the development of a cohesive energy policy, and continued to push for the consolidation of the coal industry to improve efficiency, safety and enforcement of regulations. On emissions, China is set to adopt policies that would bring the country's coal plants in line with other countries. Pricing reforms have fallen behind expectations, but are expected to move forward again during the 12th Five-Year Plan period.

The China Greentech Initiative developed three in-depth Opportunity Assessments for the Cleaner Conventional Energy sector in 2010:

- **Potential for Wide-Scale Adoption of IGCC and CCS Technologies**
  Integrated gasification combined cycle (IGCC) and carbon capture and sequestration (CCS) have the potential to revolutionize power generation in China, but their potential remains largely unfulfilled. IGCC and CCS technologies are well-suited to China's environmental imperatives, geology, and large coal plant market; both technologies can play a role in reducing the long-term impact of China's power plant construction boom of the last decade. That said, the country faces a paradox: high initial costs and technology gaps mire IGCC and CCS in the demonstration project phase; however, China is the ideal place for development given its low cost and rapid infrastructure expansion. For example, IGCC costs in China could be more than 60% less than in developed countries.[9] China will likely expand slowly from demonstration projects in the next decade, favoring incremental gains over large-scale technology adoption.

- **Strong Future for De-SO_x and De-NO_x, but Fly Ash Recycling and Utilization Lags**
  After the rollout of post-combustion desulfurization (De-SO_x) over the last five years, China will promote new regulations and investments during the 12th Five-Year Plan period for denitrification (De-NO_x) as well as fly ash recycling and utilization. In China's push to improve air quality over the last five years, coal power plant De-SO_x regulations have been relatively successful, with Chinese equipment suppliers capturing the market. China is now encouraging De-NO_x technologies with a 10% emissions reduction target and a potential tariff. Lessons learned from the De-SO_x experience will likely help improve enforcement. Fly ash recycling continues to lag, but extraction of valuable minerals increases financial incentives.

- **Potential for Carbon Pricing in China**
  Pricing carbon continues to attract hot policy debate in China. As its galloping economy brings skyrocketing energy use and greenhouse gas (GHG) emissions to the fore, China recognizes the need to address growing energy and environmental hazards. One carbon pricing option—a carbon tax—is being carefully considered, but despite indications that China could adopt a tax, perhaps as soon as 2012, many challenges remain. Such a tax could take years to put into place, and fundamental implementation questions are unresolved, such as tax neutrality, revenue management, and incentives for greentech solutions.

Reducing carbon intensity by 40-45% by 2020 will require dramatic increases in consumption of natural gas and cleaner coal.

9. Angell, Christopher, et al., "The Role of IGCC in China: Past, Present, and Future," Saistrip, May 2010, www.saistrip2010.webatu.com; IPCC, Carbon Dioxide Capture and Storage (U.K.: Cambridge University Press, 2005, 443)

Renewable Energy

Government policies and investment have transformed China into one of the world's leading adopters and manufacturers of Renewable Energy technology.

Ambitious renewable energy targets and strategic government investment have helped China become a world leader in renewable energy manufacturing and power generation. In 2010, China surpassed the U.S. to become the world's largest wind power producer with 44.7 GW of installed capacity.[10] China renewable energy manufacturers produce more solar photovoltaic panels and wind turbines than any other country. By 2020, installed capacity of wind, solar and biomass power is targeted to more than quadruple, from less than 50 GW in 2010 to more than 200 GW in 2020. Given China's installation track record, combined with reassessments of nuclear energy in the wake of the disaster in Japan, these targets are probably conservative.

Installed capacity of wind, solar and biomass is targeted to more than quadruple by 2020.

The China Greentech Initiative developed three in-depth Opportunity Assessments for the Renewable Energy sector in 2010:

- **China's Domestic Solar Market Emerges**
  China plans to boost solar capacity 20-fold by 2020, from 800 MW in 2010 to more than 20 GW, including more development in western China, with technologies beyond the crystalline silicon (c-Si PV) solutions China has favored so far. Already the world leader in solar panel manufacturing, China is poised to enter a new phase: developing domestic solar power generation capacity. In early concession rounds, western regions have been favored for large-scale projects using primarily domestically-produced crystalline silicon PV panels. As technology and power generation costs decline, it is likely that China will install a mix of solar technologies to achieve its 2015 and 2020 solar power generation targets. China is reconsidering its energy targets in the wake of Japan's nuclear crisis, which may increase solar power targets further to 10 GW by 2015 and 30 GW by 2020.[11]

- **China's Wind Market Heads to Sea**
  As a new government priority, China's offshore wind market is poised for takeoff; however, since offshore wind is more than twice as expensive to develop than China's still abundant onshore resources, the market represents a paradox for investors. China's offshore wind market only began in 2009 with the construction of its first offshore wind farm near Shanghai, but government targets call for swift growth to 30 GW by 2020.[12] Offshore wind capital costs in China are expected to be at least double onshore costs, yet the first concession round held in 2010 for four projects totaling 1 GW resulted in low bid prices—insufficient, it appears, for profitable ownership. These projects may be subsequently awarded higher tariffs by the government to ensure profitable operation, just as with early onshore wind farms. Given policy and technical uncertainties, the current market does not suit risk-averse developers. For foreign equipment and service providers, the market may be favorable, but due to pricing constraints there may be limited opportunities for foreign turbine manufacturers.

- **Distributed Renewable Energy (DRE) Leadership and Potential**
  China is a leading player in DRE with significant capacity in small hydropower, household biogas digesters and rooftop solar water heating. However, without grid improvements, more cost-effective energy storage and subsidies, promising DRE technologies will not reach their full potential. China's push for rural electrification in previous decades promoted DRE technologies for the first time. China's small hydro capacity, at 55 GW, is the largest in the world and supplies 50% of China's rural electricity. Solar hot water heaters are also prevalent in China, covering more than 145 million square meters and accounting for more than 80% of the world's solar water heating capacity.[13] Most development has been government funded and driven, although private financing models have been used successfully in wealthier urban areas for distributed rooftop solar.

10. "China has highest wind power capacity: report," Reuters, Jan. 13, 2011, www.reuters.com
11. Li Yuchuan, "China May Double Photovoltaic Capacity to 10 GW by 2015," China Securities Journal, Mar. 30, 2011, www.cs.com.cn
12. World Bank, China: Meeting the Challenges of Offshore and Large-Scale Wind Power: Strategic Guidance (Washington, D.C.: Asia Sustainable and Alternative Energy Program, World Bank, 2010, 16)
13. REN21, Renewables 2010 Global Status Report (Paris, France: REN21 Secretariat, 2010)

Electric Power Infrastructure

State Grid's ambitious plan to invest RMB 3.45 trillion (US$ 530 billion) to build a strong and smart grid by 2020 ensures that China will be one of the world's largest smart grid markets in the years to come; however, the industry's monopolistic structure poses challenges for market entrants.

China's overstretched electricity grid faces a daunting challenge: efficiently powering the nation's staggering economic growth as the energy mix diversifies. Ambitious renewable energy and energy efficiency targets, as well as growth projections for electricity demand, require a more advanced grid than exists today. State Grid, the world's largest utility and provider of 80% of China's electricity, released its Smart Grid Plan in 2009, which provides a roadmap through 2020 that ensures China remains one of the world's largest smart grid markets. China's 2010 smart grid market was already the largest in the world at RMB 47.5 billion (US$ 7.3 billion).[14] Smart grid solution providers, however, must prepare for difficult market conditions, where low-cost solutions and strong relationships with local grid companies define success.

The China Greentech Initiative developed three in-depth Opportunity Assessments for the Electric Power Infrastructure sector in 2010:

- **State Grid's Smart Grid Plan**
  Distribution and consumption are the best opportunities for private solution providers in the State Grid's Smart Grid Plan. State Grid's Smart Grid Plan could abate 1.65 billion metric tons of carbon emissions per year, the equivalent of Russia's 2009 total carbon emissions. Investments in distribution are planned at RMB 119 billion (US$ 18 billion) while consumption targets RMB 89 billion (US$ 14 billion), together over half the smart grid investment total, with these sectors relatively open to private involvement.[15] Private firms seeking to promote their smart grid products and services must engage deeply with both central and local levels of State Grid.

- **Connecting Intermittent Power to the Grid**
  State Grid has largely addressed problems with wind farm connections, but still cannot absorb intermittent energy in some regions, requiring new solutions such as UHV construction to transport power elsewhere. Despite huge growth in new wind installations since 2008, nearly 100% of all completed wind farms are now connected to the grid, compared to only two-thirds in 2008.[16] The problem has shifted to excess intermittent supply, because the windiest regions cannot absorb significant power fluctuations without posing problems for grid stability and reliability. New UHV power lines will partially address the problem by shifting power elsewhere; by 2015 China will invest RMB 500 billion (US$ 77 billion) to construct 40,000 kilometers of UHV transmission lines.[17] Management and forecasting tools that maintain grid stability are also needed, such as active and reactive power flow control and low-voltage ride-through (LVRT) technology.

- **Technology Preferences in China's Smart Meter Market**
  Although China will roll out 50 to 60 million Automatic Meter Reader (AMR) meters in 2011, and more sophisticated Advanced Meter Infrastructure (AMI) is yet to come, the meter market is currently only open to a handful of incumbents. China's smart meter roll-out of 500 million meters before 2015 poses a paradox for solution providers: implementing low-cost AMR now means that the country could require another round of new, more sophisticated AMI meters as early as 2015.[18] China's meter market is restricted to a handful of players already present, however, and no change seems likely in the near future. Grid companies rely on suppliers with low prices, a quality track record, local after-sale customer service, and relationships with internal grid company departments.

At RMB 47.5 billion (US$ 7.3 billion), China's 2010 smart grid market was the largest in the world.

14. "Top 10 Countries for Smart Grid Investment," Zpryme Research and Consulting, Nov. 9, 2010, www.gereports.com
15. 国家电网，"国家电网智能化规划总报告，" State Grid, "State Grid Smart Grid Plan Final Report"] Feb. 2010
16. Shu Yinbiao, "12th Five-Year Electricity and Energy Sector Transition Development," State Grid (presentation given at the 2020 Energy & Economy Development Forum, China, Oct. 31, 2010)
17. Bai, Jim and Aizhu Chen, "China top grid firm says to further develop UHV tech," Reuters, Jan. 28, 2011, www.reuters.com
18. Li, Min and Wendy Wang, Electronic Equipment & Services (Hong Kong: Yuanta, 2010); China Greentech Initiative analysis

Green Building

China's Green Building market has more than doubled every year since 2005, but remains only a fraction of its potential size. Numerous challenges impede growth, yet companies with a nuanced understanding of this complex, rapidly growing market can position themselves to become future industry leaders.

Given the pace and scale of urbanization, China needs to improve building efficiency to meet energy and environmental goals. Green buildings can play a substantial role: if all of China's existing buildings were green, it would mean energy savings equal to half of the total electricity generated in China in 2007.[19] Although the economics of green building are favorable in China, builders are reluctant to pursue green building projects due to misaligned incentives between developers, owners and tenants. Though enforcement may be improving for building energy codes, it lags in other areas. Despite these and many other challenges there are still attractive opportunities for foreign and domestic companies.

If all of China's existing buildings were green, it would mean energy savings equal to half of the total electricity generated in China in 2007.

The China Greentech Initiative developed three in-depth Opportunity Assessments for the Green Building sector in 2010:

- **Expanding the Building Energy Efficiency Retrofit Market through ESCOs**
  The market for building energy efficiency retrofits is expanding rapidly, as are government efficiency targets for existing buildings, yet current policies are insufficient, subsidies are still small, and ESCO solutions vary widely by market segment. Energy Services Companies (ESCOs) provide energy efficiency solutions to customers on a risk-reward basis over a specified payback period and have great potential to improve energy efficiency, but their near-term potential in China is unclear. Over the last five years the building energy efficiency retrofit market has experienced a 40% compound annual growth rate as government policies support growth.[20] The most important policies affecting ESCOs are targets for urban heating in northern China and energy management of large public buildings; however, progress is uneven and subsidies for ESCOs are too small to make a meaningful difference.

- **Accelerating Green Building Materials Adoption through Supply Chain Practices**
  Incomplete industry standards and metrics, poor enforcement of regulations, and supply chain practices that ignore the environment define China's fledgling green building materials supply chain. Despite rising green building demand in China, green building materials currently represent only 5% of the total market. Building code enforcement is uneven, giving developers little incentive to source legitimate green building materials. Building materials suppliers may certify materials with authorities without necessarily complying with requirements. Nevertheless, environmental criteria in sourcing and value-chain partnerships offer opportunities for stakeholders to move the entire market forward.

- **Rapidly Improving Market for Sustainable Indoor Environment Solutions**
  Indoor air quality (IAQ), thermal efficiency and energy efficiency solutions have considerable potential in the Sustainable Indoor Environment (SIE) market. SIE, which affects human health and productivity as well as the environment, is influenced by a number of factors, including IAQ, thermal efficiency and energy efficiency. SIE solutions such as air purification, floor heating and energy efficient lighting technologies, represent markets that are relatively well-developed or are improving quickly. China's interior fit-out market, for example, reached RMB 1.85 trillion (US$ 285 billion) in 2009, consisting of 180,000 companies with a total of 14 million employees.[21] A major challenge for SIE is weak enforcement of existing standards. Other issues include lack of motivation, design process difficulties, lack of reliable products and services, and low market awareness. Better enforcement and integrated solutions are needed for the SIE market to develop further.

19. "Total Electricity Net Generation (Billion Kilowatthours) – China," U.S. Energy Information Administration, Nov. 2010, http://www.eia.doe.gov/, accessed on Mar. 17, 2011
20. Energy Committee of China Energy Conservation Association, Annual Report on China Energy Service Industry (Beijing, China: EMCA, 2009)
21.Zhang Zhonglin, "Development of Chinese Building Decoration Market," China Building Decoration Association (presentation on press release of carpenter exhibition, Beijing, China, 2008)

Cleaner Transportation

To address growing problems with traffic congestion, energy efficiency, emissions and energy security, China is pursuing diverse Cleaner Transportation solutions ranging from alternative fuels to electric vehicles.

Rapid growth of China's transportation sector has led to major issues, including increased vehicle emissions, oil use and road congestion. In 2010, 18 million vehicles were sold in China, making it the world's largest automobile market.[22] Although China has already far exceeded the high-speed rail accomplishments of many developed countries, the government has ambitious plans to expand the industry further. Government, industry and private investors are making sizable investments in the early-stage development for electric vehicles, batteries and alternative fuels; however, the government's aggressive targets may prove unrealistic.

The China Greentech Initiative developed four in-depth Opportunity Assessments for the Cleaner Transportation sector in 2010:

- **China's Emerging Electric Vehicle (EV) Ecosystem**
  While growth prospects for China's EV market are substantial, the nascent market faces major challenges, including inadequate charging infrastructure and high battery costs. The government has set ambitious growth targets for the EV market, aiming to have 5 million EVs on the road by 2020; however, the industry faces many hurdles.[23] Government-led pilot programs are the main near-term market driver, supported by a new EV development plan and charging standards. Technology constraints, high battery costs and the lack of charging infrastructure in pilot cities all pose major barriers. Unlike in more developed countries, low-speed EVs may serve as a bridge for the eventual commercialization of high-speed electric vehicles.

- **Electric Vehicle Battery Market Evolution**
  Over 60 Chinese battery makers have set their sights on EVs, and while technical challenges abound, government support and industry optimism remain strong. Even as lithium-ion battery manufacturers vie for a share of China's early-stage EV battery market, few orders from automakers and numerous technical challenges await the victors. Major obstacles include weak R&D capabilities, lack of automated production methods and difficulties in vehicle integration. Government and investor funds continue to flow into the sector, suggesting optimism that these barriers can be overcome.

- **Alternative Fuels for Road Transportation**
  Ethanol, natural gas and methanol are the three most widely adopted alternative transportation fuels in China today; however, breakthroughs are needed in feedstock supply, technology development, infrastructure rollout and user acceptance to progress further. The government continues to promote a full spectrum of alternative fuels, yet they account for only 3% of the current market. Ethanol, natural gas and methanol have developed rapidly over the past five years, but still face major development challenges, including feedstock, technology, infrastructure and user acceptance. Other alternative fuels appear less promising, at least in the near term.

- **Rapid Growth in Cleaner Rail**
  Rapid economic development and urbanization intensify China's need for greater rail capacity, and the government is responding to the challenge. In response to the mounting need for more long-distance freight and passenger capabilities, China has embarked on a major expansion of its already extensive rail network. Metropolitan systems are also undergoing a makeover as subway and light rail coverage expands dramatically. By the end of 2010, China's rail network reached 91,000 km, making it the second largest in the world, with plans to grow to 120,000 km by 2020. China is also home to the world's largest high-speed rail network, with 8,000 kilometers constructed by 2010, and 16,000 kilometers planned for 2015—equivalent to the world's total to date.[24]

With 18 million vehicles sold in 2010, China is the world's largest automobile market by volume.

22. Patti, Waldmeir, "China car sales stay in the fast lane," Financial Times, Jan. 4, 2011, www.ft.com; China Greentech Initiative analysis. Note: Figures discussed here include on-road passenger vehicles such as cars, minivans and SUVs, and commercial vehicles such as buses and trucks.
23. "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, Sep. 21, 2010, http://auto.163.com
24. Note: This figure includes rail lines with operating speeds over 200 km/h. "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, Mar. 4, 2011, www.news.163.com

Clean Water

Given the critical importance of water to China, the government has made Clean Water a major priority, including investing in wastewater treatment, improving water efficiency, and ensuring adequate water supply.

Water pollution and scarcity due to weak enforcement, drought and over-use are some of the biggest problems facing China today. In 2009, 270 million people in rural China had no access to safe drinking water and more than 4.5 million people were short of water in northern China due to the severe drought.[25] The government is responding to these problems with new policies and major investment projects: China has tripled the number of municipal wastewater plants, initiated the controversial South-to-North diversion project, and planned desalination projects near urban areas. Between 2010 and 2020, RMB 4 trillion (US$ 615 billion) will be invested in water infrastructure improvements.[26] Better enforcement of existing water laws and new regulations to increase efficiency are also government priorities, but the scale of the problem is so large that even these laudable policies will not suffice.

RMB 4 trillion (US$ 615 billion) will be invested in water infrastructure improvements between 2010 and 2020.

The China Greentech Initiative developed three in-depth Opportunity Assessments for the Clean Water sector in 2010:

- **Private Sector Opportunities in the Municipal Wastewater Treatment Market**
  As China shifts investment in wastewater treatment to lower-tier cities in the South and Southwest, opportunities exist for private participation in build-operate-transfer (BOT) and operation and maintenance (O&M) models, though low cost solutions and inefficient operation remain the norm. China has rapidly boosted municipal wastewater treatment rates since 2007. The urban wastewater treatment ratio steadily grew from 34% in 2000 to 70% in 2010.[27] Pricing is still set locally, with no obvious national trends. Private participation can bring needed expertise to the sector, which is plagued by inefficient public operation, but most regions still focus on low-cost solutions. BOT and O&M models are the most promising areas for private sector involvement.

- **Private Sector Participation in Water Utilities**
  Despite market reforms and willingness of private domestic and foreign companies to participate in China's water sector, implementation proves to be a challenge. The private sector has only contributed 10-20% of recent water infrastructure financing. Though many private companies have formed partnerships with local water utilities, just 10% of sector investment in 2008 came from the private sector. Only a few regions support such investment, while others strongly oppose private involvement. Wastewater treatment is the main area of participation, as opposed to water supply. Public-private partnerships (PPPs) have had mixed results, with private investors facing multiple problems including limited market knowledge, scarce financing, intense competition and demanding municipal customers.

- **Wastewater Treatment Plant Lifecycle Cost and Profit Analysis**
  Municipal wastewater treatment plants have grown rapidly in China, but often at the expense of operational efficiency. Build-operate-transfer (BOT) contracts lead to higher operating efficiency and better long-term performance. BOT municipal wastewater treatment plants appear to have lower operating costs and higher net profits than alternative investment models. Investors have generally only agreed to BOT contracts where they were able to negotiate favorable revenue terms and ensure profitable long-term operational performance versus public-operated plants. Electricity is the largest area with operations improvement potential: BOT plants use up to 50% less electricity than other types of plants. Other revenue and cost improvement opportunities can also be pursued to improve plant performance.

25. "China To Invest CNY90 Billion For Waste Water Treatment," China CSR, Dec. 4, 2009, www.chinacsr.com; "Millions at risk in China drought," BBC, Aug. 23, 2009, www.news.bbc.co.uk
26. "中共中央 国务院关于加快水利改革发展的决定," [Central People's Government of the People's Republic of China, Decision on accelerating water reform and development] Jan. 31, 2011; Lu, Ting, "China's Investment Momentum: RMB 4 Trillion for Water Projects," Chinastakes, Jan. 31, 2011, www.chinastakes.com
27. China market overview: Waste water treatment (Beijing, China: Yatsen Associates Co., Ltd., 2009, 3)

Looking Forward

Opportunities to grow China's greentech markets abound.

Driven by strong government support that addresses urgent national needs, China's greentech markets have grown with astonishing speed. Though rapid continued urbanization puts incredible stress on resources, this same force could drive the growth of eco-cities when married with sustainable development. As the ambitious targets outlined in the 12th Five-Year Plan reveal, China plans to magnify previous growth, catapulting China onto the global energy and environment stage in a leading role. Seeking to capitalize on the experience gained in its sizable greentech markets, China's industrial policies aim to increase Chinese leadership at home and abroad.

China's emergence as a global greentech leader translates into opportunity, but not always directly. As China's greentech markets have grown, they have also become more complex, and growth does not always translate directly to opportunity for the private sector or foreign participants: some of the greatest opportunities are often the most surprising ones, profitable niches overlooked in the big headlines.

Some of the greatest opportunities in China's market are often the most surprising ones.

To explore in detail China's greentech market developments as well as sector-specific analyses, we invite you to turn to the respective chapters in this Report.

Jim Gourley

CHINA'S EVOLVING GREENTECH MARKETS

Jim Gourley

Jim Gourley

The Astonishing Growth of China's Greentech Markets

Propelled by China's economic expansion and ambitious policies, greentech markets in China have grown swiftly, showing no sign of slowing.

In the last two years China's greentech markets have advanced across every sector, from wind and solar to emissions control and wastewater treatment. Already home to the world's largest greentech markets, the 12th Five-Year Plan and other policies will propel China's further expansion in the coming years.

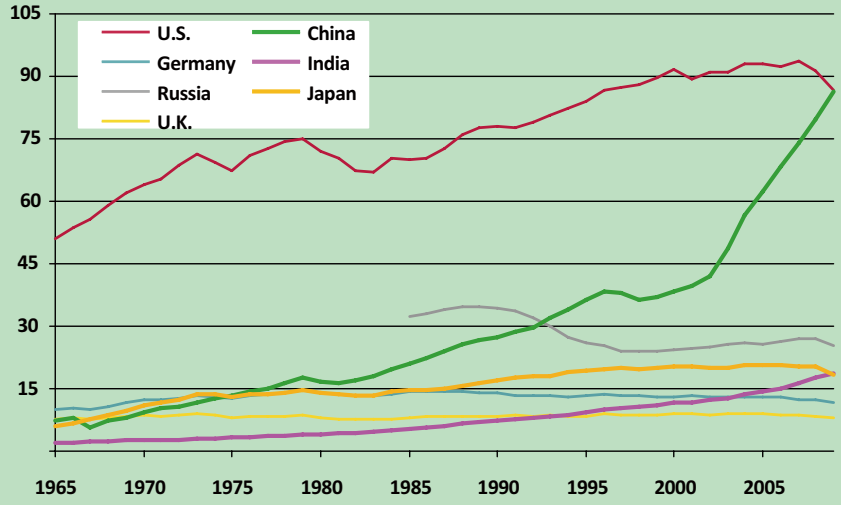
Economic growth is at the heart of China's transformation. From 1989 to 2010 China's gross domestic product (GDP) grew at an average of 9.3%, and in mid-2010 China surpassed Japan to become the second largest economy in the world.[1] At 9% growth, an economy doubles in size every eight years; if the U.S. and China continue at expected growth rates (3% versus 9%), China will become the largest economy by 2027. China's official GDP growth figure for 2010 was 10.3%.[2]

China's energy consumption has grown as rapidly, reaching approximately 950 GW of installed electric generation capacity in 2010, up from less than 800 GW in 2008.[3] Capacity has doubled in just six years: at this rate, China will surpass the U.S. in two years with the largest installed electricity generation capacity in the world.[4] China's annual additions to installed electricity capacity are comparable to the total installed capacity in countries like the U.K., Italy, and Spain. In addition, with oil consumption doubling between 1998 and 2009, China has become the world's second largest oil-importing country.[5] According to the International Energy Agency, China overtook the U.S. as the world's largest energy consumer in 2009, and also became the world's largest emitter of carbon dioxide.[6]

The writing of this chapter was led by Anders W. Hove (侯安德), based upon strategic analysis and research completed by Alan S. Beebe (毕艾伦), Qiyong Cao (曹奇永), Randall S. Hancock (汉瑞德), Stephanie Hung (洪慕德), Claire N. Nelson (聂凯怡) and Jackie Wang (王静) of the China Greentech Initiative's research team.

1. "China GDP Growth Rate," Trading Economics, Jan. 20, 2011, www.tradingeconomics.com; Barboza, David, "China Passes Japan to Become No. 2 Economy," New York Times, Aug. 15, 2010, www.nytimes.com
2. For 2010 GDP, see "China 2010 GDP up 10.3 pct, Dec CPI up 4.6 pct – media," Reuters, Jan. 19, 2011, www.in.reuters.com; for other economic indicators, see Hall, Simon, "IEA Casts Doubt on China's Economic Data," Wall Street Journal, Feb. 10, 2011, www.online.wsj.com
3. "China Energy Data, Statistics, and Analysis – Oil, Gas, Electricity and Coal," U.S. Energy Information Administration, Nov. 2010, www.eia.doe.gov
4. China Greentech Initiative analysis
5. "International Energy Statistics, Petroleum Consumption," U.S. Energy Information Administration, http://www.eia.gov/, accessed on Feb. 24, 2011; data on oil imports from "China Energy Data, Statistics, and Analysis – Oil, Gas, Electricity and Coal," U.S. Energy Information Administration, Nov. 2010, http://www.eia.doe.gov/, accessed on Feb. 24, 2011
6. Smith, Grant and Christian Schmollinger, "China Passes U.S. as World's Biggest Energy Consumer, IEA Says," Bloomberg, Jul. 10, 2010, www.bloomberg.com

Total Energy Consumption of Select Countries, quadrillion BTUs, 1965-2010



Source: BP, Statistical Review of World Energy (United Kingdom: BP, 2010)

China already dominates world consumption of commodity materials. The country is the world's largest steel consumer, utilizing an estimated 45% of world production in 2010 (more than twice what the U.S. consumes).[7] As China expands its own infrastructure while also serving as the manufacturing center of the world, it consumes 44% of the world's cement and 40% of the world's copper.[8] China is also the world's largest grain and meat consumer.[9] All of these figures make sense given the country's immense size—many Chinese provinces have larger populations than major world economies such as France or Germany.

China's Greentech Markets Are Set to Lead the World

The China Greentech Report 2009 documented the state of China's greentech sectors, including the trends the China Greentech Initiative had identified through collaboration with over 100 commercial, not-for-profit and governmental organizations. In the Report, the China Greentech Initiative estimated that China's addressable greentech market could be US$ 500 billion to US$ 1 trillion by 2013. Already the world's largest investor in the Renewable Energy sector, China has demonstrated its leadership in many greentech industries during the last 18 months, including wind, smart grid, smart meters, high-speed rail, subway construction and water:

- **Wind:** China has become the world's wind capacity leader, with almost 44.7 GW installed by 2010 (18.9 GW were installed in 2010 alone).[10] One of every two turbines installed worldwide in 2010 was in China.[11]
- **Smart meters:** To upgrade billing and improve efficiency, China will install 50-60 million automatic-meter-reading (AMR) smart meters in 2011 alone.[12] China may replace the country's meters again in 2015, if automated meter infrastructure (AMI) meters are needed.[13]

7. Brown, Lester, "Plan B Updates," Earth Policy Institute, Feb. 16 2005, www.earth-policy.org
8. For copper, see Gallegos, Ignacio, "China, second largest copper producer in 2010, ahead of the US and Peru," MercoPress, Feb. 14, 2011, www.en.mercopress.com; for cement, see "China now no. 1 in CO2 emissions; USA in second position," Planbureau voor de Leefomgeving, www.pbl.nl, accessed on Mar. 28, 2011
9. Brown, Lester, "Plan B Updates," Earth Policy Institute, Feb. 16 2005, www.earth-policy.org
10. "China adds 18.9 GW of new wind power capacity in 2010," Global Wind Energy Council, Apr. 6, 2011, www.gwec.net
11. "China Invests $10 Billion in Wind Energy Technology," Solar Thermal Magazine, Dec. 5, 2010, www.solarthermalmagazine.com
12. 中国国际金融有限公司,"即将进入全面建设期的中国智能电网, *"[CICC, "China is about to Build Smart Grid"] www.cicc.com.cn, accessed on Feb. 25, 2010*
13. China Greentech Initiative interviews

- **Smart grid:** State Grid announced it will invest RMB 387 billion (US$ 59.5 billion) to build a national "strong and smart" grid by 2020, including thousands of kilometers of new ultra-high voltage (UHV) lines to move excess intermittent power to where it is most needed.[14] While the plan does not yet include many of the enhanced technologies envisioned in the U.S. and Europe, it will vastly improve China's ability to deliver electricity efficiently to its rapidly growing markets.

- **Subways:** Beijing's new subway now has 155 stations covering 228 kilometers—in just a decade the system has quadrupled in length and almost quadrupled in ridership.[15] If plans are completed on schedule, by 2015 Beijing will far surpass Tokyo, New York, Moscow and Seoul as the largest subway system in the world in terms of length. Other major Chinese cities such as Shanghai, Shenyang and Wuhan are building or expanding similar systems. These massive build-outs may create negative short-term environmental impact; however, they put in place a transportation infrastructure that is far cleaner and more efficient than automobiles and other forms of urban transportation.

- **High-Speed Rail:** China introduced its first high-speed rail line in 1998 with the 200 kilometer per hour service from Guangzhou to Shenzhen; in 2004, China opened a magnetic-levitation train in Shanghai that reaches over 400 kilometers per hour. China has already opened dozens of new high-speed lines. By the end of 2010, 8,358 kilometers of high-speed rail were in operation, making China the world leader in operating distance. If current development plans are realized, the network will have 16,000 kilometers of high-speed rail by the end of 2015.[16] As with subways, high-speed rail reduces demand for airline and long-haul vehicle traffic within China, and thus is considered by the China Greentech Initiative as a green technology.

- **Municipal Wastewater Treatment:** In recent years, China has made great strides in expanding municipal wastewater treatment capacity. By the end of 2010, China had surpassed its 11th Five-Year Plan treatment goal by 7% to achieve a 75% treatment rate.[17] This was made possible by substantial investment in wastewater treatment plant development By early 2011, 3,000 municipal wastewater treatment plants had been constructed (up from only 792 plants in 2005), with 18 new plants added every week.[18] Some experts suggest that China may invest another RMB 90 billion (US$ 13.8 billion) in the next two years to have a total of 5,000 plants with a treatment capacity of 1.6 billion cubic meters of wastewater per day.[19]

While China's greentech achievements are admirable, the targets outlined in the new 12th Five-Year Plan (2011-2015) are even more impressive:

- **Renewable energy:** Target 200 GW of renewable capacity by 2020, including wind, solar, and biomass energy sources.[20]

14. 国家电网, "国家电网智能化规划总报告" [State Grid, "State Grid Smart Grid Plan Final Report"] Feb. 2010
15. Meng, Sishuo, "北京到2015年地铁建设静态投资将达2000亿元,"[Investment to Beijing subway to reach 200 billion yuan in 2015] Sohu News, Oct. 29, 2008, www.news.sohu.com; see also "Beijing Subway map plan," Beijing Subway, www.bjsubway.com, accessed on Feb. 25, 2011
16. "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, Mar. 4, 2011, www.news.163.com
17. "Municipal wastewater treatment rate up by 24%," China Daily, Mar. 16, 2011, www.chinadaily.com.cn
18. Ministry of Housing and Urban-Rural Development quoted in: "New directions in Chinese wastewater," Global Water Intelligence, Oct. 2010, www.globalwaterintel.com; China Statistical Yearbook, 2005-2010 (Beijing, China: National Bureau of Statistics, 2011)
19. China Greentech Initiative interviews
20. "5万亿元:新兴能源十年之约," [5 Trillion Yuan For Emerging Energy Within Ten Years] China West Electric Power Network, Sep. 15, 2010

- **Wind:** Achieve a 2015 total wind capacity of 90 GW, of which 15 GW would be offshore wind.[21] China's 44.7 GW of current wind capacity includes less than 1 GW of offshore wind.[22]
- **Solar:** Grow total installed solar capacity to 5 GW by 2016, relying mainly on utility-scale solar plants, up from less than 1 GW in 2010.[23]
- **Transportation fuels and batteries:** Expect to lead international production of electric vehicles and batteries for EVs, spending RMB 100 to 200 billion over the next 10 years to deploy a fleet of 5 million new energy vehicles by 2020.[24]
- **High-speed rail:** Raise the total length of China's high-speed rail system to 25,000 kilometers (triple its current amount and equal to the world's total today) as part of its plan to link all the nation's major cities with high-speed rail. China also plans to be involved in engineering, financing, and providing equipment for high-speed rail projects in Turkey, Thailand, Venezuela, South Africa and other countries.[25]
- **Nuclear:** Develop 86 GW of nuclear power capacity by 2020, according to statements by National Energy Administration officials, depending on the availability of uranium supplies for fuel, skilled labor and other resources.[26] China has almost 11 GW of operating nuclear power plants and 31 GW under construction.[27] However, following Japan's nuclear crisis in the aftermath of the March 11, 2011 earthquake, China's State Council suspended approvals for all new nuclear power projects until safety standards have been reassessed. At the time of publication, China's nuclear future remains uncertain.[28]
- **Coal:** Add 260-270 GW of coal-fired capacity during the 12th Five-Year Plan, representing 37% growth, and draft standards on sulfur, mercury and oxides of nitrogen (NO_x) that would bring China in line with international standards.[29] The Five-Year Plan would reduce coal as a share of total energy from 70% to 62% by 2015.[30]
- **Carbon intensity:** Commit to reduce the carbon intensity of the economy by 40-45% by 2020 versus the 2005 level, relying on hydro, nuclear, wind and solar energy, increased use of natural gas, improved coal plant efficiency, and improved auto and building efficiency.[31]
- **Water intensity:** Reduce water consumption per unit of industrial output by 30% of 2010 levels (during the 11th Five-Year Plan water intensity was reduced by 37%). Restrict total water use to 670 billion cubic meters per year (177 trillion gallons) between 2011 and 2020 (water use in 2010 was 599 billion cubic meters or 158 trillion gallons).[32]

The 12th Five-Year Plan commits to reduce the carbon intensity of the economy by 40-45% by 2020.

21. "Wind Power Capacity to be Boosted," Global Times, Nov. 11, 2011, www.business.globaltimes.cn
22. "China Dethrones U.S. as Largest Wind Power Installer," Global Times, Jan. 13, 2011, www.business.globaltimes.cn; "China Speeds Up Offshore Wind Power Construction," People's Daily, Mar. 20, 2010, http://english.peopledaily.com.cn
23. "Wind Power Capacity to be Boosted," Global Times, Nov. 11, 2010, www.business.globaltimes.cn
24. "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, Sep. 21, 2010, www.auto.163.com
25. Bradsher, Keith, "China Offers High Speed Rail to California," New York Times, Apr. 8, 2010, www.nytimes.com
26. Liu, Yiyu, "Nuclear power sector target too 'aggressive', says expert," China Daily, Feb. 9, 2011, www.chinadaily.com.cn
27. Ibid.
28. "China suspends approvals for new nuclear plants," Xinhua, Mar. 16, 2011, www.xinhuanet.com
29. 环保部,"火电厂大气污染排放标准(二次征求意见稿)-GB13223-20xx" [Ministry of Environmental Protection, "Call for Comments (second draft) on Thermal Power Plants Atmospheric Emission Standards-GB13223-200x"] 2011
30. "张国宝:"'十二五'新开工建设火电规模约在2.6至2.7亿千瓦 [Zhang Guobao: 260-270 GW of coal-fired capacity to be added during the 12th Five-Year Plan] People, Jan. 6, 2011, http://energy.people.com.cn; See also 中国电力建设企业协会, "'十二五'煤炭占一次能源比重将降至62%," [China Electric Power Construction Association, "Coal to be reduced as a share of total energy to 62% during 12th Five-Year Plan"] Nov. 2, 2010
31. "China vows to 'effectively control' emissions in next 5 yrs," Xinhua, Nov. 23, 2010, www.xinhuanet.com
32. Ivanova, Nadya, "Focusing on Sustainable Growth—China Releases Draft of 12th Five-Year Plan," Circle of Blue, Mar. 10, 2011, www.circleofblue.org

- **Water pollution: R**educe chemical oxygen demand by 8%, ammonia nitrate by 10% and nitrogen oxide by 10% versus 2010 levels. Ammonia nitrate and nitrogen oxide are new water pollution reduction targets, as the 11th Five-Year Plan only included a COD target.[33] These pollutants both come primarily from agricultural run-off, which is a growing source of water pollution in China.

The 12th Five-Year Plan's Most Important Energy and Environment Developments

Water is a top priority: The first official government document of 2011 (an annual signal of central government prioritization) focused almost entirely on water infrastructure, which was brought into sharp focus by the northern China drought.[34] China will accelerate building of water infrastructure, doubling annual investment versus 2010: the total investment over the decade is projected as RMB 4 trillion.[35] However, much of this investment is infrastructure designed to move water from one place to another, which arguably degrades the environment. Clearly, not all water infrastructure is green.

Ambitious goals for cleaner energy, with changes to the fuel mix: The plan continues to promote wind and solar, with goals of 90 GW for wind and 5 GW for solar in 2015.[36] Clean energy targets will be led by nuclear and hydro-electricity, which have greater potential to change the total energy mix given their high capacity factors. Natural gas consumption should rise by almost 150%, with its share of the energy mix growing from 4% to 8%.[37] In contrast, while coal consumption will grow in absolute terms, it will fall from 70% to 62% of the energy mix.[38]

Coal consumption will fall from 70% to 62% of the energy mix.

Policies will improve building energy efficiency in several areas: All new buildings are mandated to achieve 65% energy savings compared to the existing building stock, versus 50% under the previous five-year plan.[39] In late 2010 the government released new measures to promote demand-side management.[40] Policies will also promote the growth of energy-management contracting and energy-service companies (ESCOs).[41]

New targets on fuel-efficiency and alternative fuels: China has already adopted strong fuel-efficiency measures for vehicles. New targets from the Ministry of Industry and Information Technology (MIIT) and China Automobile Association of Manufacturers (CAAM) call for new vehicles to reduce carbon emissions and oil use by 30%.[42]

33. Finamore, Barbara, "The Next Five Years of Clean Energy and Climate Protection in China," Natural Resources Defense Council, Mar. 23, 2011, www.switchboard.nrdc.org
34. Song, Jingli, "No. 1 document may focus on water infrastructure," China Daily, Dec. 23, 2010, www.chinadaily.com.cn. The first document of the year is a tradition dating in some form back to the early 1980s. The document is a way for the central government to signal which topic or issue requires special attention and resolution in the coming years.
35. "中共中央国务院关于加快水利改革发展的决定," [Central People's Government of the People's Republic of China, Decision on accelerating water reform and development] Jan. 31, 2011; Lu, Ting, "China's Investment Momentum: RMB 4 Trillion for Water Projects," Chinastakes, Jan. 31, 2011, www.chinastakes.com
36. "Wind power capacity to be boosted," Global Times, Nov. 11, 2011, www.business.globaltimes.cn
37. "能源局发布会介绍上半年能源经济形势下半年走势," [National Energy Administration introduced the energy economy in the first half-year and trend in the second half-year] Jul. 20, 2010
38. 中国电力建设企业协, "'十二五'煤炭占一次能源比重将降至62%," [China Electric Power Construction Association, "Coal to be reduced as a share of total energy to 62% during 12th Five-Year Plan"] Nov. 2, 2010
39. Levine, Mark D., et al., Assessment of China's Energy-Saving and Emission-Reduction Accomplishments and Opportunities During the 11th Five-Year Plan, (U.S.: Ernest Orlando Lawrence Berkeley National Laboratory, Apr. 2010, 47)
40. 发改委,工信部,财政部,国资委,电监会,能源局,"电力需求侧管理办法," [NDRC, MIIT, MOF, SASAC, SERC and NEA, "Electric Power Demand-Side Management Measures"] Nov. 4, 2010
41. 国务院,"关于加快推行合同能源管理促进节能服务产业发展意见" [State Council, "Accelerating the Implementation of Energy Management Contracting and Promoting the Development of the Energy Savings Services Industry"] Apr. 2, 2010; 发改委, "合同能源管理项目财政奖励资金管理暂行办法" [National Development and Reform Commission and Ministry of Finance, "Interim Measures on Management of Financial Incentive Funds for Energy Management Contracting Projects"] Jun. 3, 2010
42. "十二五规划提出汽车碳排放强度减少30%," Sina, Sep. 21, 2010, www.sina.com.cn

More mandatory green targets: The number of green-related mandatory targets more than doubled. The 11th Five-Year Plan had 22 quantitative targets, and four of the eight mandatory targets were greentech-related: energy intensity, industrial water use, chemical oxygen demand (COD) water emissions and sulfur dioxide (SO_2) air emissions.[43] The 12th Five-Year Plan maintained the existing four mandatory greentech targets while adding six new mandates—for example, on carbon intensity of GDP, share of energy from non-fossil energy, and emissions of oxides of nitrogen (NO_x) and fly ash.[44]

Tension between provincial and national goals: Central government targets for GDP growth, energy and environmental goals will continue to conflict in some cases, with higher growth targets set at the provincial level than those implied from overall national growth rates.[45] As in the past, the central government will often allow the provinces to decide how to reconcile competing objectives, sometimes leading to uneven enforcement of energy and environmental goals.

The 12th Five-Year Plan more than doubled the number of mandatory greentech targets.

Circular economy goals include a push for resource management: As China promotes a better balance between consumption and production for export, the government recognizes the need to manage resources. This includes goals for recycling, reuse, and waste treatment and management—broadly known as the circular economy.[46]

Policies for innovation stepped up, including in energy: China recognizes that previous policies for fostering innovation have not gone far enough. New targets for the Strategic Emerging Industries, which China named in 2010 to help advance economic development, include broad policies for supporting research and development, including fundamental R&D and commercialization of domestic technology. Of the seven designated Strategic Emerging Industries, three are energy related: new energy vehicles, energy efficiency, and new energy (solar, wind, and biomass).[47]

Energy and environmental taxes are likely: Energy and environmental taxes are a likely method for addressing energy and emissions goals, though few have been implemented yet. Taxes (whether direct taxes, auctions or cap-and-trade plans) manage limited resources more efficiently than top-down plant closures or other direct orders. Resource taxes have already been introduced in some areas.[48]

Pricing reform will speed up: After lagging somewhat during the 11th Five-Year Plan period, the government may speed efforts to reform prices for electricity, liquid fuels, water and other resources.[49] Such reforms are broadly needed before other resource management plans can succeed.

43. 中华人民共和国中央人民政府,"国民经济和社会发展第十一个五年规划纲要" [Central People's Government of the People's Republic of China, "National 11th Five-Year Plan for Economic and Social Development"] Mar. 18, 2006
44. "Backgrounder: Review of some major targets during China's 11th Five-Year Program," People's Daily, Oct. 15, 2010, www.english.peopledaily.com.cn; "China vows to 'effectively control' emissions in next 5 yrs," Xinhua, Nov. 23, 2010, www.xinhuanet.com
45. "Overheating fears grow as China's local governments set GDP targets high," Xinhua, Jan. 25, 2011, www.xinhuanet.com
46. "Development plan for nonferrous metal industry," Global Times, Feb. 11, 2011, www.business.globaltimes.cn; "China to achieve 80% urban garbage treatment rate in 2015," People's Daily, Feb. 9, 2011, www.english.peopledaily.com.cn
47. China State Council, "State Council's Decision on Accelerating the Cultivation and Development of Strategic Emerging Industry," Oct. 10, 2010
48. 财政部, 国家税务总局,"新疆原油天然气资源税改革若干问题的规定" [Ministry of Finance, State Administration of Taxation, "Rules on Several Issues Regarding Xinjiang Oil and Gas Resource Tax Reform"] Jun. 1, 2010; "Resource Tax to be Expanded Nationwide," China Daily, Jan. 26, 2011, www.chinadaily.com.cn; "China on the Path Towards Putting a Price on Carbon," National Resources Defense Council, www.switchboard.nrdc.org, accessed on May 16, 2010; "China's Environmental Tax Plan Submitted to State Council," China Daily, Jan. 26, 2011, www.chinadaily.com.cn
49. "China Raises Gasoline, Diesel Prices," Xinhua, Dec. 21, 2010, www.xinhuanet.com; "Modest Rise in Electricity Price Planned," China Daily, Oct. 11, 2010, www.chinadaily.com.cn

Carbon Tax in China: What, When and How?

During the course of its research in 2010 the China Greentech Initiative interviewed officials at China's Energy Research Institute (ERI), which in addition to a range of other energy policy and research related roles, is responsible for designing the framework for resource taxes in China.[1] The Ministry of Finance (MOF), through its affiliated Research Institute of Fiscal Science (RIFS), finished designing a carbon tax framework in March 2010, which was submitted to the National Development and Reform Commission (NDRC) and other related bodies for review. The NDRC focuses on overall economic goals, while the MOF evaluates how to spend tax revenue and the State Administration of Taxation (SAT) determines collection methods. These bodies are currently reviewing the design and determining what type of tax is most appropriate to implement in China: carbon, resource, or energy taxes.

1. China Greentech Initiative interview

What Does China's 40-45% Carbon Intensity Reduction Target for 2020 Mean?

Since China announced its commitment in 2009 to reduce carbon emission intensity by 40-45% by 2020 from the 2005 baseline, observers have debated whether the plan amounts to a substantive policy or a business-as-usual forecast. Growing economies often see improvements in energy efficiency as older equipment and techniques are replaced. While reducing carbon emissions will be challenging, China already has many policies that directly or indirectly promote energy efficiency in automobiles, rail networks, renewable energy, nuclear energy, fossil-fueled industry and power plants.

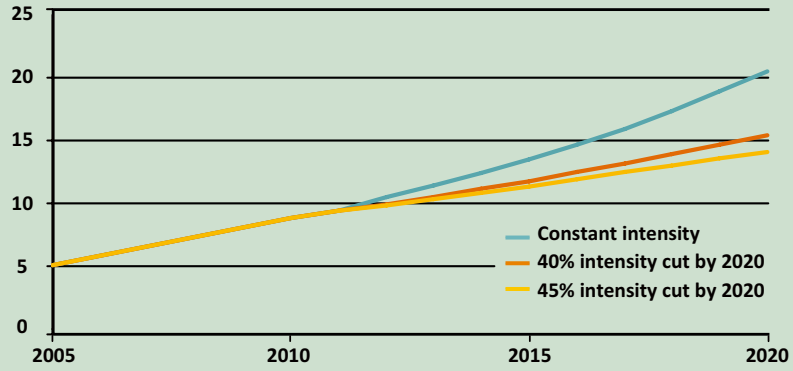
Several organizations have examined the 40-45% target to determine how much effort it will represent for China compared to what otherwise might have been expected. Based on three quantitative papers from the East-West Center, the Natural Resources Defense Council, and the World Resources Institute, their findings indicate that the 45% target is ambitious and substantive, whereas the 40% level represents a conservative forecast given policies already adopted.[50] Specific observations include the following:

If China's GDP achieves 8% annual growth, emissions can be 75-90% higher and still achieve the carbon intensity reduction target.

- Targets depend on China's energy and environmental statistics, which have been continually questioned both inside and outside China. China has yet to publish an official emissions baseline figure for the target.
- The 45% scenario represents more aggressive action than the status quo, but analysts differ about whether it would meet China's necessary contribution to achieving a 450 parts-per-million (ppm) atmospheric carbon concentration.
- The International Energy Administration estimated in 2009 that China's national policies under consideration would reduce emissions by one billion tons of carbon dioxide (CO_2) by 2020, representing a 43.6% carbon intensity change; this implies the low end of China's carbon intensity target is conservative.
- With efforts to continue current policies, such as energy intensity reductions and a 62% coal share of total energy use in 2020, China could achieve a 48% reduction in carbon intensity of GDP.
- Given more investment in new infrastructure, the higher the economic growth, the easier it is to achieve the target. For example, if China's GDP were to grow at 6% annually, China could achieve the intensity target while growing emissions 30-40%; however, if GDP achieves 8% annual growth, emissions can be 75-90% higher and still achieve that target.

*50. Zhang, ZhongXiang, "*Assessing China's Carbon Intensity Pledge for 2020: Stringency and Credibility Issues and Their Implications*," East-West Center, Oct. 2010, www.eastwestcenter.org; Cohen-Tanugi, David, "*China's Carbon Intensity Target in Perspective*," Natural Resources Defense Council, Oct. 2010, www.china.nrdc.org; Seligsohn, Deborah and Kelly Levin, "*China's Carbon Intensity Goal: A Guide for the Perplexed*," World Resources Institute, April 22, 2010, www.wri.org*

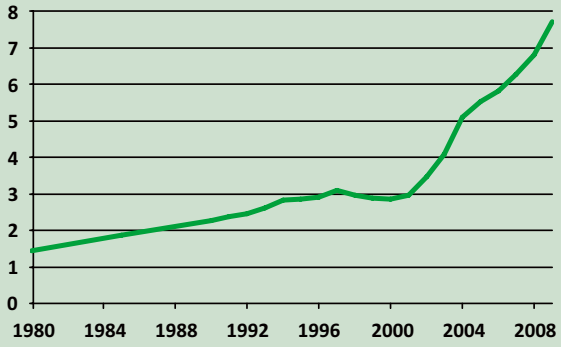
China's Annual Carbon Emissions Under Three Carbon Intensity Scenarios
billion metric tons CO_2, 2005-2020



Sources: "Per Capita and Total Carbon Dioxide Emissions," China Profile, www.china-profile.com, accessed on Mar. 23, 2010; China Greentech Initiative analysis

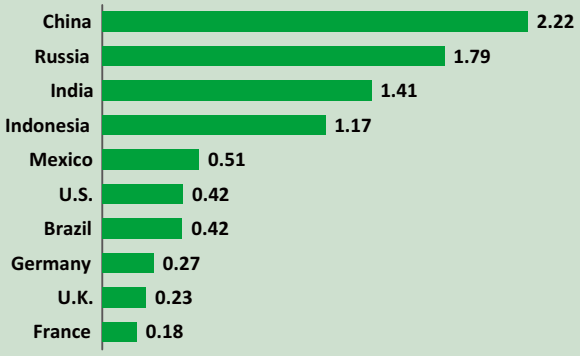
Carbon Emissions Growth and Intensity of GDP

China's Growing Carbon Emissions
billion metric tons CO_2, 1980-2009



Source: "International Energy Statistics, Carbon Emissions," U.S. Energy Information Administration, www.eia.gov, accessed on Mar. 15, 2011

Carbon Emissions Intensity of GDP
tons of CO_2 per US$ 1,000, 2009



Source: "International Energy Statistics, Carbon Intensity using Market Exchange Rates," U.S. Energy Information Administration, www.eia.gov, accessed on Mar. 15, 2011

Urgent Needs Drive Greentech Growth

Government policies respond pragmatically to China's urgent needs in energy security, food and water supply, and pollution.

The scale of the country's energy and environmental needs is just as immense as everything else in today's rapidly-growing China. Consider just three of the most pressing needs pushing China ahead on greentech policies and spending: energy security, water, and pollution. In each area, modest change would not suffice to prevent major negative consequences for China and its people.

Energy Security Concerns Compel Action to Manage Consumption Growth

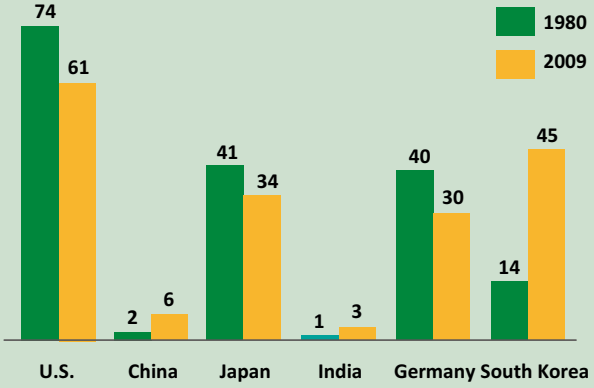
Energy security is a major concern for every large economy, and volatile oil prices and insecure supplies make oil the most pressing issue. In 2009 China consumed 8 million barrels daily out of a total daily world production of 84 million barrels. In the same year the U.S. consumed 19 million barrels per day while the E.U. consumed 14 million barrels per day.[51] This puts China's per capita oil consumption far below the average for developed countries, and just over 10% of the U.S. per capita level. China's oil consumption per unit of nominal GDP is comparable to the U.S. and higher than that of Europe.

Most future incremental world oil consumption will come from the developing world, given expectations for greater economic growth and higher car ownership. Despite China's ambitious fuel efficiency regulations for new vehicles, its oil consumption has grown more rapidly than all other developing countries in percentage terms. The country's oil consumption doubled from 1998 to 2009 and is currently growing at 5-7% per year, whereas developed world consumption is stagnant, leading to a convergence in consumption rates.[52] Of even greater concern to policymakers, China must now import over 50% of its oil since China's domestic oil production cannot keep pace.[53] 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.[54]

51. "International Energy Statistics," U.S. Energy Information Administration, www.eia.gov, accessed on Feb. 24, 2011
52. Ibid.
53. "China Energy Data, Statistics, and Analysis," U.S. Energy Information Administration, www.eia.doe.gov, accessed on Nov. 2010
54. China Greentech Initiative analysis

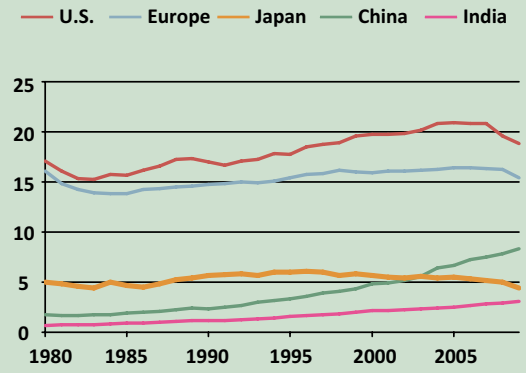
Oil Consumption: China Versus Other Countries

Per Capita Oil Consumption for Major World Countries barrels per day per thousand people, 1980 and 2009



Source: U.S. Energy Information Administration, International Energy Outlook 2010 (Washington, D.C.: EIA, 2010)

China's Oil Consumption Compared to Other Major Countries, million barrels per day, 1980-2009



Source: U.S. Energy Information Administration, International Energy Outlook 2010 (Washington, D.C.: EIA, 2010)

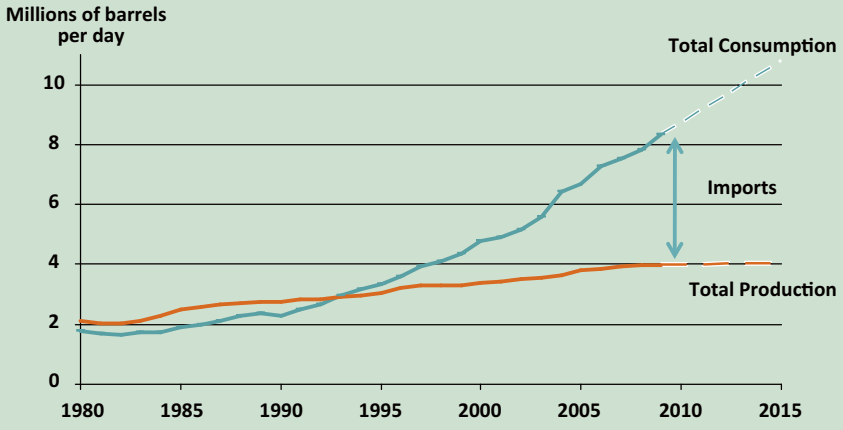
Whether or not the world may be near or even past peak in total oil production, short-term analysis must address how incremental oil demand compares with the cost of bringing on new supply.[55] New world oil supplies come from costly deepwater drilling, oil sands and other unconventional sources. As demand rises, more oil must come from these environmentally risky and (especially in the case of oil sands) energy and carbon-intensive sources.[56]

Higher demand also means higher world oil prices. How high could Chinese oil demand rise? Forecasts from the U.S. Energy Information Administration suggest that by 2030 China could reach two-thirds the U.S. level of consumption: 15 million barrels per day for China compared to 22 million barrels per day for the U.S.[57] Even if the world has enough oil to supply an additional 5-10 million barrels of oil per day to meet developing demand, the high cost of bringing on that capacity is likely to raise world oil prices substantially.

As increased demand leads to a tighter world oil market, this raises more concerns about oil diplomacy. As China's oil consumption rises, it will depend more on maintaining a steady supply of oil from the world's hot spots. From a price perspective, whether the oil physically flows from Nigeria or Iran is unimportant, since spikes in world oil prices affect every consuming country. Energy security for China will no longer be a question of how to produce more domestically, but rather how much to import and how involved to get in crises that afflict various oil-producing countries and regions. Although independence from oil imports is unlikely, acting to manage and limit growth in domestic oil consumption can only improve China's energy security picture.

55. The International Energy Agency forecasts that while crude oil production peaked in 2006, total oil production including unconventional oil supply will rise through 2035, keeping pace with demand. See "World Energy Outlook 2010 Factsheet," International Energy Agency, www.worldenergyoutlook.org, accessed on Mar. 5, 2011
56. "International Energy Outlook 2010 – Highlights," U.S. Energy Information Administration, May 25, 2010, www.eia.doe.gov
57. "International Energy Outlook 2010," U.S. Energy Information Administration, Jul. 2010, www.eia.doe.gov

China's Growing Oil Imports
millions of barrels per day, 1980-2009, forecast to 2015



Source: U.S. Energy Information Administration, International Energy Outlook 2010 (Washington, D.C.: EIA, 2010)

Rising Consumption and Climate Change Create Serious Water and Food Supply Issues

One of China's greatest accomplishments in the past three decades is raising the living standard of its citizens, partly measured by material wealth, greater education, and calories consumed. While food sufficiency is a major achievement of the past 30 years, water scarcity could undo part of that success.

China's food and water challenges have two elements: First, demand is rising in tandem with living standards. Second, changing environmental conditions challenge China's water supply picture—these include melting Himalayan glaciers, rapidly falling water tables, droughts and pollution.

China has made substantial progress in feeding its people. Thanks in part to careful management and technology innovations, China today feeds 22% of the world's people with just 7% of the world's arable land.[58] 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 six centimeters taller and six kilos heavier than a boy of the same age in 1978 at the outset of the Reform and Opening period.[59]

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

Along with rising prosperity come changes in food choices. As incomes have risen in the last 30 years, intake of meat has risen. In 1980, the average Chinese person ate 22 kilograms of meat annually. Today the average has more than doubled to 54 kilograms, nationally equivalent to 600 million pigs or 24 billion chickens. China is now the world's largest meat consumer; though per capita meat consumption is still half that of the U.S., this may indicate room for further growth. In the past 15 years, the number of overweight people in China has doubled to 200 million, according to the Asian Development Bank.[60] The trends toward more calories, including more meat and dairy consumption, appear likely to continue: the U.N. Food and Agricultural Organization projects that within a decade China will increase annual beef consumption by 1.5 million tons and mutton consumption by 1 million tons.[61] In 2007 Premier Wen Jiabao said he hoped someday every Chinese child could consume a pint of milk per day.[62] Meanwhile, McDonald's expects to have over 2,000 locations in China by 2013, double the number of just a few years ago.[63]

58. Liu, H. and Deblitz, C. Determinants of Meat Consumption in China (Australia: Asian Agribusiness Research Centre, 2007)
*59. Watts, Jonathan, "*More Wealth, More Meat. How China's Rise Spells Trouble*," The Guardian, May 30, 2008, www.guardian.co.uk*
60. Ibid.
61. Pan, Chenjun, "China Meat Demand To Soar In Coming Decade," China Daily, Jun. 7, 2011, www.chinadaily.com.cn
62. Watts, Jonathan, "More Wealth, More Meat. How China's Rise Spells Trouble," The Guardian, May 30, 2008, www.guardian.co.uk
63. Humphries, Jodie, "China's Increased Meat Demand," Next Generation Food (NGF), Mar. 10, 2010, http://www.nextgenerationfood.com, accessed Feb. 17, 2011

Thus far, China has met its rising and changing needs through domestic production. China has increased livestock production, devoted more of its grain supply and water to livestock, and become the world's largest meat producer. Pork, beef and lamb output rose from 9 million tons in 1978 to over 60 million tons in 2005, while poultry output rose from 1.5 million tons in 1984 to almost 15 million tons in 2005.[64]

How has China met its goals for food sufficiency, nutrition and rising demand for meat all at once? Chinese officials rightly credit both the gradual Reform and Opening policies as well as China's historic focus on agricultural research and development. China has agricultural universities and research centers in every province and produces more agricultural science graduates than any other country. China has developed and replaced its rice varieties five times since 1960, each time with an average 15% yield increase. China's Reform and Opening policies have also transformed productivity, first by price reform, then by improvements to land use, road and rail transportation, and incentives for efficient private investment in irrigation pumps and fertilizer. As a result of these policies, China now produces 6.3 tons of rice per hectare cultivated versus an average of 1.5 tons per hectare on the African continent.[65]

Unfortunately, several challenges now loom over China's agricultural success story, with pollution emerging as one of the most severe. The government estimates that 10% of arable land is polluted.[66] Fertilizer overuse has reduced productivity, polluted groundwater, and released greenhouse gases; nitrous oxide, a fertilizer with an estimated global warming impact almost 300 times that of CO_2, accounts for almost 90% of agriculture sector greenhouse gas emissions.[67] Pollution also affects rivers. One-fourth of river water in the Yangtze and Yellow Rivers is too polluted for use in agriculture, and in northern China, which is more vulnerable on water issues, the rate is even higher: one-third of river water in the Huai and Liao Rivers is unsafe for any purpose.[68]

The water supply crisis extends beyond the pollution issue, with the picture stark for both supply and demand. 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 with domestic water using the remaining 13%.[69] As China's diets move towards more consumption of meat, more water must go towards providing feed rather than directly for food grain: it takes 3,200 liters of water to produce one kilogram of beef.[70] Given trends towards urbanization and more diverse diets, demand for water will only grow.

One-fourth of river water in the Yangtze and Yellow Rivers is too polluted for agricultural use.

As early as 1999, then-Vice Premier Wen Jiabao had identified the water supply crisis. China's per capita water supply is 2,100 cubic meters per year, or 25% of the world average, but in northern China the per capita supply is just 500 cubic meters. Rainfall in the North has decreased between 20-40 millimeters per decade on average since the 1950s.[71] 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.[72]

64. Liu, H. and Deblitz, C. Determinants of Meat Consumption in China (Australia: Asian Agribusiness Research Centre, 2007)
65. Peng, Shaobing, "Challenges for rice production in China," Rice Today, Oct.-Dec. 2007, www.irri.org/ricetoday; Africa Rice Center (WARDA), Africa Rice Trends: Overview of recent developments in the sub-Saharan African rice sector, 2007 Brief (Cotonou, Benin: WARDA, 2007)
66. Chen, Jun, "China Meat Demand to Soar In Coming Decade," China Daily, Jun. 7, 2011, www.chinadaily.com.cn
67. 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)
*68. "*Water, Air Pollution In China Still Serious,*" China Daily, Feb. 24, 2009, www.chinadaily.com.cn*
69. 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)*
70. "Water Footprint Calculator Methodology and Tips," National Geographic, www.environment.nationalgeographic.com, accessed on Feb. 23, 2011
71. 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)
72. Ibid.

In this time of drought in northern China, it is particularly obvious that water is in short supply. The percentage of villages in the North reporting reliable surface water supplies has fallen from 64% in the early 1990s to 39% in the last decade.[73] The water table has declined as more farmers in the North rely on wells for water. In Hebei province near Beijing, the water table has been falling around one meter per year, and in some areas the change is even more rapid. Near Hebei's capital, Shijiazhuang, villagers a century ago could find water 2.5 meters below the surface, but now in some areas wells must go down almost 200 meters to find water.[74]

The South-to-North Water Diversion Project could eventually divert 44.8 billion cubic meters annually to northern China—equivalent to pumping Lake Erie to Texas over ten years.

Water management and policies contribute to the crisis. Though all groundwater belongs to the state, villagers often do not seek permission before withdrawing water. Cities and industries may be afraid to reduce water use even when they can, fearing permission to consume once given up will never be granted again. Irrigation systems are inefficient, so only 45% of the water drawn reaches the crops.[75] Agencies devoted to water management are reportedly under-staffed and regulations poorly enforced.[76]

Climate change is yet 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 (corn) by 20-36%.[77] Climate change also threatens the Himalayan glaciers, which provide water to the most populous regions on earth in India, China and Southeast Asia. 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. As glaciers melt, they reflect less light due to black carbon building up on the surface, which then compounds the melting rate. Although in 2007 the IPCC withdrew its prediction that the Himalayan glaciers might melt by 2035, the current forecast is not much better: 30% might disappear by 2030 and 40% by 2050.[78]

Aware of the water supply problem, China is taking action. To improve agricultural water use, more villages are using water markets that subject well-water to the private sector, increasing the incentive to conserve. China is investing RMB 4 trillion in water projects across China.[79] The South-to-North Water Diversion Project is one of the largest infrastructure projects underway in the world. The RMB 255 billion project would link China's four major rivers (the Yangtze, Yellow, Huaihe, and Haihe Rivers) into three routes: the nearly complete eastern route of 1,155 kilometers anticipated for 2013, the central route to Beijing covering 1,267 kilometers projected for 2014, and the most challenging western route over the Qinghai-Tibet plateau into northwest China. The project could eventually divert 44.8 billion cubic meters annually to northern China—equivalent to pumping Lake Erie to Texas over ten years;[80] that said, economic and environmental costs are likely to be substantial. Overall, water shortages are one of the most pressing issues facing China today, compelling action ranging from building new infrastructure to addressing climate change. Many of the policies that can improve water scarcity relate directly to solving another one of China's most urgent problems: pollution.

73. 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)
*74. Yardley, Jim, "*Beneath Booming Cities, China's Future Is Drying Up*," New York Times, Sep. 28, 2007, www.nytimes.com*
75. Xie, Jian, Addressing China's Water Scarcity: Recommendations for Selected Water Resource Management Issues (Washington D.C.: U.S.: World Bank, 2009)
76. 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)
77. 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)
78. "The IPCC's 2035 Prediction About Himalayan Glaciers," Skeptical Science, Jan. 21, 2010, www.skepticalscience.com
79. Ting, Lu, "China's Investment Momentum: RMB 4 Trillion For Water Projects," Chinastakes, Jan. 31, 2011, www.chinastakes.com
80. "South-to-North Water Diversion Project, China," Water-technology, www.water-technology.net, accessed on Feb. 17, 2011

Environmental Issues Also Compel Action

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 study estimates diseases caused by indoor and outdoor air pollution kill 656,000 people in China every year, and polluted drinking water kills another 95,600.[81] A more recent study put the total figures higher, at 1.3 million deaths per year for air and water pollution.[82] The number of China's pollution-related deaths is akin to wiping out most of the population of Boston and San Francisco each year.[83]

Looking beyond the death count, pollution also affects the health and welfare of the living. As noted earlier, China's official statistics show that, as of 2010, 43% of China's rivers and 77% of China's lakes are polluted by substances ranging from fecal waste, sulfates and nitrous oxides to heavy metals.[84] These substances also make their way into ground water, irrigation water and the food supply.

Pollution's high economic cost

Pollution's human costs can also be considered in terms of impact on China's GDP. The Chinese 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 3.8-4.3% annually.[85]

Certain industries, such as tourism and agriculture, bear a disproportionate burden of pollution. Air pollution undoubtedly reduces the attraction of many cities and scenic areas of the countryside. 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. Pollution damages China's overall economy by reducing growth and by increasing inflation as domestic food supplies tighten.

Pollution's social cost

If heavy pollution kills hundreds of thousands and hurts the country economically, can pollution still be justified as a necessary evil by pointing to the social stability economic growth enables? According to the Chinese central government, pollution is a major cause of social instability in China today. Mass incidents related to pollution are increasing, ranking only below land and wage disputes. China's domestic press has increasingly responded to public interest in environmental matters by openly covering ecological disasters that affect humans. In 2010 state media reported on the major pipeline explosion that dumped thousands of gallons of oil into the Yellow Sea, a copper mine where toxic effluent killed tons of fish in Fujian province, and on the poisoning of dozens of children by lead from illegal gold operations in Yunnan province.[86]

The Ministry of Environmental Protection estimates pollution reduces China's annual GDP by 3.1%.

The government recognizes the potential for environmental hazards to lead to unrest, as a pointed 2006 speech by China's then-new minister at the State Environmental Protection Administration (SEPA), Zhou Shengxian, showed. "The environment has become a focal issue that triggers social contradictions," Zhou said, as quoted by Beijing News.[87] Zhou blamed rising riots on pollution incidents and called on the public to engage in a "struggle" against polluters, who he said violate laws, often under the protection of interested local officials.[88]

81. Platt, Kevin Holden, "Chinese Air Pollution Deadliest in World, Report Says," National Geographic News, Jul. 9, 2007, www.news.nationalgeographic.com
82. "Environment problems pose health risk for China: Lancet," The Independent, Mar. 26, 2010, www.independent.co.uk
83. "American FactFinder," U.S. Census Bureau, www.factfinder2.census.gov, accessed on Mar. 10, 2011
84. 环保部, "2010年重点流域水环境质量状况*." [Ministry of Environmental Protection, "Environmental quality of key water bodies in 2010"] Feb. 10, 2011*
85. "China Is Set to Lose 2% of GDP Cleaning Up Decades of Pollution," Bloomberg, Sep. 17, 2010, www.bloomberg.com; "Pollution controls used during China Olympics could save lives if continued, study concludes," Oregon State University, Feb. 11, 2011, www.sciencedaily.com; The World Bank and State Environmental Protection Administration, P.R. China, Cost of Pollution in China (Washington D.C., 2007)
*86. Jacobs, Andrew, "*In China, Pollution Worsens Despite New Efforts*," New York Times, Jul. 29, 2010, www.nytimes.com*
87. Coonan, Clifford, "Chinese PM admits sandstorms are sign of 'ecological destruction'," The Independent, Apr. 21, 2006, www.independent.co.uk
88. "Pollution fuelling social unrest in China," Reuters, Jul. 7, 2007, www.reuters.com

There may be a relationship between the lax enforcement and official collusion in pollution incidents and the pervasive public distrust; however, the situation may benefit from SEPA's 2008 restructuring to become a ministry (now known as MEP), which empowered the regulatory body with more authority in environmental regulation, monitoring and enforcement.[89] As affluence and environmental awareness grow, tolerance for corruption that allows for pollution may decline. 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 environmental and energy-efficient sectors as Strategic Emerging Industries 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."[90]

Coal power plants are the leading cause of air pollution in China.

Incentives Often Emphasize Growth over Environmental Compliance

Even with increased government attention to environmental problems, construction and investment targets still appear to take precedence over enforcement of energy and environmental goals.

The paramount issue of air pollution, potentially responsible for over a million deaths, has a huge impact on GDP. Coal power plants are the undisputed leading cause of air pollution in China.[91] Coal accounts for 70% of total energy use in China, and the country has added over 200 GW of coal capacity in the last five years, equal to a fifth of total U.S. generation capacity.[92] In the 11th Five-Year Plan (2006-2010), China mandated installation of sulfur scrubbing equipment at new plants and launched over 200 installation projects at existing plants, ultimately leading to over 76% of total capacity having scrubbers installed by 2009.[93] Over 137 GW of scrubber capacity was installed at existing power plants for a total cost of RMB 34.2 billion, and the government granted a subsidy of RMB 0.015 per kilowatt hour to plants that had scrubbers.[94]

Yet because initial targets focused on speed, cost, and installed capacity, an estimated one-third of the over 1,200 scrubbers installed in China do not work properly; in fact, many scrubbers are non-operational. Though China exceeded its target to reduce sulfur dioxide emissions by 10% from 2005 baseline levels (reporting a 14.3% reduction at a time when coal power generation expanded rapidly), the improvement seems modest given the huge outlay of funds.[95] Furthermore, the 11th Five-Year Plan attached little importance to particulates and NO_x—also caused by coal plants—even though abating these two pollutants is typically cheaper than abating sulfur. New draft standards are addressing both issues by potentially bringing actual emissions standards from new and older plants into line with international norms—as a result, total coal power plant sulfur emissions would fall by half versus those projected under the 2003 standard (529 million tons annually versus 1,049 million tons), though the target enforcement period is uncertain.[96]

89. 中国环境保护网, "环保总局拟改为环境部,"[China Environmental Protection Network, "Environmental Protection Administration to be changed to Ministry of Environment Protection"] Mar. 11, 2008
90. "State Council's Decision on Accelerating the Cultivation and Development of Strategic Emerging Industry," China State Council, Oct. 10, 2010
91. Kahn, Joseph and Jim Yardley, "As China Roars, Pollution Reaches Deadly Extremes," New York Times, Aug. 27, 2007, www.nytimes.com; see also "China's Health and Environment: Air pollution and health effects," World Resources Institute, 1998-99, www.wri.org
92. "China: Background," U.S. Energy Information Administration, www.eia.doe.gov, accessed on Feb. 18, 2011; China Greentech Initiative analysis
93. Ni, Chunchun, China Energy Primer (U.S.: Ernest Orlando Lawrence Berkeley National Laboratory, Nov. 2009); 电监会 "2009年电力企业节能减排情况通报" [SERC, "2009 Power Company Energy Saving and Emission Reduction Report"] Nov. 2, 2010
94. Ni, Chunchun, China Energy Primer (U.S.: Ernest Orlando Lawrence Berkeley National Laboratory, Nov. 2009)
95. Li Jing, "Senior official calls for cap on coal consumption," China Daily, Mar. 13, 2011, www.chinadaily.com.cn
96. 环保部, "火电厂大气污染排放标准(二次征求意见稿)-GB13223-20xx" [Ministry of Environmental Protection, "Call for Comments (second draft) on Thermal Power Plants Atmospheric Emission Standards-GB13223-200x"] 2011

Off-the-Charts Pollution in Beijing

Although press coverage of pollution incidents has increased in China, readers may have to read between the lines of press reports to understand their significance. Consider the coverage during three weeks of particularly severe air pollution in Beijing in late November and early December 2010, when fine particulate levels exceeded the U.S. Embassy particulate monitoring device's maximum level of 500 on the U.S. Air Quality Index. Pollution was literally off-the-charts.[1] The China Daily ran the pollution story in guarded terms, with the "fog" warranting a front-page A1 headline. Other media outlets were more forthcoming.

New York Times:[2]

A 'Crazy Bad' Day in Beijing. Elizabeth Rosenthal, Nov. 26, 2010

Last week, just after Beijing's mostly coal-fired heating system kicked in for the winter, the pollution became what an official Twitter account of the United States Embassy in Beijing briefly referred to as "crazy bad."

…

Since last year, the United States Embassy has been issuing hourly Twitter updates on Beijing's air quality, and some of the readings have been pretty shocking. The tweet emerged last week when levels of tiny particulate matter (known as PM 2.5) rose to over 500 [on the U.S. Air Quality Index]. That's about 20 times the limit that the World Health Organization regards as "acceptable and achievable" for a 24-hour period.

Xinhua:[3]

Wind can't blow away Beijing's pollutants. Dec. 3, 2010

The sky appears blue, but the air remains polluted, Beijing's environmental watchdog ruled Thursday as strong winds blew away the murky haze that shrouded China's capital for days.

Beijing Environmental Monitoring Center's daily report shows that Beijing's average air quality from mid-day Wednesday to Thursday was "slightly polluted" (pollution reading 101 to 200).

Test results from 14 out of the 27 monitoring sub-stations in the city even show the day's air was "poor" (201 to 300) or "hazardous" (over 301).

Just a week after the headlines hit the world press, China announced a new web site with data on hourly particulate levels in Beijing, and recently launched a single national web site to provide the public with readings from cities across the country—the site includes both current information from over 2,000 monitoring devices and historical graphs.[4]

1. The U.S. Embassy particulate monitor uses the U.S. Environmental Protection Agency Air Quality Index. The calculation of the index value is non-linear and based on the level of fine particulates per square meter. See Johnson, D.L., et al., Meanings of environmental terms (U.S.: Journal of Environmental Quality: 26, 1997, 581-89

2. Rosenthal, Elizabeth, "A 'crazy bad' day in Beijing," New York Times, Nov. 26, 2010, www.green.blogs.nytimes.com

*3. "*Wind can't blow away Beijing's pollutants*," Chinagate, Dec. 3, 2010, www.en.chinagate.cn*

4. "重点城市空气质量发布系统" [Major City Air Quality Publishing System], www.58.68.130.147/Air/Welcome.html*, accessed on Feb. 25, 2011*

The emphasis on achieving the 11th Five-Year Plan targets (as opposed to addressing the intention behind the targets) is even more apparent when it comes to the effort to address water pollution. The mandate to build wastewater treatment plants shifted the focus from the end to the means, prioritizing building as many large plants as possible over improving long-term water quality. Local officials reportedly focused on building plants with large rated capacity, regardless of whether the plants were capable of operating at the stated capacity.[97] Shoddy equipment, low maintenance budgets, and minimal attention to reducing operating cost meant that state-owned municipal wastewater treatment plants operate at far lower efficiency and higher cost than their private counterparts. But importantly, many plants have simply shut down and stopped operating altogether, effectively delaying achievement of the water quality goals the targets were intended to promote.[98]

*97. Wang, Jin, "*BOT*对污水处理厂建设的新要求," [New requirements from a BOT wastewater treatment plant] Hebei Wastewater Treatment Engineering Center, www.200863.com, accessed on Nov. 21, 2010*

98. 财经网,"中国污水处理能力四分之一形同虚设," [Caijing, "China Wastewater Treatment Capacity is One-Fourth Wasted"] Jun. 23, 2009

Although China's greentech targets to date have produced dramatic results, compromised by the prioritization of investment, growth and domestic industry targets over environmental goals, they did not achieve their full ecological potential. For example, China's rush to install wind turbines outpaced the grid's ability to connect wind plants and absorb the power they produce. As a result, at the end of 2008 a reported one-third of installed wind capacity was not connected to the grid, and those turbines that were connected produced far less power than equivalent capacity turbines in the U.S. or Europe.[99] Local officials seeking growth and developers chasing quick returns (including state-owned enterprises) responded to incentives that promoted capacity over lifetime energy production, and thus often failed to meet grid connection requirements. The situation improved dramatically in 2010 due to new incentives for grid operators to link up renewable power sources: State Grid announced in early 2010 that over 90% of wind plants are now connected.[100] By promoting clean power production as opposed to rewarding capacity, the government should see greater emission reductions.

The incentives included in the 12th Five-Year Plan for the lifetime performance and efficiency of greentech equipment will do much more to improve quality of life than previous installation targets.

Other examples of mixed incentives abound. China Greentech Initiative analysis in the Electric Power Infrastructure sector indicated meter installation incentives put a low priority on reducing power consumption. Findings highlighted in the Green Building chapter shows that though China fell short of targets for urban heating and building energy efficiency due to poor enforcement, the 12th Five-Year Plan should bring improvements. There are other cases where China's environmental quality standards and enforcement have improved, such as in building codes and, perhaps most strikingly, auto emissions regulations. China achieved a sizeable improvement in energy intensity, albeit shy of the 20% improvement originally set, through a combination of better efficiency standards and top-down enforcement actions (such as plant closures).[101] Though the record on efficiency and enforcement is decidedly mixed, there were positive gains. The 12th Five-Year Plan includes incentives for the lifetime performance and efficiency of equipment that improve quality of life much more than short-term installation targets.

The government is responding to national needs related to energy security, increasing water scarcity and pollution. At its heart, China's greentech policy is a pragmatic one, aimed at helping near- and long-term growth, and ultimately promoting social stability, public health and national security.

99. Howell, Thomas, et al., China's Promotion of the Renewable Electric Power Equipment Industry (Washington D.C., U.S.: Dewey & LeBoeuf LLP for the National Foreign Trade Council, 2010)
100. Verbal comments at State Grid conference, Oct. 30, 2010
101. "China's Energy Intensity Likely Fell 19% In 2006-2010," ytwhw.com, Feb. 10, 2011, www.ytwhw.com

Continuing Urbanization and the Growth of Eco-Cities

The immense resource demands brought about by China's continuing historic urbanization compel policymakers to make existing cities more sustainable and establish new eco-city projects.

China's population shift from rural to urban areas represents the largest migration in human history, but to date this has occurred without great emphasis on sustainability. Many aspects of today's cities need attention, such as their sprawling urban design, energy-inefficient buildings, and cheap construction. Policymakers recognize that achieving national goals on energy efficiency and carbon emissions will depend upon the progress made by the cities, reflected in the newly announced eco-cities and policies on building and heating efficiency.

Urbanization in China is more than a trend—it is an immense social and ecological shift on a scale and at a rate never before witnessed in human history. In 1980 China was still overwhelmingly rural and agricultural, with a mere 20% of the population living in cities. Only 30 years later, the urbanization figure stands at over 47%, with no sign of slowing.[102] The absolute numbers are even more stunning: in 1980 China had 200 million urban residents, compared to 622 million today, of whom 167 million are migrant workers.[103] Since 1980 China's cities have grown by more than the total population of North America, and yet the majority of Chinese people still live in the countryside.

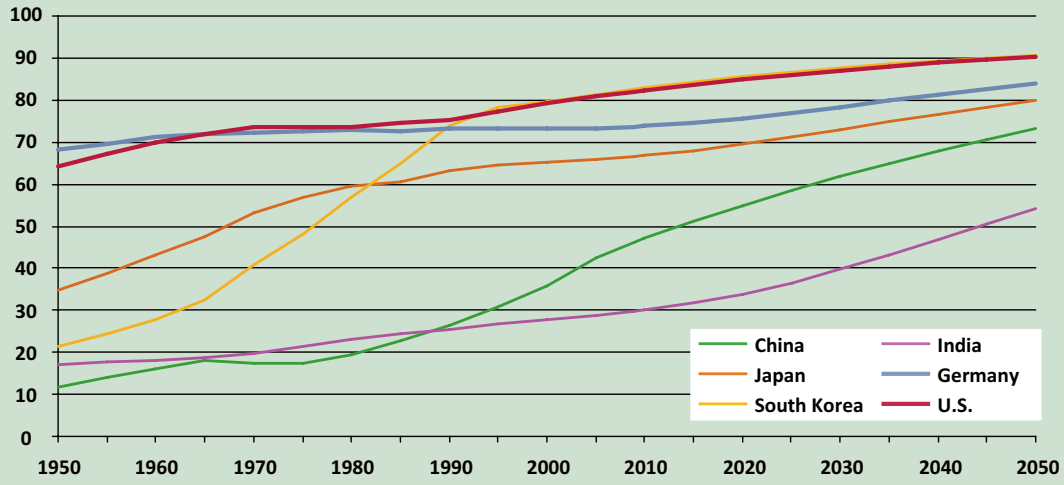
This immense migration has meant the construction of gigantic new cities. Shenzhen, a southern Chinese city whose name originally referred to deep drains in nearby rice paddies, grew from a small fishing village in 1980 to a city of nearly nine million, thanks to its status as a Special Economic Zone in the early days of China's Reform and Opening.[104] Similarly in the North, the capital of Hebei province, Shijiazhuang, has grown to over nine million from just 335,000 in 1950—and unlike Shenzhen, this city has not benefited from any designation as a Special Economic Zone.[105]

Shanghai, Beijing, Guangzhou and other cities already well-established 50 years ago have also experienced astonishing growth, constructing entirely new satellite cities on their outskirts, complete with rings of superhighways and newly-built subway lines. Shanghai's Pudong skyscraper district and Beijing's Central Business District (CBD) symbolize urban China.

102. Goldman Sachs, Hukou Reform: A Mid To Long Term Goal, Picking Up Pace (U.S.: Goldman Sachs, 2011)
103. 国家统计局, "中华人民共和国*2009*年国民经济和社会发展统计公报,"*[National Bureau of Statistics, "PRC 2009 National Economic and Social Development Statistics Report"] Feb. 2010*
104. "Population in Shenzhen Increases 31 Times in 25 years," China.org.cn, Aug. 22, 2005, www.china.org.cn
105. Yardley, Jim, "Beneath Booming Cities, China's Future Is Drying Up," *New York Times, Sep. 28, 2007, www.nytimes.com*

Even if China's growth slows, urbanization will continue. China's urbanization rate is still under 50%, compared to above 80% in most developed countries. Rural incomes are less than one-third of urban incomes, and migrant workers can typically double their salaries by moving to the city, even if this means hardship and loss of some social benefits tied to China's historic hukou resident registration system.[106] If the hukou system undergoes reform, as is being discussed, a new wave of migration to the cities could begin as workers bring in their families to take advantage of new benefits.[107]

Urbanization Rates of Selected Countries, Historical and Forecast, percent, 1950-2050



Source: United Nations, World Population Prospects: The 2008 Revision and World Urbanization Prospects: The 2009 Revision (New York, NY: United Nations, 2010)

The government has strong economic motivation to encourage urbanization. Not only are workers drawn to the city by higher wages and urban living conditions, the economic output of workers rises dramatically once they arrive. China's agricultural productivity is far below that of Western countries, and currently 38% of China's labor force is devoted to agriculture, far higher than the percentage in developed countries (6%) or even in other rapidly-developing countries (14%). The value-added per agricultural worker in China today is less than a tenth that of a non-agricultural worker, meaning that the more urbanization continues, the faster China's economy can grow. For this reason, the United Nations forecasts that China's urbanization rate will reach 60% by 2025 and nearly 80% by 2050. Hundreds of millions more people are on their way to live in China's cities.[108]

Urbanization's immense effect on the environment can be both positive and negative. On the positive side, cities have inherent efficiencies over rural or suburban living: shorter and more efficient transportation for goods and people, potential energy and materials savings gained from living and working in large buildings, and productivity gains from combining various services in a smaller area. On the negative side, urbanization at this scale requires a vast outlay of natural resources to construct new cities, which often replaces productive arable land. The higher income level of urban dwellers also leads to greater consumption, often with outsized impact, illustrated by the status symbol of flashy new gas-guzzling cars.

106. Goldman Sachs, Hukou Reform: A Mid To Long Term Goal, Picking Up Pace (U.S.: Goldman Sachs, 2011); the hukou household registration system dates from ancient times and includes data on household location, births, deaths, marriages, spouses and parents. Health care, education, and other benefits are often available only to those registered locally, and many migrant workers lacking a local hukou live in shantytowns. See Moxley, Mitch, "'Hukou' Registration System Trips Over Inequity," IPS, Nov. 25, 2010, www.ipsnews.net

107. "让房子和户口不再令我们心痛,"[Let house and hukou not hurt us] CNTV, www.news.cntv.cn, accessed on Mar. 28, 2011

108. Goldman Sachs, Hukou Reform: A Mid To Long Term Goal, Picking Up Pace (U.S.: Goldman Sachs, 2011)

The government is acutely aware of the challenges of urbanization and its effect on the environment. The 11th Five-Year Plan included a number of targets related to improving the efficiency of cities. For example, China met its target of building 150 million square meters of district heating, and removed many low-efficiency coal boilers and heating ducts.[109] The plan also required new public buildings to reduce energy use by 50% compared to the existing building stock (typically built in the 1980s), mainly by improving heating, ventilation and air conditioning, lighting, and building insulation. Overall, the building sector was intended to meet two-fifths of the overall national energy intensity target set in the 11th Five-Year Plan.[110]

Cutting the carbon emissions of existing eco-cities by 20% would equal 32 million tons of carbon, equivalent to the emissions of New Zealand.

Targets for cities are bound to be more ambitious given the scale of the challenge. For the 12th Five-Year Plan, new buildings may need to reduce energy use by two-thirds compared to the existing stock; for existing buildings policies will promote more advanced metering and energy service contracts to reduce energy use.[111] Shanghai, Wuhan, Tianjin, and Nanjing are experimenting with green buildings policies. Overall, green buildings certified under 3-Star or Leadership in Energy and Environmental Design (LEED) account for 7 million square meters of newly-built urban floor space in China in 2010. Though this figure represents a great increase over the 2008 baseline of next to nothing, it still accounts for less than 0.5% of total new floor space in 2010. If China's cities must accommodate another 200 to 300 million people over the next few decades, these policies are likely just the start.[112]

Eco-Cities Offer the Potential to Make China's Cities More Sustainable

Eco-cities are one of the most intriguing trends to emerge in the last few years of China's urbanization. While sustainable design, green buildings, and low-carbon cities have taken off elsewhere, no country has shown as much enthusiasm for these buzz words as China. China now has 18 cities or urban areas designated as eco-cities (including those officially described as low-carbon, green, or sustainable), with more expected. These existing cities currently hold 28 million people, far larger than any such program or set of programs elsewhere.[113]

If we look only at these existing cities, a few quick calculations illustrate their importance. Cutting the carbon emissions of existing eco-cities by 20% would equal 32 million tons of carbon, equivalent to the emissions of New Zealand. Cutting energy use by 20% would equal 62 million tons of standard coal, equal to the energy use of Tunisia (or half that of New Zealand).[114] However, it is the tremendous growth potential that shows the most promise: not only are the existing cities just getting off the ground, but there are also more eco-cities on the way.

The case of Chongqing illustrates how growth potential makes eco-cities more important than their present populations imply. The urban area of Chongqing is one of China's largest inland cities with 5 million people.[115] Recently, the central government designated a vast area north of the existing city as the Liangjiang New Area, meant to replicate the recent success of economic zones in Shanghai and Tianjin but with a low-carbon thrust. Targets for the Liangjiang New Area include raising its existing

109. 住房和城乡建设部建筑节能中心, *"关于推进北方采暖地区既有居住建筑供热计量及节能改造工作的实施意见" [Center Of Energy Efficiency In Buildings, MIIT, "Comments On Accelerating The Implementation Of Building Heating Measurement And Energy Saving"] May 21, 2008*

*110. "*国民经济和社会发展第十一个五年规划纲要*" [National 11th Five-Year Plan for Economic and Social Development] Mar. 16, 2006; China Greentech Initiative analysis*

111. Levine, Mark D. et al., Assessment of China's Energy-Saving and Emission-Reduction Accomplishments and Opportunities During the 11th Five-Year Plan (U.S.: Ernest Orlando Lawrence Berkeley National Laboratory, Apr. 2010, 47)

112. "LEED Projects and Case Studies Directory," USGBC, www.usgbc.org, accessed on Nov. 13, 2010; China Greentech Initiative analysis

113. "Sino-Singapore Tianjin Eco-City (SSTEC): a case study of an emerging eco-city in China," The World Bank, www-wds.worldbank.org, accessed on Jan. 20, 2011

114. China Greentech Initiative analysis

*115. "*China: Chongqing*," City Population, www.citypopulation.de, accessed on Mar. 20, 2011; 5 million refers to the urban population of the vast Chongqing Municipality, which has a total population of 30 million, mostly living in rural areas.*

urban population from 1.7 million to 4 million by 2020, and increasing GDP from RMB 90 billion to RMB 640 billion.[116] The city's targeted industries include wind-turbine manufacturing, energy efficient buildings, electric vehicles, and high-speed trains.[117]

What are the potential carbon emissions of the Chongqing Liangjiang New Area? If carbon emissions in the new zone rise in line with GDP, one would expect the zone to emit an additional 167 million tons annually, more than five times that of New Zealand. If the zone merely complies with the central government's 45% targets for carbon intensity reduction in China as a whole, it would save almost 90 million tons of carbon emissions, or nearly three times the emissions of New Zealand—while meeting GDP targets.[118] If eco-cities live up to their potential, they could substantially reduce carbon emissions.

China's Urbanization Leaves Many Policy Problems Unresolved

For both existing cities and newly-designated eco-cities, the urbanization trend presents major problems. For existing cities, these include how to handle growth in car-ownership and traffic, how to increase building construction quality, energy efficiency, and compliance with related laws, and how to plan cities for greater overall efficiency.

Road transport presents a major dilemma for China, and a controversial one. As in other countries, car ownership is not just a transportation choice, but rather a lifestyle statement. Car ownership is rising much more rapidly than the economy overall. In 2009 China surpassed the U.S. as the world's largest car market by unit volume, with passenger car sales rising over 33%.[119]

In Beijing, car ownership has risen from 2.5 million in 2005 to 4.8 million in 2010, with 700,000 new cars in 2010 alone. A study by IBM categorized Beijing traffic jams alongside those in Mexico City as the worst in the world. However, the Beijing government's recent announcement that it would ration license plates to limit car-ownership yielded unintended consequences. In the 24 hours before the new system limited new car licenses to 20,000 per month, more than 100,000 new drivers rushed to buy cars. Many of the buyers were first-time car-drivers with no driver's license.[120]

Over half of China's residential buildings will need to be rebuilt in the next 20 years.

Despite China's new subway, train and bus lines, plus new policies such as higher fuel prices and license-plate restrictions, an irrepressible car-culture has emerged. China's cities today are designed with the car in mind—they are not noted for being pedestrian or mass-transit friendly even where mass transit exists. Beijing has five ring roads (not counting the non-existent first ring) and its major urban centers such as Guomao and Sanyuanqiao devote vast tracts of precious land to highway interchanges that are difficult for a pedestrian to navigate at any hour of the day. Stricter policies might include congestion pricing (already proposed for Shenzhen) and land-use planning to restrict vehicle access and prevent urban expansion into far-flung areas.[121] However, these policies might prove just as controversial in China as they have in developed country cities already wedded to long commutes from attractive but traffic-choked suburbs.

Building quality and efficiency are also serious unresolved issues. For example, in 2010 China Daily quoted a senior researcher from the Ministry of Housing and Urban-Rural Development saying that due to poor quality construction, over half of China's residential buildings will need to be rebuilt in the next 20 years.[122] The same report

116. 重庆新闻,"两江新区将增*230*万人 农民工有条件可落户" [*Chongqing News, "Population of Liangjiang New Area will be increased 2.3 million, migrant workers could get hukou"] Jun. 22, 2010*
117. "Chongqing Liangjiang New Area Official Website," CLNA, www.liangjiang.gov.cn, *accessed on Feb. 18, 2011*
118. China Greentech Initiative analysis
119. "China Ends U.S.'s Reign As Largest Auto Market," Bloomberg, Jan. 11, 2010, http://www.bloomberg.com
*120. "Beijing To Limit Number Of New Car License Plates To Ease Traffic Congestion," Xinhua, Dec. 23, 2010, www.xinhuanet.com; "*被摇晕的治堵前夜,"[*Chaos the day before lottery system enacted] SMW, Jan. 14, 2011, www.nbweekly.com; "Congestion: IBM 2010 Commuter Pain Survey," IBM, www-03.ibm.com, accessed on Feb. 18, 2011*
121. "Shenzhen Likely to Introduce Congestion Charge," eChinaCities.org, Mar. 8, 2011, www.echinacities.org
122. Qian, Yanfeng, ""Most homes' to be demolished in 20 years," China Daily, Aug. 7, 2010, www.chinadaily.com.cn

quoted officials saying the average lifespan of a residential building in China is only 25 to 30 years, compared to over 70 years in the U.S. and over 100 years in Britain. Various trends have contributed to shoddy construction over the years. Buildings over 30 years old were originally rushed into place to meet the short-term needs of workers, and never intended for long-term use. More recently-constructed buildings have suffered from profit-minded developers who cut corners and violated standards to complete buildings on schedule at low cost. Naturally, these quality issues affect energy efficiency. A startling 95% of China's houses rate as "high energy consumption," and district heating—which is intended as an energy-saving technology—wastes enormous quantities of heat through leaking pipes and building envelopes.[123] One study estimates that old heating stations and pipes lose twice the energy consumed by the already-high heating load of the buildings themselves.[124]

China's system of urban planning has emphasized huge new projects, some of which are large by necessity, while others simply may project a glamorous and prosperous image. As the head of the China City International Association noted in 2011, local governments seek short-term profits through land development, and an "urban image cultivated by skyscrapers and luxurious products is always a shortcut for city officials to showcase their achievements."[125] The skyscraper districts of Shanghai's Pudong and Beijing's CBD show how government has used scale to create an image. To promote Shanghai years before the 2010 World Expo, local officials approved a US $1 billion Formula One track, a US $300 million tennis center, a 33-kilometer magnetic levitation (Maglev) train to the airport, and the stunning Pudong skyscraper zone dominated by state-run firms.[126] Similarly, the new Rem Koolhaas and Ole Scheeren-designed CCTV headquarters in Beijing's Central Business District (CBD), one of the most distinctive and striking buildings in the world, cost over US$ 1 billion.[127] Although Beijing's existing commercial office stock ranked among the top ten most over-supplied in the world with 23% sitting vacant as recently as June 2010, Beijing's city government announced plans in late 2010 to double its CBD by adding three square kilometers of skyscrapers, including a 500-meter tower.[128]

The city of Ordos in Inner Mongolia has attracted worldwide media attention in the past year as a possible indicator of waste in infrastructure planning. The newly-built Kangbashi district is designed for 300,000 people, but may have just 28,000, according to a Bank of America-Merrill Lynch report. The new city features empty six-lane highways and sumptuous villa-style houses—although 90% of the units have been sold, as few as 5% may have residents. The government has also spent over RMB 500 million on a Great Theater of Ordos, RMB 362 million on a new Ordos National Theater, and RMB 318 million on a cultural center—fairly lavish for a city with few restaurants due to a lack of customers.[129]

Ninety-five percent of China's houses rate as "high energy consumption."

However, deciding whether new skyscrapers or new cities are excessive is a matter of perspective; in Ordos, its 25% annual GDP growth may eventually attract wealthy residents to fill the empty houses and cultural venues.[130] And grandiose scale is certainly not limited to present-day China, as government-funded skyscrapers in New York in the 1930s, Malaysia in the 1990s, or Dubai in the last decade have shown. Nonetheless, rapid urbanization combined with central planning could benefit from additional market incentives for efficiency and sustainability as opposed to bright lights and glamour.

123. Li, Xiaodong and Zhang Xiaodi, The Problems and Countermeasures of China Energy-Saving Building (China: Advanced Materials Research, Vols.179-180, 2011, 855-858)
124. Kerschberger, Alfred, "Drei Pilotprojekte zur energieeffizienten Sanierung von Mehrfamilienhäusern in Nordchina" [Three pilot projects on energy efficiency refurbishment of apartment buildings in Northern China], Sino-German technical Cooperation – Energy Efficiency in Existing Buildings Project output, www.rk-stuttgart.de, accessed on Mar. 10, 2011
125. "Urban China: Playground for the Rich?" Xinhua, Feb. 22, 2011, www.xinhuanet.com
126. McGregor, R., The Party: The Secret World of China's Communist Rulers (UK: London Allen Lane, 2010)
127. "China Central Television (CCTV) Headquarters, China," Designbuild, www.designbuild-network.com, *accessed on Feb. 18, 2011*
128. "CBD Set To Double In Size By 2017," People's Daily Online, Oct. 13, 2009, www.english.people.com.cn; "Office Vacancy Rates," The Economist, Aug. 19, 2010, www.economist.com; Cai Muyuan, "Citic to build Beijing's tallest building," China Daily, Dec. 22, 2010, www.chinadaily.com.cn
129. "China's Desert Ghost City Shows Property 'Madness' Persists," Bloomberg, Jun. 24, 2010, www.bloomberg.com
130. "Profile Of Ordos City," Ordos Online, www.ordos.gov.cn*, accessed on Feb. 18, 2011*

China's Eco-Cities Face Unique Problems

While government support for the eco-city movement is impressive, unresolved issues remain. For one, the pace and size of announcements has far outpaced the substance, which is true both for China and internationally.

Consider the international examples of the Masdar eco-city in the United Arab Emirates and the Songdo International Business district in South Korea. For Masdar, the government has faced criticism that the desert city will face high air-conditioning loads and large water supply challenges—all difficult to cost-effectively address without resorting to fossil fuels. Most of the funding for Masdar will come from the government, and its high cost makes it unlikely that it can serve as a model for other projects elsewhere.[131] Similarly, critics cite high costs and difficult financing for the Songdo International Business District eco-city, where typical apartments cost US$ 500,000 and school fees run US$ 25,000 per year.[132]

Through market incentives, China's eco-cities could achieve greater results with less upfront cost.

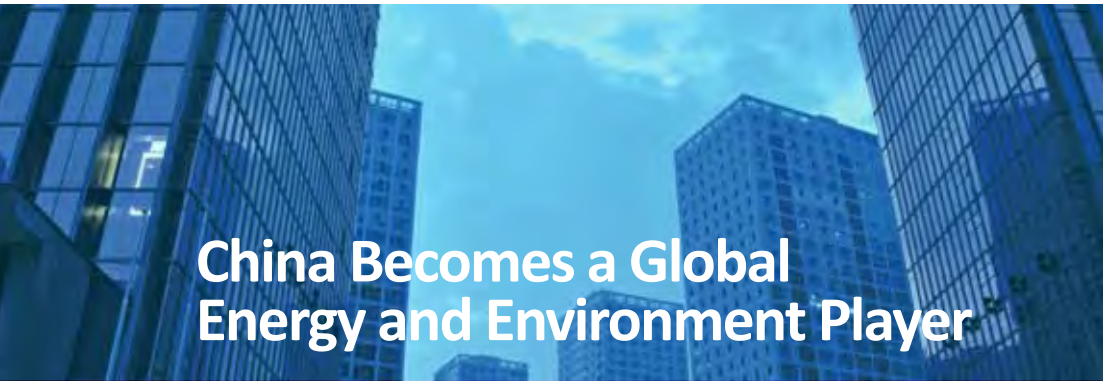
These challenges of limited access, high cost, and unclear paths to environmental improvement also apply to one of China's earliest announced eco-cities, the Sino-Singapore Tianjin Eco-City. It remains unclear how the government will encourage developers to meet targets for 100% green buildings in the zone, and a lack of renewable resources in Tianjin will make it hard to achieve renewable energy targets. As with Masdar and Songdo, the high costs of the project may make it difficult for anyone but the wealthy to live there, reducing its potential to serve as a model for anything other than gated communities.[133]

In the case of the Chongqing Liangjiang New Area, the government has announced targets for GDP growth, but has yet not stated energy efficiency or carbon intensity goals. While several industrial zones will target greentech sectors such as wind turbines, electric cars, or high-speed rail, there is no public definition for what the government plans to achieve environmentally, beyond attracting manufacturing associated with clean energy. To be sure, the project is in its early stages, and international case studies alert the leaders of this early stage project to the dangers of green-washing and aware of the need to incorporate environmental targets in their plans.

While urbanization presents great challenges, it also offers immense opportunity. Through market incentives, China's eco-cities could achieve greater results with less upfront cost. Higher or staggered electricity or energy prices, road traffic congestion pricing, emissions taxes or trading, and tax incentives for achieving certified energy efficient building results over time all have a limited track record in China, but eco-cities could prove the ideal test bed for experimenting with these regulations.

Similarly, many national targets have so far relied on top-down planning, which means that the burden falls on certain industries and cities rather than on others that might have more to gain. Top-down planning is easier in a system where enforcement lags due to historically weak regulatory agencies, conflicting government goals, or powerful overriding local interests. While China emphasizes environmental goals must be compatible with growth, this does not imply enforcement cannot improve in ways that could permit more systematic regulation, such as better enforcement of building codes or green building materials standards.

131. "Masdar City: Small Hiccups, Or Total System Failure?" Green Prophet, Aug. 2010, http://www.greenprophet.com
132. "Songdo City Defies Crisis Odds," Asia Times Online, Nov. 12, 2009, www.atimes.com
133. "Sino-Singapore Tianjin Eco-City (SSTEC): a case study of an emerging eco-city in China," The World Bank, www-wds.worldbank.org, accessed on Jan. 20, 2011



China Becomes a Global Energy and Environment Player

Jim Gourley

As China's energy demands and greentech policies have expanded, so has its role on the international stage.

China's energy demands and environmental impact are vast and growing, with two distinct forces combining to expand China's international role. The first is rising energy demand, giving China a greater stake in the world energy and resource economy than ever before. This has profound effects on geopolitics, world commodity markets, and international business. Second, China's greentech market growth has helped change China's image from that of a laggard on the environment to a position of leadership in many instances.

China Leads Through Action

What does it mean to be a leader in environmental policy? No country has a perfect environmental record, and the world's largest economies are no exception. Common sense suggests that those with the largest environmental problems must work harder to address them—so the question is, of the world's largest economies, which is working hardest to bring about change? China's policies on conventional air pollutants and carbon dioxide as well as on renewable energy and energy efficiency make it an unquestioned leader in terms of action. China has set out to achieve ambitious targets in each of these areas, and its past record of achieving such targets makes it clear that the government has the resources and the will to execute them, whether through economic incentives or top-down management.

Ever since the 1992 Rio de Janeiro Earth Summit, the world's major countries have fiercely debated relative roles and responsibilities for global environmental problems, particularly global warming. In the last two decades, press articles on world climate meetings have often portrayed tensions between developed country leaders urging greater action from developing countries, and developing country leaders pushing back. In the last two years, this narrative has lost some of its force with respect to China. China's leaders can now not only point to their national commitment to cutting carbon intensity by 40-45% by 2020, but also to China's investment in and installation of clean energy technology. China is investing and committing more than any other nation in wind, high-speed rail, nuclear, and other areas relevant to global environmental issues. Increasingly, this will translate into influence on the global stage, since these activities may have as much or more climate change impact as cap-and-trade policies and clean energy investments in other regions.

China appears to lead by action, as opposed to seeking binding commitments at international conferences. At the 2009 U.N. Climate Change Summit in Copenhagen, China and the U.S. both received criticism for blocking legally binding emissions targets.[134] Indeed, some observers noted that 2009 marked a tipping point when environmental critics began blaming China, rather than just the U.S., for blocking such targets. Behind the angry headlines, however, China has also received more and

134. Rapp, Tobias, "How China and India Sabotaged the UN Climate Summit," Speigel Online, May 5, 2010, www.speigel.de

more attention—some of it positive, some not—for domestic policy actions on the environment, particularly in renewable energy.

This story of leadership through action is not without caveat, however. As China's emissions continue to grow, it will hold its position as the largest carbon emitter in the world. Pollution will remain an immense challenge, and China can fall short of its own ambitious environmental goals, as with the 11th Five-Year Plan energy intensity target.[135] The quality and accuracy of national statistics on economics and the environment remain a bone of contention between China and its international partners.[136]

China's greentech markets are poised for increased growth over the next five years and the international perception of China will evolve as a result. Even if China's policies and enforcement have mixed results, China will increasingly look like a leader on the environmental stage, with other countries forced to play catch-up in the global greentech race.

China's Resource Scarcity Issues Are Shared by the World

China's energy security problems are a major impetus to the country's domestic energy policies, but also affect global diplomacy. First, regardless of China's international policies, oil demand from every major consuming country affects both oil markets and diplomacy. Tight oil supplies lead not only to higher oil prices, but also to increased tensions over the remaining supply. Like every other major economy, China will continue to seek and win oil contracts in volatile regions of the world, and will pursue policies to protect supplies sourced from those regions. If China's oil demand does double again over the next ten years as the U.S. Energy Information Administration forecasts, we can expect its influence over world oil politics to rise as well. [137]

Oil is only one of the many scarce resources China's economy needs to support growth. Others include copper, steel, and commodities such as rare earth metals and the obscure mineral coltan used in cell phones. Chinese companies in many cases must seek these resources abroad, leading to the opening of huge new mines around the world to supply China's demand. These range from copper mines in Zambia and lumber mills in Indonesia to the gigantic new China First coal mine in Australia's Outback along with the shipping terminals to bring the coal to China.[138] More economic links mean more vested interests, and more concern over the outcome of other countries' domestic policies on the environment or international ownership of assets.

Over the last 18 months Chinese firms have stepped up efforts to invest and do business abroad, with goals ranging from securing new technologies or resources to selling Chinese industrial equipment and services. Many of the largest deals are in oil and gas exploration, but the purpose is not always to secure resources—in many cases, the energy supplies will not go to China—but rather to obtain technological know-how. Notable deals included:

- Sinopec acquired Addax Petroleum for US$ 7.2 billion in mid-2009, the largest Chinese acquisition abroad so far. Geneva-based Addax owns oil reserves in Nigeria, Gabon, and the Kurdistan region of Iraq.[139]

135. "China aims to reduce energy consumption per unit of GDP by 16 to 17 pct in next five years," Xinhua, Feb. 27, 2011, www.news.xinhuanet.com
136. Zhang, ZhongXiang, "Assessing China's Carbon Intensity Pledge for 2020: Stringency and Credibility Issues and Their Implications," East-West Center, Oct. 2010, www.eastwestcenter.org
137. "International Energy Outlook 2010," U.S. Energy Information Administration, Jul. 2010, www.eia.doe.gov
138. Barbeler, David, "Australia's largest coal mine unveiled," Sydney Morning Herald, May 27, 2009, www.news.smh.com.au
139. Sanati, Cyrus, "Dealbook: A Big Leap for a Chinese Oil Giant," New York Times, Jun. 24, 2009, www.dealbook.nytimes.com

- China has been very active in marketing its high-speed rail technologies to other countries. China's rail ministry has concluded a deal to license rail technology and supply engineering services and components to GE. China is also building high-speed lines in Turkey, Venezuela, and Saudi Arabia.[140]
- In late 2009, Shenyang Power Group announced a deal with U.S.-based Cielo Wind Power and U.S. Renewable Energy Group to build a US$ 1.5 billion wind farm in Texas using turbines from China-based A-Power Energy.[141]
- CNOOC announced in March 2010 that it would pay US$ 3.1 billion to invest in Argentinean oil exploration firm Bridas Energy.[142]
- Sinopec announced in April 2010 that it would pay US$ 4.65 billion to acquire a 9% stake in Syncrude Canada from Conoco-Phillips.[143]
- CNOOC announced in May 2010 that it would acquire a third of Chesapeake Energy's oil and gas assets in the Eagle Ford Shale project in South Texas for US$ 1.1 billion.[144]
- In October 2010, Sinopec acquired 40% of Spanish oil company Repsol's Brazilian unit for US$ 7.1 billion, giving the Chinese oil firm access to Brazil's deepwater Santos Basin.[145]
- Sinopec announced in December 2010 that it would spend US$ 2.5 billion to acquire the Argentinean operations of Occidental Petroleum.[146]
- In February 2011, PetroChina and Encana announced their US$ 5.4 billion joint venture to develop Alberta's Cutbank Ridge shale gas reserves.[147]
- In 2011 Chinese automaker BYD opened its first U.S. operations and offered journalists a test of BYD's F3DM plug-in electric car. A *New York Times* review of the car noted several major quality problems, but concluded the flaws were all easily corrected: "After my day with the impressive, though imperfect, F3DM, I see that Chinese cars—electric and affordable—are not only possible, but imminent." The BYD F3DM would bear a much lower sticker price than competing plug-in models from Toyota or GM.[148]

As China's role in the world's economy grows, Chinese companies face increasing scrutiny. Coltan, one of the so-called conflict minerals blamed in part for the Second Congo War–the most deadly war since World War II–is essential for manufacturing portable electronics. North American and European companies and consumers have attracted public attention for profiting from the violent conflict over coltan. Since most products using coltan are made in China, or source tantalum processed in China, Chinese companies have faced questions over responsibility for the ongoing war in the Democratic Republic of Congo.[149] As China's demand for resources grows, attention to such issues will grow apace, profoundly influencing business and international relationships.

140. Bradsher, Keith, "China Offers High Speed Rail to California," New York Times, Apr. 8, 2010, www.nytimes.com
141. Johnson, Keith, "Lone Star, Meet Red Star: China's $1.5 Billion Wind-Power Deal in Texas," Wall Street Journal, Oct. 29, 2009, www.blogs.wsj.com
142. Mouawad, Jad, "Deal for South American Oil Fields Extends China's Global Quest for Energy," New York Times, Mar. 14, 2010, www.nytimes.com
143. "ConocoPhillips to Sell Syncrude Stake to Sinopec," New York Times, Apr. 12, 2010, www.dealbook.nytimes.com
144. Tudor, Alison, "China's Relentless Hunt for Energy," Wall Street Journal, Jan. 3, 2011, www.blogs.wsj.com
145. Nicholson, Chris V., "Repsol in $7.1 Billion Brazil Deal With Sinopec," New York Times, Oct. 1, 2010, www.dealbook.nytimes.com
146. Shannon, Kerri, "Sinopec Continues China's Latin America Energy Moves With $2.45 Billion Argentina Deal." Morning Money, Dec. 14, 2010, www.moneymorning.com
147. Rosenbaum, Eric, "Energy Winners: Encana's $5 Billion China Deal," TheStreet.Com, Feb. 10, 2011, www.thestreet.com
148. Berman, Bradley, "BYD Is the First Ripple in a Potential Chinese Wave," New York Times, Feb. 18, 2011, www.nytimes.com
149. Ma, Tiffany, "China and Congo's coltan connection," Project 2049 Futuregram (09-003), www.project2049.net, accessed on Feb. 17, 2011

Steve Bale

China Seeks to Capture Greentech Markets

China's industrial policy deliberately promotes domestic greentech industry to ensure China's future energy security.

National industrial policy is a central driver of China's greentech markets. The country's booming greentech markets represent a huge social and technological shift, and have real potential to solve serious energy and environmental problems, but would not have been possible without government policies. Because of the scale of China's energy development, the government has made it a priority to ensure the country and its businesses capture these new markets.

China seeks to address its own and the world's energy and environmental problems while promoting its domestic industry, and indeed the two sets of policies are closely linked in almost every area of greentech. From the very beginning of its clean energy push in the 1990s, China has publicly stated its intent to use industrial policy to capture markets. By virtue of its size and needs, the country was bound to become the largest market for energy and environmental technology. China's leaders recognized early on that the country had the chance to capture markets not only at home but also abroad. The energy sector is among the most capital-intensive industries, and China was poised to spend trillions of RMB on new energy equipment on a scale never before seen. Relying mainly on foreign technology would not only give foreign companies a boost over domestic players, but doing so could also leash China to foreign parts and services for decades to come.

The government's objective now is to ensure most energy equipment, especially in wind, solar, and biomass, will be made in China, based on domestically-owned intellectual property, using Chinese standards. Industrial policies favoring China's domestic industry include:

- State planning at the highest levels, embodied by five-year plans and regulations, to ensure industry conforms with rules and meets targets, guiding China's economy and strategic industries in particular.
- State-owned enterprises (SOEs) dominate the energy sector, which the government considers a strategic national industry. SOEs depend on government financing and make major corporate decisions based on government policies which, in some cases, are contingent on the approval of government officials.
- Government procurement laws require government organizations to purchase domestic goods, construction and services except when the good or service is not available from a domestic supplier, is not available at a reasonable price, or is intended for foreign markets. SOEs generally apply these principles to their procurement. Government procurement qualifications may be posted only five days prior to bid submission.[150] Other countries have also enacted government procurement laws, such as the U.S.'s Buy American provision in the American Recovery and Reinvestment Act of 2009.

150. Howell, Thomas, et al., China's Promotion of the Renewable Electric Power Equipment Industry (Washington D.C., U.S.: Dewey & LeBoeuf LLP for the National Foreign Trade Council, 2010)

- Government ministries required that China's 2009 stimulus funds should go generally to domestic firms, and that all equipment imports required prior authorization from government officials.
- As in other countries, China subsidizes public and private research for the development of domestic energy technologies. These include direct subsidies and tax deductions for R&D, as well as a government priority list for procuring products of domestic innovation.[151]

By 2008 Chinese manufacturers and joint ventures held 75% of the expanded wind market.

The language used in major public documents to support domestic industry is both unambiguous and ambitious. A combination of subsidies, government purchasing preferences, and state control of the energy sector will encourage domestic industry:

- Government measures for renewable energy projects specified in 1997, "The purpose of issuing the measures is to encourage and support the development of new energy industry in China, promote the build-up of the new energy industry, and accelerate the localization process of new energy equipment production. New energy capital construction projects with foreign investment, imported equipment and technology (including new energy projects with direct foreign investment) must be examined and approved by the State Planning Commission. No one is allowed to sign official contracts with foreign entities prior to approval."[152]
- China's Medium- to Long-Term Plan states, "On the basis of bringing foreign technology from abroad, the capacity to absorb and innovate should be strengthened so that as soon as possible, self-dependent innovation capabilities are achieved. By 2010, a basic system of renewable energy technologies and industry will have been established, so that equipment capabilities based mainly on domestic manufacturing will have been established."[153]
- The State Council's 2010 plan for Strategic Emerging Industries named energy-related industries as three of the seven strategic sectors. These were energy efficiency, new energy generation (nuclear, solar, wind, biomass, and smart grid), and new energy vehicles (including electric vehicles). The plan calls for SEI sectors to account for 8% of GDP by 2015 and 15% by 2020.[154]

These policies have helped China increase the domestic content of its greentech sectors, nowhere more so than in renewable energy. In 2004 foreign firms held over 75% market share in wind power equipment, but by 2008 Chinese manufacturers and joint ventures held 75% of the then much larger wind market.[155] Foreign firms have generally not won tenders for developing utility-scale solar, onshore wind, and offshore wind plants. (A long-delayed 2 GW solar plant by First Solar, still in early stages, is a possible exception, though First Solar recently announced it will work through a local partner to develop the project.[156]) Whereas Chinese officials have sometimes argued that equipment sold by foreign firms is inappropriate for China or is not priced competitively, in some cases foreign firms have pointed to evidence that domestic Chinese equipment only appears cheaper on rated capacity, as opposed to on life cycle cost and energy production.

Aside from achieving short-term commercial benefits for China, industrial policies have had two longer-term results. First, they are leading to more conflicts with trading partners, ranging from wind turbine manufacturers in Europe, to nuclear plant builders in the U.S. and train manufacturers in Japan. Second, and perhaps more importantly, these policies have the potential to help China leapfrog more developed countries in terms of energy infrastructure if not in terms of basic technology and innovation.

151. Howell, Thomas, et al., China's Promotion of the Renewable Electric Power Equipment Industry (Washington D.C., U.S.: Dewey & LeBoeuf LLP for the National Foreign Trade Council, 2010)
152. Ibid.
153. Ibid.
154. "State Council's Decision on Accelerating the Cultivation and Development of Strategic Emerging Industry," China State Council, Oct. 10, 2010
155. Howell, Thomas, et al., China's Promotion of the Renewable Electric Power Equipment Industry (Washington D.C., U.S.: Dewey & LeBoeuf LLP for the National Foreign Trade Council, 2010)
156. Wang, Ucilia, "First Solar Moves Closer to Delayed China Project," Gigaom, Jan. 5, 2011 http://gigaom.com

Consider the impact of industrial policy on supply and demand in wind, rail, and nuclear. Can we even imagine a policy change in Europe, Japan, or North America that might cause those regions to build 20,000 kilometers of high-speed rail in a decade, add 60 to 70 GW of nuclear energy, or take the lead back from China in wind installations? If China continues to lead in installations of this equipment, and continues technology transfer and reengineering of existing technology, Chinese firms could play as large a role in the broader energy industry of 2020 as Chinese solar manufacturers do in the solar photovoltaic field today.

Research and development is an area where government has increasingly pursued measures to improve and strengthen indigenous innovation. State-owned enterprises are investing more in research and development, and government leaders are increasing research budgets and subsidies, as noted above. From 1995 to 2005, Chinese R&D spending rose by 20% annually, while still accounting for less than 2% of GDP.[157] Chinese universities boosted the number of graduates six-fold, and increasingly those graduates were in science, technical or management fields. The energy field is ripe for innovation, given the high cost and drawbacks of the world's current energy technologies, but technology change in the field is frustratingly slow, due to the high capital costs, long lead-times and long lifecycles of energy generating and using equipment.

Surging investment in greentech, both in China and around the world, will undoubtedly lead to additional breakthroughs, but does China have policies in place to compete on innovation? By one estimate, China is now the world's third largest market for R&D. Patents and licenses are also on the rise. Not only are foreign firms opening R&D centers in China, but some Chinese firms are also branching out abroad. R&D spending in China has also shifted from SOEs to private firms, though many may be former state-owned enterprises continuing prior activities. Innovation in China can take several forms. On one hand there is adaptation, such as when metals producers adapt their automotive metals to satisfy local Chinese manufacturers needs for metals that can be hand-welded. Alternatively, fundamental research and development is another form of innovation, embodied by Tsinghua University's gas-cooled pebble-bed nuclear reactors that were later used in a commercial demonstration project in Shandong province. China conducts both types of R&D today, but for now, the emphasis remains on adaptation, reengineering and technology transfer.[158]

By 2020, Chinese firms could play as large a role in the broader energy industry as Chinese solar manufacturers do in the solar photovoltaic field today.

China's government recognizes weakness in this area, as the 2010 State Council statement on Strategic Emerging Industries showed. "China also faces a series of major problems such as enterprises' poor technology innovation, fewer core technologies, unsound policies and laws for new techniques and products' access to market as well as poor investment and financial policies for innovation."[159] The China Greentech Initiative's analysis suggests that policies adopted over the next five years can address some of these problems, but perhaps not all.

157. Steinfeld, Edward S., Playing Our Game: Why China's Rise Doesn't Threaten the West (U. S.: Oxford University Press, 2010)
158. Steinfeld, Edward S., Playing Our Game: Why China's Rise Doesn't Threaten the West (U. S.: Oxford University Press, 2010)
159. "State Council's Decision on Accelerating the Cultivation and Development of Strategic Emerging Industry," China State Council, Oct. 10, 2010

While entrepreneurship pushes innovation, it typically relies on open markets. In the SOE-dominated energy industry, lack of market access may therefore hamper significant progress in innovation. While there appear to be many areas where China has opened up to competition, there are still others that appear to have moved in the opposite direction. Several initially promising areas for the private sector provided less in practice. In some cases the beneficiaries of less-open markets are SOEs, and in others not. For example, SOEs have so far captured almost all renewable energy project development—an area where the private sector leads in Europe and America—partly due the fact that private enterprises in China have great difficulty attracting financing from state-owned banks. But in bidding for smart meters, a few well-established players with good relationships to the state-owned grid companies have won most of the contracts. As in the past, the ability of a firm to enter a market in China, whether the firm is Chinese, foreign or a joint venture, depends very much on the dynamics of each market segment and whether there are specific policies in place to encourage competition and new entrants.

Jim Gourley

Steve Bale

Looking Forward

Opportunities to grow China's greentech markets abound

China's greentech markets have grown with astonishing speed, and national needs compel China to adopt policies to continue that growth. China's industrial policies aim to increase Chinese greentech leadership both at home and abroad, helping enable a large number of opportunities in China's greentech markets.

The size, growth and overall potential to influence world energy trends leads industry to ask what specific opportunities do China's greentech markets hold, whether domestically or abroad. The China Greentech Initiative's collaborative research shows that many opportunities are not necessarily where one would expect. Market size—for example, in grid expansion or wind power—does not necessarily translate into market opportunity for all players. The reasons are sometimes related to closed or uncompetitive markets, but not always. Guided by input from over 300 industry experts, the sector chapters of the Report delve into these surprises, underscoring how research and input from partners and advisors led the China Greentech Initiative to assess 18 opportunities across six greentech sectors. These findings reveal that China's greentech markets are considerably more complex and challenging than top-line growth figures would indicate.

Cleaner Conventional Energy

Given that China's energy and environmental problems cannot be solved without Cleaner Conventional Energy, the government has implemented a range of policies within the last 18 months to encourage the development of related greentech solutions.

Cleaner Conventional Energy—energy derived from non-renewable fossil fuels in ways that minimize their negative impact on the natural environment—continues to be a focal point for government and industry. The government established the National Energy Commission (NEC) in 2010 to overcome competing interests and ensure the development of a cohesive energy policy, and also has pushed for the consolidation of the coal industry to improve efficiency, safety and enforcement of regulations. On emissions, China is set to adopt policies that would bring the country's coal plants in line with other countries. Pricing reforms have fallen behind expectations, but are expected to move forward again during the 12th Five-Year Plan period (2011-2015).

Cleaner Conventional Energy Sector Definition

The China Greentech Initiative defines Cleaner Conventional Energy as energy derived from non-renewable fossil fuels (such as coal, oil and natural gas) in ways that minimize their negative impact on the natural environment. This sector also includes nuclear power.

Cleaner Coal is a term used that defines the cleaner use of coal by emphasizing methods which reduce its negative impact on the environment. Cleaner coal technologies usually address atmospheric pollution from burning coal, and include such solutions as coal screening and scrubbing, gasification, flue gas desulfurization, carbon capture and sequestration (CCS, also referred to as carbon capture and storage), and coal blending.

Cleaner Oil refers to technologies that help reduce wastewater, gas and residue emissions as well as increase energy utilization rates. Cleaner oil technologies can be applied to oil exploration and extraction (e.g. reinjection of water, steam or gas for improving oil production and reducing pollutant emissions) and oil transportation and refining (e.g. oil-tanker automatic dehydrators, vapor recovery and wastewater sulfur removal).

Cleaner Gas denotes the use of technologies to help reduce greenhouse gas emissions as well as increase energy utilization rates. Cleaner gas technologies facilitate improved usage of coal bed and coal mine methane (CBM/CMM), reduction of greenhouse gases through the use of low concentration methane, and support of natural gas combined-cycle (NGCC) processes.

Nuclear Power uses nuclear fission reactions to produce steam, which then generates electricity. It is an alternative energy source that reduces carbon emissions and decreases dependence on fossil fuels.

The writing of this chapter was led by Ivan H. Torres, based upon strategic research deliverables completed by Qiyong Cao (曹奇永) and Junda Lin (林骏达) of the China Greentech Initiative's Cleaner Conventional Energy sector research team.

This chapter begins by providing an overview of Cleaner Conventional Energy sector developments since the publication of *The China Greentech Report 2009*. It then summarizes three Opportunity Assessments developed by the China Greentech Initiative in collaboration with partners and advisors 2010.

- Potential for Wide-Scale Adoption fo IGCC and CCS Technologies
- Strong Future for De-SO_x and De-NO_x , but Fly Ash Utilization Lags
- Carbon Tax Option Under Careful Review

The China Greentech Initiative's partners and advisors 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 the detailed proprietary research and analysis developed in collaboration with and for the organizations participating in the China Greentech Initiative Partner Program. The chapter concludes with an outlook on additional opportunities and issues in the Cleaner Conventional Energy sector that the China Greentech Initiative plans to explore during 2011.

Market Update

Coal's domination of China's energy production makes Cleaner Conventional Energy critical

Cleaner Conventional Energy continues to be a focal point for government and industry. The reasons for this are inescapable: China is now the world's second biggest economy, with the dual distinction of being the world's largest consumer of energy and emitter of greenhouse gases.[1] Coal and other conventional energy sources still dominate energy production.

Cleaner Conventional Energy technology solutions hold the key to China's energy security as well as domestic and international environmental protection efforts. Markets in China are large and growing rapidly, yet in the midst of huge change one element remains constant: China's dependence on conventional energy to drive economic growth. Government and industry are gradually shifting to technologies and processes that utilize these energy sources in a more efficient and environmentally-friendly manner. However, this has not prevented conventional energy use from going into overdrive—predictably led by coal.

Fast growth of coal means energy mix remains unchanged

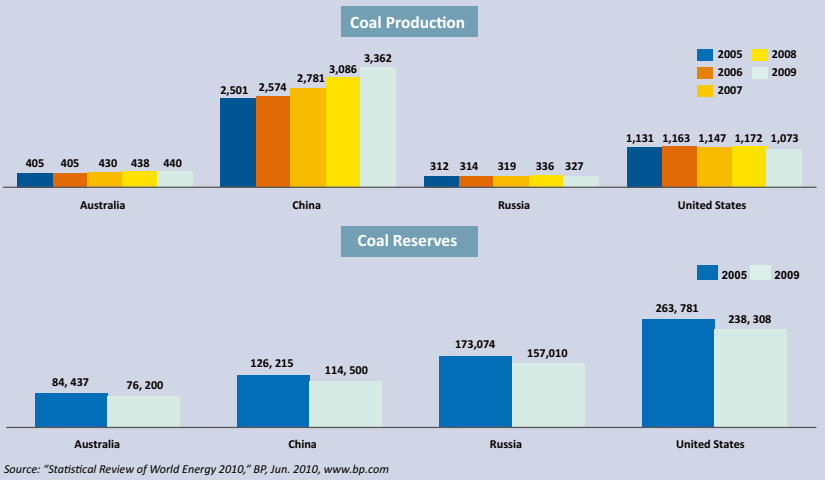
Coal continues to dwarf all other energy sources in China, driven by China's larger reserves of coal relative to oil and natural gas. Basic economics make coal king—it is relatively plentiful and cheap, and has a mature consumption base. China's coal reserves—third largest in the world and accounting for nearly 14% of the global total—are more strained than elsewhere, with domestic output in 2009 reaching 45% of the global total.[2] China's domestic coal output has steadily risen at an 8.1% compounded annual growth rate, from 2.19 billion metric tons to 3.24 billion metric tons between 2005 and 2010.[3]

1. "China Overtakes the United States to Become World's Largest Energy Consumer," IEA, Jul. 20, 2010, www.iea.org

2. "Statistical Review of World Energy June 2010," BP, Jun. 2010, www.bp.com; "International Energy Statistics," U.S. Energy Information Administration, http://www.eia.doe.gov, accessed on Feb. 28, 2011

3. 国家统计局, "中华人民共和国2005年国民经济和社会发展统计公报,"*[National Bureau of Statistics, "PRC 2005 National Economic and Social Development Statistics Report"] Feb. 2006;* 国家统计局, "中华人民共和国2009年国民经济和社会发展统计公报,"*[National Bureau of Statistics, "PRC 2009 National Economic and Social Development Statistics Report"] Feb. 2010;* 国家统计局, "中华人民共和国2010年国民经济和社会发展统计公报,"*[National Bureau of Statistics, "PRC 2009 National Economic and Social Development Statistics Report"] Feb. 2011*

China's Coal Production and Reserves
millions of tons, 2005-2009



Source: "Statistical Review of World Energy 2010," BP, Jun. 2010, www.bp.com

Although China's production currently satisfies much of domestic consumption demands, imports are rising rapidly. Globally, as in China, coal reserves far outstrip reserves of oil and gas.[4] China has been active in securing coal from reserves in Indonesia, Australia and Russia.[5] Imports surged threefold in 2009 when China became a net importer for the first time.[6] In 2010, net imports rose nearly 30% to 145 million metric tons, accounting for 4.6% of domestic demand.[7] The industry will undoubtedly see more increases in 2011, though some estimate that the rate of growth will slow.[8]

While other parts of the world experienced flat or diminished demand for coal in 2009, China's consumption marched ahead at a year-on-year growth rate of over 9%.[9] China's coal consumption topped 3.02 billon metric tons in 2009, approximately 47% of the world total.[10] Much of the coal goes to China's thermal power plants—at the end of 2009 coal accounted for 92% of fuel used.[11] Production of steel and iron, chemicals, and building materials also consumes large amounts of coal. Rapid growth in coal production and consumption for electric power and industrial uses has led some to estimate China's known reserves will be exhausted in 38 years. This is similar to reserve-life estimates for Germany, but much shorter than those for the U.S., Australia, and the Russian Federation.[12]

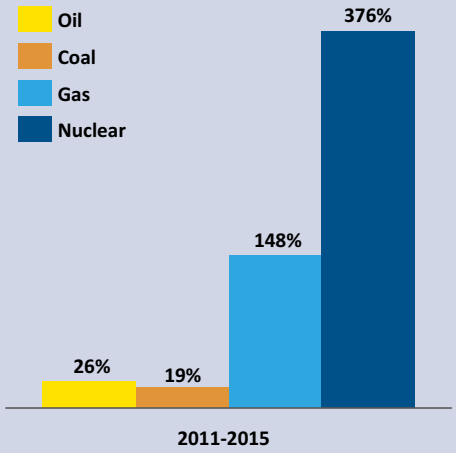
4. "Where is Coal Found," World Coal Association, http://www.worldcoal.org, accessed on Feb. 1, 2011
5. "Country Analysis Briefs, China, Coal," U.S. Energy Information Administration, http://www.eia.gov, accessed Feb. 20, 2011
6. Stanway, David and Wong Fayen, "China Tries to Give Old King Coal a Merrier Soul," Reuters, Jan. 11, 2011, www.reuters.com
7.国家统计局,"中华人民共和国2010年国民经济和社会发展统计公报," [National Bureau of Statistics, "PRC 2009 National Economic and Social Development Statistics Report"] Feb. 2011
8."China to Take Measures to Ensure Energy Supplies in 2011: NEA," People's Daily, Jan. 30, 2011: Zhu, Winnie, "China's Coal Import to Slow as Floods Boost Prices," Bloomberg, Feb. 1, 2011
9. "Statistical Review of World Energy June 2010," BP, Jun. 2010, www.bp.com
10. "Statistical Review of World Energy June 2010," BP, Jun. 2010, www.bp.com; 国家统计局,"中华人民共和国2009年国民经济和社会发展统计公报," [National Bureau of Statistics, "PRC 2009 National Economic and Social Development Statistics Report"] Feb. 2010
11. 国家电力监管委员会,"2009年度发电业务情况通报," [SERC, "Bulletin on Business Conditions for Power Generation in 2009"] Dec. 2010
12. "Statistical Review of World Energy June 2010," BP, Jun. 2010, www.bp.com

Government promotes Cleaner Conventional Energy for energy security and the environment

Over the last 18 months, the Chinese government has continued to roll out regulations to enable cleaner production and use of energy while maintaining its affordability and reliability. China's dependence on conventional energy to drive economic growth and increased standards of living, however, makes conventional energy reforms a delicate balancing act, with progress gradual. Recent policy discussions and regulations include increased approval requirements for coal-to-gas projects, planned public bidding for shale gas exploration, and the passage of the Oil and Gas Pipeline Protection Law.[13]

China's Aggressive Push to Gas and Nuclear

China's Conventional Energy Growth Projections
percent, 2011-2015



Crude oil and natural gas use has risen steadily in China over the past years. This trend continued in 2010, with China consuming 12.9% more crude oil (to 410 million metric tons) and 18.2% more natural gas (to 104 billion cubic meters) than in 2009. Targets and projections over the next five years show that natural gas and nuclear (target of 38 GW of new installed capacity by 2015) will be pushed aggressively, while the government will attempt to moderate coal and oil growth.

Plans for nuclear power, however, may be slowed in the wake of the nuclear disaster in Japan caused by the March 2011 earthquake and tsunami. While the eventual impact is not yet known, China temporarily suspended development of new nuclear plants and began reassessing safety plans immediately after the events in Japan.

Source: 能源局, "2010年能源经济形势及2011年展望," [NEA, "Energy Economy Development in 2010 and Outlook in 2011"] Jan. 28, 2011, www. gov.cn; 国家统计局, "中华人民共和国2010年国民经济和社会发展统计公报," [National Bureau of Statistics, "PRC 2010 National Economic and Social Development Statistics Report"], 2011; China Greentech Initiative analysis

Other noteworthy events include the establishment of the National Energy Commission (NEC), escalation in the campaign to shut down small, outdated coal mines and coal power plants, and mixed progress on price and tax reforms.

New National Energy Commission will help coordinate energy policy

In January 2010, the Chinese government established the NEC as the highest agency in charge of China's energy policy, outranking other executive government agencies and subordinate only to the State Council. Members of the Commission include Premier Wen Jiabao and 21 minister-level officials from, among others, the National Development and Reform Commission (NDRC), the National Energy Administration (NEA), and the Ministry of Environmental Protection (MEP).[14] The NEC held its first meeting in April 2010.

13. 国家发展和改革委员会,"国家发展改革委关于规范煤制天然气产业发展有关事项的通知,"[NDRC, "Notice on Regulating the Development of Coal-to-Gas Industry"] Jun. 2, 2010; Chen, Aizhu, et al., "China to Auction 8 Shale Gas Blocks in Q1," Reuters, Jan. 19, 2011, www.reuters.com; 全国人民代表大会,"中华人民共和国石油天然气管道保护法,"[NPC, "PRC Oil and Gas Pipeline Protection Law"] Jun. 25, 2010

14. 国务院办公厅。"关于成立国家能源委员会的通知,"[State Council, "Notice on Establishing the National Energy Commission"] Jan. 22, 2010

Primarily responsible for researching and drafting national energy strategies, reviewing issues concerning energy security and development, and coordinating work between ministries and other government organizations, the NEC reflects the growing desire to ensure a cohesive energy policy despite competing interests. Since 2005, the central government has established a number of bodies with similar mandates. Notably, the NEA was established in March 2008 to design and implement a unified energy policy; however, it was only moderately successful in accomplishing this task.[15]

Coal industry consolidation should lead to more rapid technology adoption

China's campaign to consolidate the coal mining and coal power generation industry continued over the last 18 months and is set to become even more ambitious over the next five years. In the first nine months of 2010, China shut down more than 1,300 small-scale coal mines with a production capacity of 125 million metric tons, eliminating inefficient and highly polluting operations.[16] The NDRC plans to reduce the number of coal mines from over 11,000 in 2010 to 4,000 by 2015.[17] Small, inefficient coal power plants are also being shuttered, with over 70 GW eliminated since 2006.[18] MEP has tied construction of new large power plants to closing and replacing inefficient smaller ones.[19]

The National Development and Reform Commission plans to reduce the number of coal mines from over 11,000 in 2010 to 4,000 by 2015.

The closures are good news for the adoption of Cleaner Conventional Energy solutions. Large organizations have more capital to invest in equipment upgrades or additions. For coal mines this includes advanced equipment for mining, coal screening and scrubbing equipment, and the capture and use of coal mine methane. New coal power plants use super- or ultra-supercritical boilers, and one day could use emerging technologies such as integrated gasification combined cycle and carbon capture and sequestration.[20] Other aspects of industry consolidation are positive for greentech adoption. Large operations are easier to monitor, alleviating enforcement problems. The Chinese government often targets large operations when designing energy conservation or environmental protection targets and standards, making achieving such goals simpler.

Pricing and tax reforms have lagged

The rational pricing or taxation of conventional fuels, electricity and carbon emissions enables energy prices to reflect both market conditions and environmental costs. China continues to study and implement gradual energy price and tax reforms; however, implementation of electricity price reforms begun in 2002 is currently lagging. Electricity generation and consumer prices are still capped by the government, in some instances at artificially low levels.[21] For example, even if electricity prices rise 3% annually through 2020, electricity bills may not capture resource price levels or volatility, which may force power companies to accept lower revenues, as was the case in 2010; insufficient revenues can also delay deployment of cleaner energy technologies.[22] While the government has drafted reforms proposing tiered residential electricity prices based on the volume of power usage, this may be years away.[23] Carbon pricing is also in the design stage.

15. Wong, Julian, "The National Energy Commission: Myth-busting the New Energy Super Ministry," Green Leap Forward, Feb. 9, 2010, http://greenleapforward.com

16. "China Intensifies Coalmine Consolidation," China Daily, Oct. 22, 2010, www.chinadaily.com.cn

17. 国家发展和改革委员会, "关于加快推进煤矿企业兼并重组的若干意见,"[NDRC, "Opinions on Accelerating the Mergers and Acquisitions of Coal Mining Enterprises"] Oct. 26, 2010

18. "China Meets National Target of Closing Outdated Coal-fueled Power Stations," Xinhua, Jul. 25, 2010, www.news.xinhuanet.com

19. 环境保护部等部门, "关于推进大气污染联防联控工作改善区域空气质量的指导意见," [MEP, et al., "Notice on Guiding Opinions on Pushing Forward the Joint Prevention and Control of Atmospheric Pollution to Improve the Regional Air Quality"] May 2010

20. Bradsher, Keith, "China Outpaces U.S. in Cleaner Coal-Fired Plants," New York Times, May 10, 2009, www.nytimes.com

21. "Analysis: China Electricity Price Reform Shambles Ahead Despite Pressure of CPI," IstockAnalyst, Dec. 22, 2010, www.istockanalyst.com

22. "China Electricity Consumption to Almost Double By 2020: China Electricity Council," Xinhua, Dec. 21, 2010, http://news.xinhuanet.com; "五大电企亏损透视: 煤电"顶牛" 电价改革滞后,"[Perspectives on Losses at Big Five Power Enterprises: Coal Electricity Tariff Reform Lags] Xinhua, Dec. 9, 2010, http://news.xinhuanet.com

23. 国家发展和改革委员会, "关于居民生活用电实行阶梯电价的指导意见(征求意见稿)," [NDRC, "Guiding Opinions on Implementing Price Ladder for Residential Use of Electricity"] Oct. 8, 2010

SOE domination somewhat diminishes market attractiveness

Although the markets for conventional energy are large and growing rapidly, the most promising cleaner coal technologies are not yet mature, and development depends on government regulation and on implementation—largely by state-owned enterprises (SOEs).

The China Greentech Initiative developed a Market Attractiveness Assessment (MAA) to evaluate the cleaner coal subsector on six criteria: government support, addressable market size, solution attractiveness, five-year market growth potential, market accessibility, and profit opportunity. Information on the Market Attractiveness Assessment methodology can be found in the Research Methodology chapter.

Cleaner Conventional Energy Market Attractiveness Assessment—Cleaner Coal

Assessment Criteria	Attractiveness	Explanation
Government Support	●	■ Cleaner coal post-combustion solutions (De-NOx and De-SOx) supported by tariffs, mandatory targets and standards, and R&D ■ Coal power plants increasingly commercialize mature cleaner coal technologies, while other technologies, like IGCC, still in demonstration project phase ■ Mining consolidation spurs adoption of advanced extraction technologies
Addressable Market Size	●	■ Annual addressable market size of approximately RMB 1.1 trillion (US$ 175 billion) ■ Current installed capacity approximately 700 GW, biggest thermal market in the world; China's annual coal output the largest in the world
Solution Attractiveness	◑	■ Cleaner coal post-combustion technology adoption advantaged because of substantial government incentives and increasing monitoring and enforcement ■ Cleaner coal power plants incrementally adopt advanced technology but lag in more costly solutions
Five-Year Market Growth Potential	◕	■ Government targets addition of 260-70 GW of coal power plant installed capacity by 2015 primarily through utilization of advanced coal technologies, but target is not mandatory and may be exceeded ■ De-NOx installed capacity is projected to increase very rapidly from 50 GW in 2010 to 800 GW in 2015
Market Accessibility	◑	■ State-Owned Enterprises dominate most areas of market, from coal production to power generation, with private sector competing to provide equipment and services to SOEs
Profit Opportunity	◔	■ Dominance of SOEs as primary buyers limits profits for solution providers ■ Where technology solutions are mature, fierce competition among domestic solution providers drives prices down

Market Attractiveness Assessment Legend

Government Support	Addressable Market Size	Solution Attractiveness
● Highest priority	● Very large	● Advantaged
◕ High priority	◕ Large	◕ Attractive
◑ Medium priority	◑ Medium	◑ Emerging
◔ Low priority	◔ Limited	◔ Disadvantaged
○ No priority	○ Niche	○ Unavailable
Five-Year Market Growth Potential	**Market Accessibility**	**Profit Opportunity**
● Very rapid	● Fully open	● Superior
◕ Rapid	◕ Open with restrictions	◕ Above average
◑ Medium	◑ Partially limited	◑ Average
◔ Slow	◔ Limited	◔ Limited
○ Very slow	○ Restricted	○ Challenging

Source: China Greentech Initiative analysis

Cleaner coal

The attractiveness of the cleaner coal market is spearheaded by strong government support as exhibited by the continued rollout of air pollution targets, technology standards, and increased power plant and mining infrastructure utilization of advanced technologies. Addressable market size and five-year growth potential are rated above average, with solution attractiveness and market accessibility viewed as average, and profit opportunities generally seen as limited.

The annual addressable market size for cleaner coal technologies is over RMB 1.1 trillion (US$ 175 billion).

Government support falls in the *highest priority* ranking. Over the last five years the government has made substantial progress in air pollution mitigation at thermal power plants, and over the next five years the scope of these efforts will widen. China is also bringing online increasingly advanced cleaner coal combustion technologies. Moreover, government-guided industry consolidation in mining is expected to improve investment in technologies to improve mining efficiency and safety.

The cleaner coal market size is *very large* based in part on China's thermal power plant installed capacity and annual coal output, ranking first in the world for both of these measures, thus underscoring the need to produce and use coal in a more environmentally-friendly manner. This translates into an annual addressable market size for cleaner coal technologies of over RMB 1.1 trillion (US$ 175 billion).

Solution attractiveness varies widely across the value chain, but on average can be classified as *emerging*. Cleaner coal post-combustion technology adoption is advantaged because of substantial government incentives and increasing monitoring and enforcement. Though advanced combustion technologies for cleaner coal power plants are being incrementally adopted, many of the most promising technologies, such as integrated gasification combined cycle (IGCC) and carbon capture and sequestration (CCS), are years away from wide-scale adoption.

The five-year market growth potential is *rapid*, even though the government has indicated it will endeavor to contain economic growth and energy consumption to achieve more sustainable development. Nevertheless, heavy utilization of advanced coal technologies for thermal power plants and the advent of new air pollution standards (for De-SO_x and De-NO_x) will require cleaner coal technology rollout at new and existing plants.

Market accessibility is *partially limited* and profit opportunities are *limited*, both in large part because of the dominance of SOEs in coal mining and thermal power generation. Market access is either officially restricted or limited by SOE monopolies, and profit opportunities for cleaner coal technology solution providers are limited due to SOEs' central role as buyer and, more often than not, as supplier through an affiliated company. In some cases project bidding can move technology solution prices to below-cost levels, with business losses covered by an affiliated parent company.

The path ahead

Cleaner Conventional Energy trends over the last 18 months have confirmed many of the observations made in *The China Greentech Report 2009*. Cleaner Conventional Energy technologies have a large market and the potential to make a major environmental impact. The Chinese government's approach to greening conventional energy is gradual, as it looks to raise efficiency and slowly diversify the energy mix while simultaneously addressing fundamental administration, pricing, and implementation issues. In the near term, these issues will remain at the forefront, and the more ambitious goals outlined in the 12th Five-Year Plan will deepen government support and expand markets.

Potential for Wide-Scale Adoption of IGCC and CCS Technologies

Opportunity Assessment

While integrated gasification combined cycle (IGCC) and carbon capture and sequestration (CCS) have the potential to revolutionize power generation in China, their potential remains largely unfulfilled.

IGCC and CCS technologies are well-suited to China's environmental imperatives, geology and large coal plant market; both technologies can play a role in reducing the long-term impact of China's power plant construction boom of the last decade.[24] That said, the country faces a paradox one hand, high and uncertain initial costs and technology gaps mire IGCC and CCS in the demonstration project phase; on the other hand, China is the ideal place for development given its low cost and rapid infrastructure expansion and cost for IGCC and CCS could be far lower than in developed countries. For example, IGCC costs in China could run from RMB 5,850 to 11,700 per kW (US$ 900 to 1,800 per kW) versus RMB 15,600 to 29,900 per kW (US$ 2,400 to 4,600 per kW) in developed countries.[25] In the next decade, China will likely expand slowly from demonstration projects, favoring incremental gains over large-scale technology adoption.

China has abundant underground geological capacity near emission sources: more than half of China's large point sources are located directly above a potential geologic sink.

Large market and technology fit make China a good place for IGCC and CCS

Given that China will likely continue to rely on coal as the major source of energy for decades to come, both IGCC and CCS offer long-term potential to help address the immense environmental problems the country faces as a result of coal combustion. IGCC has higher thermal efficiency, uses less water, and produces lower emissions versus conventional coal plants.[26] In the U.S. and Europe, IGCC technologies have undergone three generations of development, but are still not commercially economical.[27] Many of the characteristics of IGCC are well-suited to China, such as IGCC's 40% water savings and fuel flexibility with respect to low-grade coal plentiful in China.

CCS has an even larger emissions reduction potential. When applied to a modern conventional power plant, CCS can reduce CO_2 emissions by approximately 80-90%. Like IGCC, it has been developed outside of China over many decades, with some mature or economically feasible components, but many others remain in the R&D stage.[28] China appears to be a logical place to experiment with underground sequestration of coal plant carbon emissions. Not only is China the largest emitter of carbon dioxide with more coal plant capacity planned than any other country, but China also has abundant underground geological capacity near emission sources: more than half of China's 1,623 large point sources emitting over 100,000 tons of CO_2 per year are located directly above a potential geologic sink, and more than 80% are within 80 kilometers of such a site.[29]

IGCC and CCS are stuck in the demonstration phase due to high cost and emerging technologies

The Chinese government has explored IGCC and CCS technologies for decades, mostly through R&D and feasibility studies. The NDRC, NEA, and Ministry of Science and Technology (MOST) lead these projects, supported by many other agencies. For IGCC, projects have been included in economic planning and major technology innovation programs for over 20 years.[30] CCS is a more recent focus, having been included in climate change and innovation planning in the last five years.

24. Hurst, Timothy, "China's Massive Coal-Fired Power Plant Boom Visualized," Ecopolitology, Aug. 26, 2010, http://ecopolitology.org

25. Angell, Christopher, et al., "The Role of IGCC in China: Past, Present, and Future," Saistrip, May 2010, www.saistrip2010.webatu.com; IPCC, Carbon Dioxide Capture and Storage (U.K.: Cambridge University Press, 2005, 443); China Greentech Initiative analysis

26. IGCC's thermal efficiency advantage versus conventional coal power plants has been narrowed with the development of ultra-supercritical pulverized coal technology over the last decade.

27. 中国环境保护产业协会, "IGCC国外现状及发展趋势," [China Association of Environmental Protection Industry, "IGCC International Circumstances and Development Trends"] Aug. 6, 2009

28. "Carbon Dioxide Capture and Storage: Technical Summary," IPCC, Sep. 2005, www.ipcc.ch

29. Qian, J., et al., "Identifying Near-Term Opportunities for Carbon Capture and Sequestration (CCS) in China," NRDC, Oct. 2009, www.nrdc.org

30. Heinz Center, Carbon Capture and Storage Development in China (Washington, U.S.: The H. John Heinz III Center For Science, Economics and the Environment, 2010, 16)

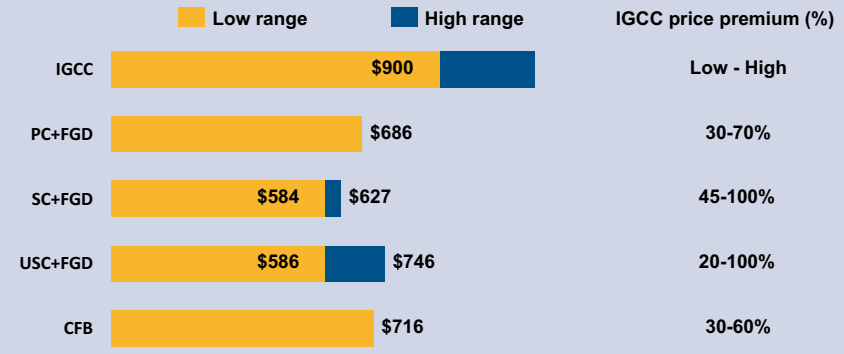
The results of these efforts are mixed. IGCC has a longer history of government support, and thus has achieved modest domestic breakthroughs. Chinese companies or academic institutes can now provide technologies for gasifiers, gas turbines, air separation, combined cycle and system integration.[31] Nevertheless, these advances have not resulted in IGCC's commercialization in China or elsewhere.[32]

After years of R&D, China has started to look to demonstration projects in the last decade to gain construction and operational expertise as well as better understand investment requirements. For IGCC, high initial capital costs continue to hinder market growth. IGCC power plants in China can be between 20-100% more expensive than conventional coal alternatives—the broad range demonstrating the cost uncertainties. Given the cost premium and uncertainty, the government and power companies plan to move slowly: under government plans, IGCC gains traction only as 2020 nears, with capacity hitting 44 GW that year and 170 GW by 2030.[33]

CCS also faces a major issue on cost. Capital costs are estimated at 44-74% higher than conventional plants, due to the price tag of carbon capture equipment and lower net power output. In addition, the utilization of CCS technologies results in a 10-40% net energy penalty, increasing fuel use by 25-40% to maintain the same net power output. Other uncertainties surround costs for carbon sequestration, including the price of coal, the risk of carbon leaks, groundwater contamination, and even earthquakes.[34]

High and uncertain cost has limited IGCC and CCS to R&D and demonstration projects to further test technologies and determine capital costs. China's signature IGCC and CCS pilot is the government-supported 400 MW GreenGen Project in Tianjin, which will include CO_2 capture for enhanced oil recovery (EOR) in the nearby Dagang Oil Field. Other projects include two IGCC coal-to-liquids plants, three demonstration power plants, and one gas turbine demonstration project, supported by a modest RMB 350 million (US$ 53 million) in seed funding from MOST.[35] CCS projects also include a number of small, stand-alone demonstration projects.[36]

Construction Cost Estimates of IGCC versus Alternatives in China
US$ per kW, 2010



PC = pulverized coal; FGD = flue gas desulfurization; SC = supercritical; USC = ultra-supercritical; CFB = circulating fluidized-bed

Source: Angell, C., et al., The Role of IGCC in China: Past, Present, and Future (US: Johns Hopkins University School Of Advanced International Studies, 2010)

31. Heinz Center, Carbon Capture and Storage Development in China (Washington, U.S.: The H. John Heinz III Center For Science, Economics and the Environment, 2010, 43)
32. 中国环境保护产业协会, "IGCC国外现状及发展趋势," [China Association of Environmental Protection Industry, "IGCC International Circumstances and Development Trends"] Aug. 6, 2009
33. OECD/IEA, Cleaner Coal in China (Paris, France: IEA, 2009, 363); China Greentech Initiative analysis
34. IPCC, Carbon Dioxide Capture and Storage (U.K.: Cambridge University Press, 2005, 443)
35. Hart, Craig, and Liu Hengwei, "Advancing Carbon Capture and Sequestration in China: A Global Learning Laboratory," Wilson Center, 2010, www.wilsoncenter.org
36. "CCS Activities in China," UK-China Near Zero Emissions Coal, 2009, www.nzec.info

China GreenGen Project Profile (Tianjin, China)

- **Entity:** China Huaneng Group (CHNG)
- **Stakeholders:** Datang, Huadian, Guodian, China Power Investment Corporation, Shenhua, State Development and Investment Corporation, China Coal Group and Peabody Energy; CHNG holds 52% of shares and others each hold a 6% share.
- **Purpose:** Construct an IGCC 400 MW demonstration project and capture CO_2 for EOR in the Dagang Oil Field.
- **Goal:** Develop and demonstrate integrated coal gasification, hydrogen production, hydrogen power generation and CO_2 sequestration systems.
- **Domestic collaboration:** Part of the Tianjin Lingang Industrial Zone Circular Economy Plan; working with Chinese oil companies (EOR technology), equipment manufacturers, academic institutions and research organizations; strong government support from NDRC, MOST and MEP.
- **International cooperation:** COACH (Cooperation Action within CCS China-EU) and NZEC (Near-Zero Emissions Coal)

Construction Phase

Phase 1 (2006 – 2011)
- 250 MW IGCC power plant
- 2000 tons/day gasifier
- GreenGen laboratory

Phase 2 (2012-2013)
- Optimize gasification technology
- R&D on CCS technologies
- Preliminary work on GreenGen pilot project

Phase 3 (2014-2016)
- 400 MW GreenGen power plant
- Operate with near zero emissions
- Prove economic viability

Financing

- Investment cost for Phase 1 is estimated at US$ 420 million; costs are estimated to near US$ 1,800/kW
- Received a small amount of financial support from MOST
- Asian Development Bank will lend US$ 135 million for construction of Phase 1; provide US$ 1.25 million in technical assistance in Phases 2 and 3; provide a US$ 5 million grant from its Climate Change Fund during the initial operational stage, and work with GreenGen to file application for CDM funding

Source: China-UK Near Zero Emissions Coal (NZEC) initiative, CCS activities in China (UK: NZEC, 2009); Angell, C., et al., The Role of IGCC in China: Past, Present, and Future (US: Johns Hopkins University School Of Advanced International Studies, 2010); Asian Development Bank, Proposed Loan and Grant: PRC Tianjin

Lower cost makes China an attractive R&D destination

For both IGCC and CCS, lower capital costs and the number of coal plants being planned make China a good proving ground relative to the developed world. For IGCC, costs abroad have generally risen, reaching as high as RMB 29,711 per kW (US$ 4,571 per kW) for a U.S.-based project in 2007. In China, the GreenGen IGCC project bears an estimated cost of between RMB 5,850 to 11,700 per kW (US$900-1,800 per kW)—much cheaper by comparison.[37] China's cost advantage for IGCC is no surprise, and derives from factors including lower cost of concrete and steel, less stringent design standards, lower quality standards, fewer safety requirements, and a speedier approval process. CCS has many of the same cost advantages. Input from China Greentech Initiative partners and advisors indicates that CCS costs in China could be up to 30% lower than in the U.S.

China has long been a low-cost manufacturing destination, attracting foreign companies and propelling the domestic export economy. IGCC and CCS are unique among many other greentech solutions in that they are deployed within China's highly centralized power generation sector and limits on market access could present challenges. However, commercial loans, minority equity stakes, or the supply of technology or related services are potential channels for market access, as well as R&D projects that take advantage of China's shift from manufacturing to services and high-tech innovation.

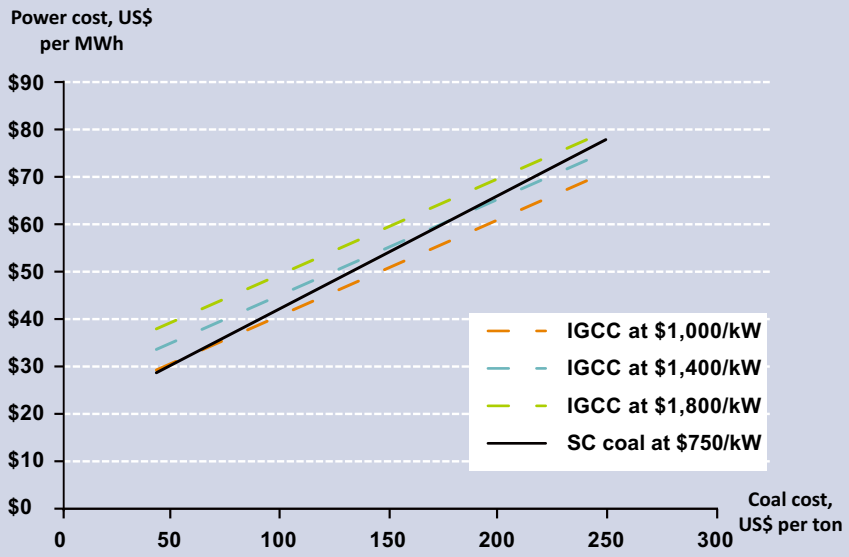
37. Angell, Christopher, et al., "The Role of IGCC in China: Past, Present, and Future," Saistrip, May 2010, www.saistrip2010.webatu.com; China Greentech Initiative analysis

The cost competitiveness of CCS could improve with advances made in current demonstration projects, many of which seek to offset costs. These include enhanced oil recovery and enhanced coal bed methane recovery.[38] They also include projects for the use of micro-algae to absorb CO_2 in flue gas and produce bio-diesel.[39] All provide the possibility of additional revenue that could offset energy penalty concerns.

The maturation of CCS technology and the development of cost offsets could trigger a knock-on effect for IGCC, especially when the cost of retrofitting power plants is taken into consideration. Retrofit costs are higher for IGCC's advanced coal plant rivals, most of which have cheaper initial capital costs but lower efficiency levels and higher emissions.[40] When including CCS in total construction costs, IGCC plants with CCS may be cheaper than other cleaner coal technologies coupled with CCS using post-combustion capture.[41] Widespread adoption of CCS could thus propel IGCC past its current rival cleaner coal technologies, such as power plants that use super- or ultra-supercritical boilers.

With the substantial environmental and commercial gains at stake, international collaboration on IGCC and CCS has progressively expanded. Although indigenous innovation policies, concerns over intellectual property protections, and restricted market access may limit the impact of these activities, international collaboration is critical if China is to effectively roll out these two technology solutions.

Power Cost Comparison of IGCC and Supercritical Coal Plants at Various Coal Costs, US$ per MWh



At low coal prices, conventional supercritical coal plants are clearly cheaper than more efficient IGCC plants; however, even at coal prices five times the present level (world coal prices have ranged from US$ 50-100/ton in the last decade), IGCC plants from US$ 1,000-1,800/kW, but IGCC costs could be higher. For thermal efficiency, we compared IGCC at 44% thermal efficiency with super-critical coal plants at 37% thermal efficiency. Under these assumptions, IGCC technology adoption is not attractive until capital costs reach the lower end of current per kilowatt capital cost estimates.

Source: China Greentech Initiative analysis

38. IPCC, Carbon Dioxide Capture and Storage (U.K.: Cambridge University Press, 2005, 443)
39. Hart, Craig, and Liu Hengwei, "Advancing Carbon Capture and Sequestration in China: A Global Learning Laboratory," Wilson Center, 2010, www.wilsoncenter.org
40. Angell, Christopher, et al., "The Role of IGCC in China: Past, Present, and Future," Saistrip, May 2010, www.saistrip2010.webatu.com; China Greentech Initiative Analysis
41. Angell, Christopher, et al., "The Role of IGCC in China: Past, Present, and Future," Saistrip, May 2010, www.saistrip2010.webatu.com

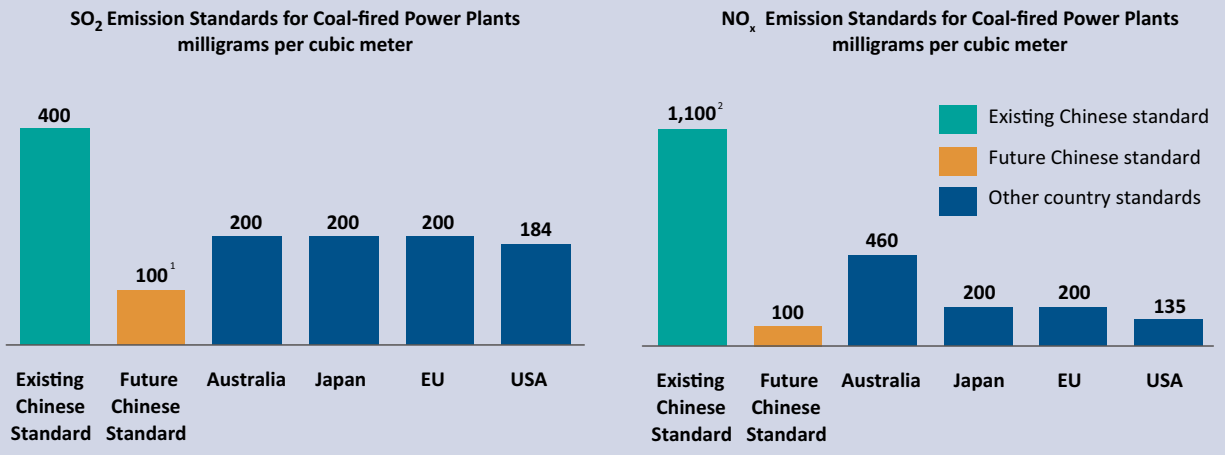
Strong Future for De-SO_x and De-NO_x, but Fly-Ash Utilization Lags

Opportunity Assessment

After the rollout of De-SO_x over the last five years, the 12th Five-Year Plan will promote new regulations and investments for both De-NO_x and fly ash recycling and utilization.

In China's push to improve air quality over the last five years, coal power plant De-SO_x regulations have been relatively successful, and in the process Chinese equipment suppliers captured a large share of the market. China is now poised to encourage De-NO_x technologies with a 10% emissions reduction target and a potential tariff of 0.008 to 0.01 RMB per kilowatt hour (US$ 0.0012-0.0015 per kilowatt hour). Fly ash recycling continues to lag, but extraction of valuable minerals increases financial incentives. While implementation challenges are a common thread for all three solution areas, lessons learned from the De-SO_x experience will likely help improve enforcement.

Existing and Future Chinese SO_2 and NO_x Standards Versus Other Countries



Note: 1. 50 mg/m³ for environment sensitive regions; 2. 650mg/m³ for 10%≤Vdaf≤20%; 450mg/m³ for Vdaf>20%
Source: 环保部, *"火电厂大气污染排放标准-GB13223-2003" [MEP, "Thermal Power Plants Atmospheric Emission Standards- GB13223-2003"] 2003;* 环保部, *"火电厂大气污染排放标准(征求意见稿)-GB13223-200x," [MEP, Call for Comments on Thermal Power Plants Atmospheric Emission Standards-GB13223-200x] 2011; China Greentech Initiative analysis*

Post-combustion technologies are prioritized due to high environmental benefits

When China's power plants burn coal, the resulting exhaust flue gas contains a wide range of toxic substances, including sulfur oxides (SO_x) and nitrogen oxides (NO_x). These substances contribute to acid rain, ozone layer depletion, smog, and can cause a litany of adverse health effects. Cleaner coal technologies such as De-SO_x and De-NO_x remove these pollutants before flue gas is released into the atmosphere.

Fly ash is particulate matter generated during fossil fuel combustion that rises with flue gas, and which contains heavy metals and radioactive components. In China, one ton of coal produces roughly 0.3 tons of fly ash; with the mountains of coal consumed each year, fly ash is China's single largest source of industrial solid waste. Proper management of fly ash is critical to limiting air, water, and soil pollution, as well as preventing contamination of food and health issues including lung cancer and birth defects.

Fly ash is China's single largest source of industrial solid waste.

De-SO_x has made gains, but implementation issues remain

After decades of near inaction, over the last five years China has begun serious efforts to address air pollution. In 2006, the government made mitigating sulfur dioxide (SO_2) a priority, and since then reduced emissions over 14% through targets, emission standards, and tariffs. Along the way, Chinese service providers mastered much of the basic technology, enabling them to dominate the flue gas De-SO_x market.

SO_2 emissions in the power sector were reduced 29% between 2005 and 2009.

Over the last five years, the NDRC and MEP have driven development of De-SO_x by issuing mandatory targets and standards. Current De-SO_x mandates flow out of the 11th Five-Year Plan (2006-2010), where China for the first time set a nationwide target: a 10% SO_2 reduction from 2005 levels. In 2010, the scope of De-SO_x was expanded beyond the electric power sector to include metal processing and manufacturing. The 12th Five-Year Plan extends SO_2 targets—MEP's proposed emission standards show greater alignment with standards in the U.S., Australia, and Japan.[42]

Driven by government initiatives, the De-SO_x market has grown rapidly since 2006. Total installed capacity of coal power plants with flue gas desulfurization (FGD) systems has risen at an annual rate of 34%.[43] The 10% overall reduction in the 11th Five-Year Plan has been exceeded, and SO_2 emissions in the power sector, a key government target, were reduced 29% between 2005 and 2009.[44]

Chinese service companies dominate the De-SO_x market in China, with Chinese FGD service providers claiming the top ten spots. Many De-SO_x service providers today are owned by large state-owned power generation groups, and thus have obvious advantages in winning in-house contracts. Foreign companies—including ABB, Mitsubishi, Alstom and others—are primarily limited to supplying De-SO_x technology to domestic service providers. The preferred FGD technology in China uses limestone to remove SO_2, with Chinese service companies directly producing 90% of the components.[45]

De-SO_x gains have not come without implementation challenges. The current fixed FGD tariff of RMB 0.015 per kWh (US$ 0.0022 per kWh) is considered low and in some cases fails to cover FGD costs.[46] Few other financial incentives and tax preferences are available for De-SO_x projects. As equipment costs money to run and can lower power plant efficiency, some operators simply deactivate FGD systems to improve their bottom line. In 2010, MEP fined eight power plants for fraudulent FDG operations reports, while media reports indicate that one-third of FGD equipment may not be functioning properly.[47] Although regulators are now relying more on continuous emissions monitoring systems, fewer than 30% of such systems are connected to government networks.[48] In addition, below-cost project bidding can spell trouble for a project. Although capital costs for adding FGD in China have fallen from RMB 800-1200 per kW (US$ 123-184 per kW) to RMB 100-200 per kW (US$ 15-30 per kW) since 2000, many services companies win contracts by bidding below cost, leading to inferior project quality and higher retrofit costs.[49]

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42. Emission standards in any given country are subject to periodic review and revision. For example, in March 2011, the U.S Environmental Protection Agency issued a proposed rule that would further limit emissions of toxic air pollutants from power plants in the U.S.

43. 环境保护部, *"2009*年全国投运燃煤机组脱硫设施清单,*" [MEP, "2009 National Inventory of FGD Facilities"] 2010*

44. 国家电力监管委员会等部门, *"2009*年电力企业节能减排情况通报,*"[SERC, et al., "2009 Power Enterprise Energy Conservation and Emission Reduction Report"] Sep. 2010*

45. 王犇犇, *"*我国火电脱硫行业现状及'十二五' 前景展望,*"[Wang Yangyang, "China's FGD Industry Overview and 12th Five-Year Plan Outlook"] China Environmental Industry Association, Jul. 2010, http://air.chinaep-tech.com*

46. 厦门大学, *"*环保装置对火电厂运行的影响及排污权交易研究,*"[Xiamen University, "Research on Environmental Facility's Effect on Coal- fired Power Plants and Pollution Right Trading"] 2008;* 国家电力监管委员会等部门, *"*关于火电厂脱硫电价政策要点检查技巧的把握和探索,*"[SERC, "Study on the Inspection Techniques of FGD Tariff at the Thermal Power Plants,] Dec. 31, 2010*

47. 中国环境信息, *"*低价中标,脱硫受伤,*"[China Environment News, "Low Bids Win, FGD Suffers"] Feb 3, 2010*

48. 国家电力监管委员会等部门, *"*美国火电厂污染物排放监测和控制基本情况及其对我国的启示*"[SERC, "Emission Monitoring and Regulation at Coal-fired Plants in U.S. and its Implications to China"] 2010*

*49. "*低价中标, 脱硫受伤*" [Low Bids Win, FGD Suffers] China Environment News, Feb. 3, 2010, www.cenews.com.cn*

De-NO_x is positioned to follow the path of De-SO_x

After the relative success of De-SO_x over the last five years, the 12th Five-Year Plan has added NO_x to emission controls, with a reduction target of 10% from the 2010 baseline.[50] In addition, the government issued proposed emission standards for NO_x in January 2011. NO_x targets and standards are essential to stem ballooning emissions: from 2003 to 2010 estimated NO_x emissions from coal-fired power plants rose from 597 million tons to 1,310 million tons.[51]

Fly ash production has increased fourfold in the last decade, hitting 380 million metric tons in 2010.

With new NO_x mandates, the estimated 50 GW of current NO_x installed capacity could increase to as much as 800 GW by 2015.[52] Service companies, mostly Chinese, will step in to fill much of the demand, though at least two foreign companies—Babcock and Wilcox (U.S.) and IHI (Japan)—have already established joint ventures to provide De-NO_x services. Technologies are mainly controlled by foreign companies which cooperate with domestic service companies to provide De-NO_x solutions. Government spending on R&D, however, will likely narrow the technology gap in the coming years.

De-NO_x solutions are guided by MEP technology priorities published in 2009. Selective catalyst reduction (SCR), a mature technology with a high removal rate, is the dominant flue gas De-NO_x solution, but downsides include an expensive catalyst (currently RMB 50,000 (US$ 7,692) per cubic meter) that requires careful recycling or disposal to limit environmental threats.[53] Integrated De-SO_x and De-NO_x technologies, though not currently commercially viable, are promising future solutions that the Chinese government is keen to deploy because of the potential to reduce upfront investment, increase removal rates and streamline management.[54]

Given that a De-NO_x tariff has yet to be set, the only current incentive is the avoided NO_x pollution fee of RMB 0.63 per kg (US$ 0.09 per kg), equal to approximately 7% of SCR project operation costs. By 2012, MEP is expected to set a tariff of between RMB 0.008 to 0.01 per kWh (US$ 0.0012-0.0015 per kWh).[55] This could be too low, given estimates indicating costs of approximately RMB 0.0089 per kWh (US$ 0.0013 per kWh),[56] which might lead to familiar implementation and enforcement issues. Other challenges mirror those existing for De-SO_x, including project bidding at near-or-below cost and quality control issues. However, the government is likely to build on De-SO_x experiences to design effective responses for De-NO_x implementation.

Fly ash recycling is minimal, but extracting minerals increases financial incentives

Although fly ash regulations were first introduced in the 1990s, progress has lagged. The problems and opportunities continue to grow—fly ash production has increased fourfold in the last decade and hit 380 million metric tons in 2010, far exceeding the amount of urban domestic waste. Recycling—mostly for building, road construction and agricultural uses—is reported by the government to be as high as 67%, but may in fact be much lower.[57]

50. 国家发展改革委, "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,"*[NDRC, "PRC 12th Five-Year Plan for National Economic and Social Development"] Mar. 2011*

51. 世纪证券, "硫'暗,'？'硝'明,'！技术成就未来,"*[Century Securities, "SOx 'Dim,' Nox 'Bright': Technology Achieved Future"] May 27, 2009*

52. 王志轩, "我国燃煤电厂烟气脱硝产业发展的思考,"*[Wang, Zhixuan, "China's Coal-Fired Power Plant Flue Gas Denitrification Industry Development"] China Electricity Council, Oct. 2009*

53. SCR catalyst regeneration, a technology widely used in Europe and the U.S. since the 1990s, can reduce catalyst costs and disposal issues and is receiving MEP attention.

54. 环境保护部, "火电厂烟气脱硝工程技术规范 选择性催化还原法（征求意见稿),"*[MEP, "Thermal Power Plant Flue Gas Denitrification Engineering Specifications (Draft for Comment)"] 2009*

55. 经济观察网, "环境保护倒逼经济增长方式转变,"*[Economic Observer, "Environmental Protection Push the Destructing of Economy Development"] Apr. 27, 2010*

56. 环境保护部, "火电场氮氧化物防治技术政策（征求意见稿）编制说明,"*[MEP, Reference on Thermal Power Plant De-NOx Technology Roadmap], 2009;* 经济观察网, "环境保护倒逼经济增长方式转变,"*[Economic Observer, "Environmental Protection Push the Destructing of Economy Development"] Apr. 27, 2010; China Greentech Initiative analysis*

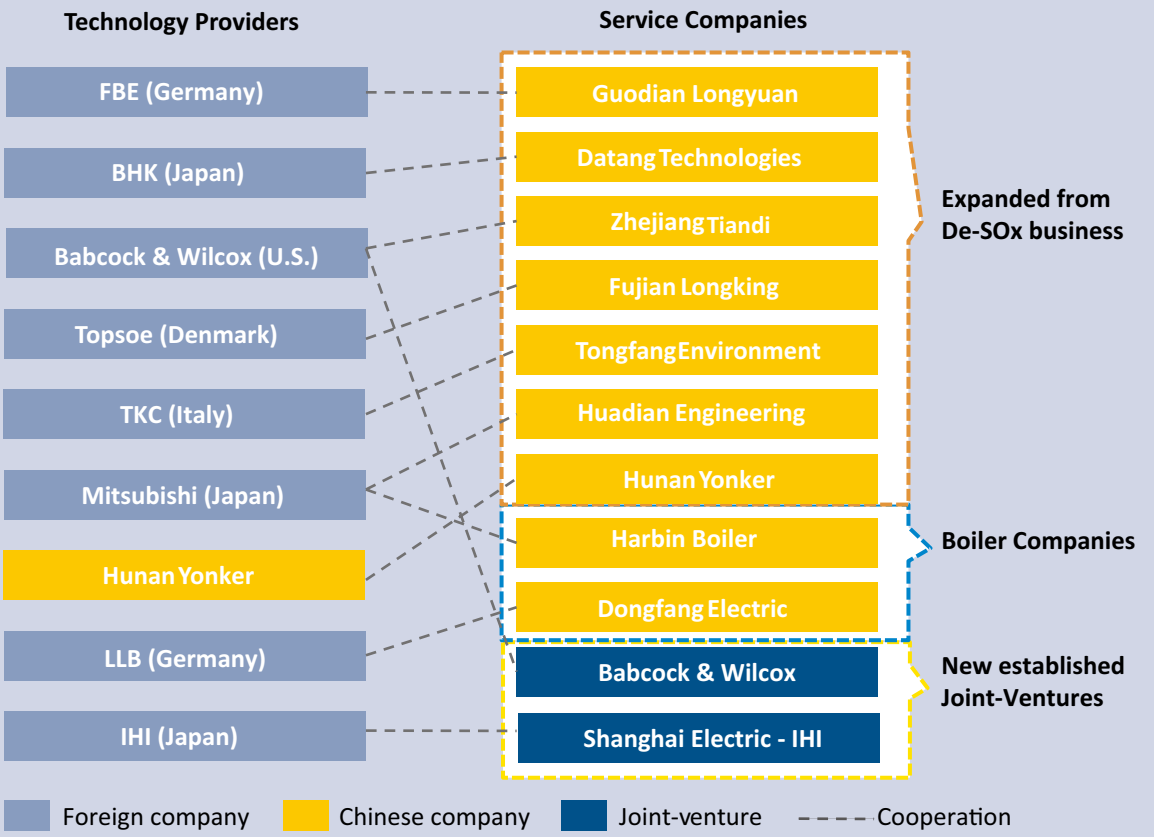
57. 国家发展改革委等部门, "中国资源综合利用技术政策大纲,"*[NDRC, et al., "China Comprehensive Resource Use Technology Policy Outline"] Jul. 1, 2010; "The True Cost of Coal: An Investigation into Coal Ash in China," Greenpeace, Sep. 15, 2010, www.greenpeace.org*

Fly ash utilization received a boost in 2008 when the new Circular Economy Law mandated recycling; however, market growth is challenged by inconsistent standards and utilization requirements, lack of government incentives, and limited access for foreign players who can only participate through joint venturess.

Nevertheless, many emerging technologies capitalize on mineral extraction of alumina, spherical particles and carbon from recovered fly ash. One demonstration project in Inner Mongolia aims to extract up to 600,000 metric tons of alumina, which can be used to produce aluminum or substituted for industrial diamonds. Reports indicated in late 2010 that the project had achieved net profits of 23% during the first two stages of development.[58] With the extraction of valuable metals as the incentive, fly ash utilization could move forward quickly once proven technologies are commercialized in China.

Overall, the next few years look promising for post-combustion technologies, with a few caveats. In SO_x control, the government will focus on tweaking incentives and enforcement to ensure industry meets emissions goals. For NO_x and fly ash recycling, the market is poised to take off as new regulations and enforcement come into effect and government and industry leverage past experience with SO_x. If the SO_x example can be taken as a guide, the main opportunities will eventually flow towards domestic equipment suppliers, with international players offering higher-end technology solutions.

Selected De-NO_x Technology and Service Companies in China



Source: 王志轩(中电联)，"我国燃煤电厂烟气脱硝产业发展的思考," *[Wang Zhixuan (China Electricity Council), "Some Thoughts on the Development of Flue Gas Denitrification Industry"] 2009; China Greentech Initiative analysis*

58. 中国化工报, *"大唐粉煤灰综合利用初显风采,"[China Chemical Industry News, "Datang Fly Ash Comprehensive Utilization Project Shows Early Promise"] Oct. 15, 2010*

Carbon Tax Option Under Careful Review

Opportunity Assessment

Pricing carbon continues to attract hot policy debate in China.

A galloping economy has brought skyrocketing energy use and greenhouse gas (GHG) emissions, putting pressure on China to revamp its response to the growing energy and environmental hazards. One carbon pricing option—a carbon tax—is being carefully considered, but despite indications that China could adopt such a tax, perhaps as soon as 2012, many challenges remain.[59] Such a system could take years to put into place, and questions central to implementation are unresolved, such as tax neutrality, revenue management, and incentives for greentech solutions.

China has completed carbon tax research and design, but many issues are unresolved

Putting a price on carbon would boost China's current response to climate change and other environmental issues. China's current policies include participation in the United Nations Framework Convention on Climate Change (in part though China's National Climate Change Program launched in 2007) as well as related domestic energy savings and emission reduction policies introduced over the last five years. Research in late 2009 from the NDRC's Energy Research Institute indicated that without more active policies on carbon emissions, China would face unacceptable consequences related to climate change and energy security.[60]

The Ministry of Finance (MOF), through its affiliated Research Institute of Fiscal Science (RIFS), leads the research and design of a carbon tax; the NDRC, MEP and State Administration of Taxation (SAT) and Chinese universities and international organizations, support RIFS' reserach. In March 2010, MOF and the NDRC completed a potential framework for the design of a carbon tax system.[61] The design lists eight main carbon tax components: payer, scope, emissions calculations, tax rate, incentives, tax process, attribution and distribution. Each component shows how a carbon tax would balance competing interests to meet national objectives.[62]

Many questions central to implementing a carbon tax remain unresolved. To avoid excessive tax burden on companies, will a carbon tax be revenue neutral with costs passed on to customers? Will carbon tax revenues be put into the government's general budget or dedicated to a specific purpose? In addition, implementation faces basic issues of inadequate experience and an uneven track record on emissions monitoring and control. These systems could take years to implement.

Putting a price on carbon would further boost China's response to climate change.

There is no clear indication of when a carbon tax might come online. One MOF scenario shows implementation between 2012 and 2013, after fuel tax and resource tax reforms get underway, but before environmental taxes go into effect.[63] Contingencies such as the success of earlier resource or energy taxes, macro-economic conditions, and stability of global markets make predicting the timing of a carbon tax difficult.

Several government bodies would participate in the final adoption of a carbon tax, including legislative enactment by the National People's Congress, general administrative implementation by the State Council, and more specific implementation and monitoring by a number of government agencies. Many laws in China are implemented slowly, even after becoming effective, during which detailed implementing regulations are refined to improve enforcement. As a result, there could be a lag between the official introduction of the tax and the efficient operation of the system.

59. Government and industry remain divided over which system is best for China—cap-and-trade versus carbon tax or some combination

60. Jiang, Kejun, "Low Carbon Future Energy and Emission Scenario Up to 2050 for China," Presentation given at IGES-ERI Policy Dialogue, Beijing, China, Sep. 22, 2009

61. China Greentech Initiative interview with Jiang Kejun of ERI on Aug. 23, 2010

62. 财政部, "中国开征碳税问题研究详细技术报告,"[MOF, "Research on Levying Carbon Tax in China: Full Technical Report"] Sep. 2009

63. Ibid.

Overall, there remains considerable uncertainty surrounding the potential introduction of a carbon tax in China. Although MOF and NDRC have completed the design of a carbon tax, the ultimate acceptance of this design and the timing of its implementation are both uncertain. Difficult policy choices surrounding levels of carbon emissions, revenue collection and use and incentives linger. In addition, even if China does announce policy decisions on a carbon tax in the near future, full implementation will take time given the need for improved monitoring, control and expertise. In the interim, other easier-to-implement energy and resource taxes are being rolled out on a regional basis and will be gradually extended nationwide.

Cleaner Conventional Energy Opportunities for 2011

This chapter provides an update on China's Cleaner Conventional Energy sector and three Opportunity Assessments prioritized by the China Greentech Initiative's partners and advisors in 2010. As the sector evolves, participants in the China Greentech Initiative Partner Program will continue to collaborate on additional opportunity areas. The first topic in 2011 covers China's market prospects for coal bed methane, coal mine methane and shale gas. Other topics may include water and energy-efficient clean coal value chains, gas turbine, and gas transmission and distribution network expansion. The China Greentech Initiative will also continue to track the overall development of China's Cleaner Conventional Energy sector.

Reuters

Renewable Energy

Government policies and investment have transformed China into one of the world's leading adopters and manufacturers of renewable energy technology, but many challenges remain for market players.

Ambitious renewable energy targets and strategic government investment have helped China become a world leader in renewable energy manufacturing and power generation. In 2010, China surpassed the U.S. to become the world's largest wind power producer. China also produces more solar photovoltaic panels and wind turbines than any other country.[1] By 2020, installed capacity of wind, solar and biomass power is targeted to more than quadruple, from less than 50 GW in 2010 to more than 200 GW in 2020. The 12th Five-Year Plan also calls for non-fossil fuel energy sources (renewable and nuclear energy) to account for 11.4% of the energy mix. Given China's recent installation track record, 200 GW of renewable energy capacity in 2020 may be conservative; some predict that by 2020, China may install more than 240 GW of wind power alone.[2] This will create a Renewable Energy electricity market worth more than US$ 1.4 trillion by 2035, according to an International Energy Agency forecast.[3] However, rapid growth does not necessarily translate into market opportunities for all companies in China. Renewable energy equipment manufacturers, project developers and operators entering the market must address significant challenges.

This chapter begins by providing an overview of Renewable Energy sector developments since the publication of *The China Greentech Report 2009*. It then summarizes the three Opportunity Assessments the China Greentech Initiative developed with its partners and advisors throughout 2010:

- China's Domestic Solar Market Emerges
- China's Wind Market Heads to Sea
- Distributed Renewable Energy (DRE) Leadership and Potential

The China Greentech Initiative's partners and advisors 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 the organizations participating in the China Greentech Initiative Partner Program. The chapter concludes with an outlook on additional opportunities and issues in the Renewable Energy sector that the China Greentech Initiative plans to explore in 2011.

The writing of this chapter was led by Claire N. Nelson (聂凯怡), based upon her leadership of the strategic research deliverables completed by the China Greentech Initiative's Renewable Energy sector research team.

1. "Chinese PV companies dominate solar manufacturing spending in 2010," SolarServer, Nov. 24, 2010, www.solarserver.com
2. "China: 248 GW of wind power in 2020," Renewable Energy Focus, Jan. 31, 2011, www.renewableenergyfocus.com
3. International Energy Agency, 2010 World Energy Outlook (Paris, France: International Energy Agency, 2010)

Renewable Energy Sector Definition

The China Greentech Initiative defines Renewable Energy as energy produced from sources that are naturally replenishing, such as sunlight, wind, waves, underground heat, surface water flows and biomass. Of these, the China Greentech Initiative focuses on the markets and technology for wind power, solar energy (including power as well as cooling and heating) and bioenergy (also including power as well as cooling and heating). For a more in-depth definition and explanation of existing and emerging renewable energy solutions, refer to the Renewable Energy chapter of *The China Greentech Report 2009.*

Market Update

Strong law and policy foundation enables growth

Large-scale, non-hydropower renewable energy development in China can be traced back to the landmark 2005 Renewable Energy Law and the 2007 Medium to Long-Term Renewable Energy Development Plan, two regulatory instruments that provided fertile ground for renewable energy growth. These and more recent regulations and financial incentives have helped China surpass its initial 2010 installation targets. Original targets for wind power capacity, for example, were set at 5 GW in 2006. By the beginning of 2011, however, China had already installed 41.8 GW, topping the U.S.'s 40 GW to become the world's largest wind power producer.[4] 2010 Renewable Energy Law Amendments clarified rules for grid connection and helped increase the proportion of grid-connected wind farms to nearly 100% (as recently as the end of 2009 up to 30% of all wind power was not grid-connected). The new rules have created better oversight of grid connection issues and planning, while also raising penalties for grid companies that fail to connect wind farms. It also established a Renewable Energy Development Fund to pay for extending transmission line extension.[5]

China has also used specific incentives to accelerate renewable energy deployment. China was the first country outside of the European Union to establish feed-in tariffs (FiTs) for its wind sector.[6] FiTs are fixed rates paid to all power producers for electricity provided to the grid, which typically include a premium over conventional power rates. China's FiTs vary by region and level of wind resources, ranging from RMB 0.51 to 0.61 per kilowatt hour (US$ 0.08 to 0.09 per kilowatt hour), about 30% to 50% higher than the average tariff paid for coal-fired electricity. FiTs have substantially improved the appetite for wind power project development and helped more than triple China's total wind power capacity in the last two years.[7]

China's market for solar power also took off in the last 18 months and looks to grow substantially in the coming five to ten years. The Golden Sun and Solar Roofs subsidy programs, introduced in 2009 to prevent oversupply in China's solar PV manufacturing industry, now have a project pipeline of 640 MW for the coming years. The government has consolidated the two programs to help meet 2015 and 2020 targets. The new subsidies fund up to 50% of project costs in 13 newly-designated Renewable Energy Development Zones across eastern China.[8] The government announced the first round of projects under the new program in late 2010, which included 34 projects using panels supplied by three domestic producers: Yingli, Shanghai Solar Energy Science, and Hareonsolar.[9]

4. "China has highest wind power capacity: report," Reuters, Jan. 13,2011, www.reuters.com
5. Finamore, Barbara, "China Renews Its Commitment to Renewable Energy," Natural Resources Defence Council, Feb. 1, 2010, www.switchboard.nrdc.org
6. Gipe, Paul, "China launches differentiated wind tariffs," Renewable Energy Focus, Sep. 7, 2009, www.renewableenergyfocus.com
7. National Academy of Sciences, The Power of Renewables: Opportunities and Challenges for China and the United States (Washington, D.C.: The National Academies Press, 2010)
8. "China solar energy subsidies increase to expand market," Taipei Times, Dec. 20, 2010, www.taipeitimes.com
9. 中华人民共和国财政部, "关于做好2010年金太阳集中应用示范工作的通知," [Ministry of Finance, "Notice on the 2010 Golden Sun Demonstration Projects"] Nov. 19, 2010

2010 also saw the launch of the second bidding round using a concession scheme approach for 13 projects totaling 280 MW in capacity.[10] Whereas some observers anticipated a solar FiT announcement in 2009, the government has so far relied on concession schemes in which project developers bid low tariffs for electricity production. Winning projects receive a long-term power-purchase agreement with the grid company; through this process, the government determines acceptable tariff levels. This is a strategy the government first used in the wind industry before the wind FiT was established. Projects are typically awarded to the lowest priced bids, and China's large power generation SOEs have won all solar concession rounds to date.

Biomass power continues to receive less attention than solar and wind power in China. On a positive note, however, the central government increased the nationwide biomass FiT to RMB 0.75 per kilowatt hour (US$ 0.11 per kilowatt hour) in 2010 and enacted a retroactive tax reduction for biodiesel producers.[11] Additional growth of the sector is likely to require further support, as growth has stagnated in recent years due largely to feedstock supply challenges. As evidence of this, biomass power was the only category of renewable energy to miss its 2010 target, reaching 3.2 GW by 2010 versus the planned 5 GW.[12]

Government acts as an investor

China led the world in clean energy investment in 2010. A staggering RMB 354 billion (US$ 54.4 billion) was invested in renewable energy, energy efficiency, smart grid, and related infrastructure investments. China's investment rose 39% from 2009, constituting over 20% of the world's total clean energy investment of US$ 243 billion.[13] This propelled China to the top of Ernst & Young's list of the world's most attractive countries for renewable energy investment in the fourth quarter of 2010.

China's investments take the form of asset financing, public markets, FiTs, subsidies like the Solar Roofs Program and other traditional incentive programs. China also supports its domestic renewable energy companies with low-interest loans and incentives enabling companies to scale up production capacity and expand into global markets—incentives which have featured prominently in recent trade disputes. The Obama administration has filed a complaint with the World Trade Organization claiming that China unfairly subsidizes its domestic renewable energy companies.[14]

China led the world in clean energy investment in 2010 with over RMB 354 billion (US$ 54.4 billion).

The China Development Bank, a state-run institution dedicated to strategic infrastructure development, drew attention in 2010 for offering credit lines worth RMB 282 billion (US$ 43.6 billion) to top-tier Chinese renewable energy manufacturing companies. Solar panel producers LDK Solar, Suntech, Yingli and Trina Solar as well as wind-turbine makers Sinovel and Goldwind, each received the largest loans, amounting to RMB 42 billion (US$ 6.5 billion) on average.[15] These loans are fueling astounding growth in the solar PV manufacturing sector. By the end of 2011, China's solar PV manufacturers are expected to reach up to 35 GW of PV cell manufacturing capacity from just 2.4 GW in 2008.[16]

Government acts as a buyer

China's largest SOEs, including the "Big Five" power producers (Huaneng, Datang, Guodian, Huadian and China Power Investment Group), are at the forefront of developments in China's renewable energy market. Since the first wind power concession round in 2004, they have dominated development and operation of renewable energy projects. SOEs have developed more than 90% of wind power

10. "China solar power project tender draws 50 firms," Reuters, Aug. 11, 2010, www.af.reuters.com
11. Lucas, Paul, "China exempts taxes on biofuels," The Green Car Website, Dec. 27, 2010, www.thegreencarwebsite.com
12. American Council on Renewable Energy and Chinese Renewable Energy Industry Association, US China Quarterly Market Review, Winter 2011 (Washington, D.C.: ACORE and CREIA, 2011)
13. Pew Charitable Trusts, Who's Winning the Clean Energy Race? (Washington, D.C.: Pew Charitable Trusts, 2011)
14. Kurtenbach, Elaine, "China says wind, solar subsidies WTO complaint," *Bloomberg, Dec. 23, 2010, www.bloomberg.com*
15. Bloomberg New Energy Finance, Joined at the hip: the US-China clean energy relationship (New York, NY: Bloomberg New Energy Finance, 2010)
16. "PV Module Production Doubles in 2008," Renewable Energy World, Oct. 1, 2009, www.renewableenergyworld.com; "PV Capacity in China Faces Tough 2011," Asia Pulse, Dec. 30, 2010, www.electroiq.com

farms in China and 100% of large-scale solar power plants to date, leaving little room for private players.[17] Their influence is not limited to China: Guodian, Datang and Huaneng are listed amongst the world's top ten owners of non-hydropower renewable energy projects.[18]

Renewable energy projects do not guarantee large profits, however, and SOEs have other, non-financial incentives and requirements for entering the sector. China implemented a renewable energy portfolio standard (RPS) in 2007, which required utilities to supply 3% of power by non-hydropower renewable energy by 2010 and 8% by 2020.[19] However, the RPS is only part of the story. Because of their close links to the government, SOEs must help the government meet its strategic targets, like carbon intensity reduction and clean energy production. Aware of the lucrative future clean energy development offers globally, SOEs have clear ambitions to be leading players in the international market.

Renewable Energy Transformation Taking Place in Remote Regions Across China

The National Energy Bureau began planning in 2008 for seven multi-GW scale wind power bases across six provinces in China. Until recently, the majority of installed capacity consisted of sub-50 MW projects, due to the easier and faster approval process for smaller projects. However, ten years from now, these multi-GW bases are expected to have 138 GW of wind power capacity and account for the majority of China's 2020 capacity.[1] As most of these wind power bases are in remote regions, new large-scale grid networks will need to be constructed.

The Jiuquan base in Gansu, for example, boasts such powerful wind resources (estimated at 40 GW of exploitable capacity) that local residents call the nearest city to the base "the wind warehouse of the world." Construction on the Jiuquan wind power base started in August 2009, with all of China's Big Five power generation SOEs involved. The planned output of the base was incentive enough to convince Goldwind and Sinovel to set up manufacturing facilities there, reducing the cost of transporting turbines by 80%.[2] The first phase of the project was completed in December 2010, with 5.2 GW of installed capacity (1.2 GW of which was grid connected), making it China's largest wind farm.[3] By 2020 the local government hopes to increase wind power capacity in the region to create what they have dubbed the "Three Gorges on Land" (the Three Gorges Dam in Hubei Province has a capacity of just over 18 GW).

Targeted Capacities of China's Wind Power Bases, GW, 2020

Location	Capacity
Inner Mongolia	58.8
Western Jilin	23
Bashang, Hebei	14.1
Jiuquan, Gansu	12.7
Kumul, Xijiang	10.8
Jiangsu	10

1. Li Junfeng, et al., China Windpower Outlook 2010 (Beijing, China: Chinese Renewable Energy Industries Association, 2010)
2. Ibid.
3. Ernst & Young, Renewable energy country attractiveness indices, Issue 28 (London, United Kingdom: Ernst & Young, 2010)

Ambitious 12th Five-Year Plan

The 12th Five-Year Plan (2011-2015) is China's most environmentally-focused plan to date. The plan mandates that by 2015, 11.4% of the energy mix must come from non-fossil fuel sources.[20] One of the cornerstones of the plan, which will help

17. American Council on Renewable Energy and Chinese Renewable Energy Industry Association, US China Quarterly Market Review, Winter 2011 (Washington, D.C.: ACORE and CREIA, 2011)
18. International Energy Agency, 2010 World Energy Outlook (Paris, France: International Energy Agency: 2010, 290)
19. World Business Council for Sustainable Development, "China blasts through wind energy target," *www.wbcsd.org, accessed on Feb. 20, 2011*
20. Note: China's definition of non-fossil fuel energy sources includes renewable energy and nuclear power

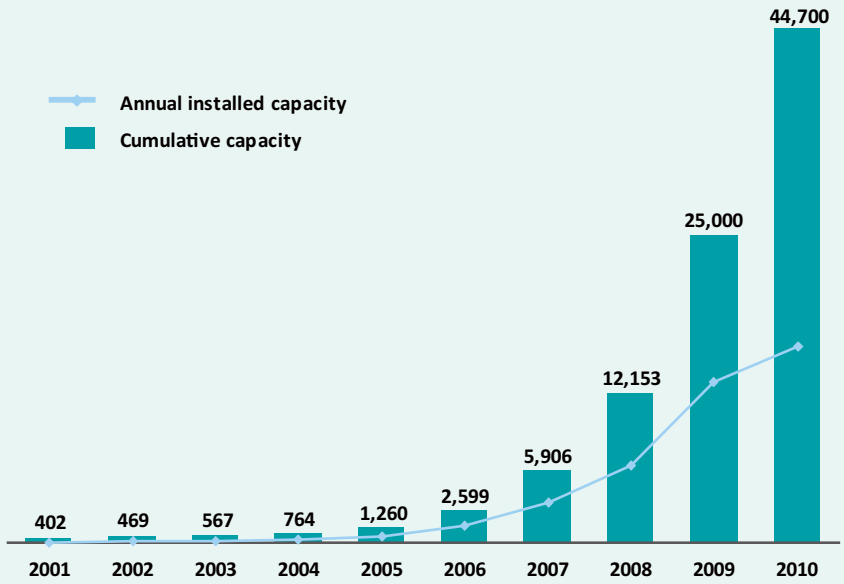
China achieve this and other targets, are the inclusion of seven Strategic Emerging Industries (SEIs). The New Energy SEI (which includes renewable energy), will receive RMB 5 trillion (US$ 769 billion) in investment over the next ten years, or 50% of the total SEI investment target.[21] Renewable energy development targets for 2015 have also been set: construct 120 GW of new hydropower capacity (for a total of 330 GW), 70 GW of new wind power capacity (for a total of 110 GW) and 5 GW of new solar power capacity.[22] According to National Energy Administration officials the solar power target is likely to be upwardly revised to 10 GW due to the desire to promote renewable energy in the aftermath of Japan's nuclear crisis.[23] Hydropower and wind power, with the highest targets, will continue to be the stars of China's renewable energy sector and will likely surpass the set targets.

China's Renewable Energy market experienced another year of astounding growth in 2010

China has attained a position of global leadership in renewable energy with astounding speed. Although China has long led in hydropower generation, solar energy, wind power and bioenergy have until recently been niche markets. China now has the highest capacities of small and large hydropower, wind power, solar water heaters and small-scale biogas compared with any other country. The outlook is also promising for solar PV and municipal waste-to-energy.

Wind power is the most stunning example of China's push for global renewable energy leadership. China had less than 1 GW of wind power capacity in 2004, but by the end of 2010 this amount skyrocketed to 44.7 GW. If China reaches 248 GW of wind power capacity in 2020, as the China Wind Power Association forecasts, this would represent an increase of more than 300 times over 2004 capacity.[24]

China's Wind Power Capacity Growth, MW, 2001-2010



Sources: Global Wind Energy Council et al., Global Wind Energy Outlook 2008 (Brussels, Belgium: GWEC, 2008) ; Schwartz, Louis, "China's New Generation: Driving Domestic Development," Renewable Energy World, Mar. 2009, www.renewableenergyworld.com

21. Chien, Joanne, "Overview of China's 12th Five-Year Plan," DigiTimes, Jan. 31, 2011, www.digitimes.com
22. "China announces ambitious clean energy plans for next five years," Xinhua, Mar. 5, 2011, www.english.peopledaily.com.cn; Finamore, Barbara, "The Next Five Years of Clean Energy and Climate Protection in China," Natural Resources Defense Council, Mar. 23, 2011, www.switchboard.nrdc.org
23. Li Yuchuan, "China May Double Photovoltaic Capacity to 10 GW by 2015," China Securities Journal, Mar. 30, 2011, www.cs.com.cn
24. "China: 248 GW of wind power in 2020," *Renewable Energy Focus, Jan. 31, 2011, www.renewableenergyfocus.com*

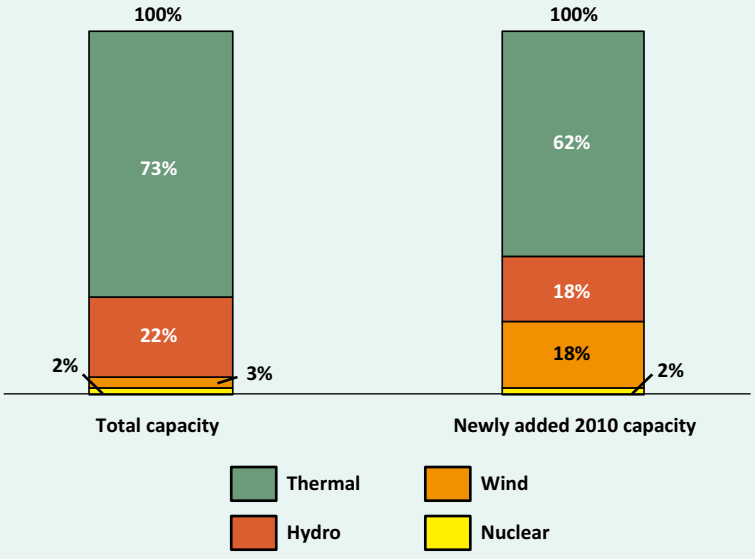
In a market focused on price, the low cost of hydropower and solar water heater technologies has resulted in significant market penetration. China has more than 80% of the world's installed capacity of solar water heaters because of their cost-competitiveness with conventional water heating technologies. The low cost of solar water heaters in China—only US$ 27 annually over the lifetime of the unit versus US$ 82 for gas and US$ 95 for electrical heaters—explains why 145 million square meters have been installed without substantial government incentives.[25] China is also home to a fiercely competitive market of more than 5,000 solar water heater manufacturers, who by their sheer number help keep prices low.

Small and large hydropower can also be cheaper than the cheapest coal-fired power per kilowatt hour, in part due to China's long history of hydropower development.[26] As early as 1950, planners began to develop hydropower on a large scale for rural electrification. After some time out of the spotlight, for environmental and social reasons, government officials are again touting the benefits of hydropower.[27] China's current hydropower capacity of 210 GW is on track to more than double to 430 GW by 2020, thereby exploiting virtually all the country's hydropower resource potential.[28]

Fossil fuels still dominate China's energy mix: they supply 74% of China's electricity (wind power currently only accounts for 3%), and coal-fired power plants continue to be built at a rapid rate. Given China's expected power needs by 2035 (more than three times today's levels), it is unrealistic to expect a revolution in the way China produces and supplies power. Nevertheless, a palpable change is taking place. Only 62% of power generation capacity added in 2010 was from conventional sources, while 18% came from wind power, 18% from hydropower and 2% from nuclear power.[29] Therefore, 38% of the power generating capacity installed in 2010 will emit no carbon dioxide during its operation, an impressive achievement for such a rapidly urbanizing country.

Thirty-eight percent of the power generating capacity installed in 2010 will emit no carbon dioxide during its operation.

China's Existing and Newly Installed Energy Generation Capacity by Energy Type, percent, 2010



Source: 能源局, "2010年能源经济形势及2011年展望, " *[NEA, "Energy Economy Development in 2010 and Outlook in 2011"] Jan. 28, 2011, www.gov.cn*

25. International Energy Agency, 2010 World Energy Outlook (Paris, France: International Energy Agency: 2010, 349); REN21, Renewables 2010 Global Status Report (Paris, France: REN21 Secretariat, 2010)
26. Pan, Jiahua, et al., Rural Electrification in China 1950-2004: Historical Processes and Key Driving Forces, Working Paper #60 (Palo Alto, California: Stanford University, 2006)
27. Xie Liangbing, "Making up for Lost Time, China's Hydropower Push," Economic Observer, Jan. 24, 2011, www.eeo.com.cn
28. International Energy Agency, 2010 World Energy Outlook (Paris, France: International Energy Agency: 2010, 290)
29. American Council on Renewable Energy and Chinese Renewable Energy Industry Association, US China Quarterly Market Review, Winter 2011 (Washington, D.C.: ACORE and CREIA, 2011)

Formidable competitors define China's Renewable Energy markets

In the early 2000s, China was a net importer of renewable energy technology. In 2004, 75% of wind turbines installed in China were foreign-made; however, China has transformed its domestic production capabilities remarkably over the last 10 years.[30] Seeking to transition to a high-tech, innovation-based economy, the government enacted policies that gave birth to a thriving domestic renewable energy industry. Government investment and regulations, such as the 70% local content requirement for wind power projects, were instrumental in making that change possible.[31] Contrary to popular understanding, this rule did not make foreign manufacturing firms uncompetitive, as many of them chose to establish factories in China in order to meet the requirement. Rather, domestic manufacturers were simply more willing to use lower-cost domestic components and reduce their prices sharply, making them more attractive to cost-conscious developers (primarily SOEs). This resulted in large orders, which enabled dramatic scale-up of wind power equipment production capacity. Chinese wind turbine producers supplied more than 85% of the local market by 2010, and were able to compete on price and quality.[32] In addition to China's well-understood manufacturing advantages, such as low-cost labor and raw materials, this also suggests the success of China's wind power industrial policies.

Buoyed by success and a supportive government at home, many Chinese wind developers, Longyuan, Datang and Huaneng for example, and equipment manufacturers, such as Goldwind, Sinovel and Dong Fang, have become leading global renewable energy companies. Although these manufacturers have relatively little presence outside of China to date, this is likely to change in the near future. Nevertheless, when it comes to global market share, their dominance in the sizable domestic wind market already qualifies them as global leaders.[33]

China is also home to some of the world's leading solar PV manufacturing companies. Five of the top ten solar PV cell and panel producers in 2010 were Chinese; and more than 50% of global PV panel production was based in China.[34] Suntech, LDK Solar, JA Solar, Trina Solar, Yingli and Hanwha SolarOne have all become prominent names in the international solar industry.

Despite the increasingly competitive nature of China's domestic renewable energy markets and technology suppliers, there is still room for new and innovative companies. China's renewable energy industry presently revolves around low-cost technologies, so companies with innovative solutions, especially in market segments that are underdeveloped, such as bioenergy, geothermal and concentrated solar power (CSP) will continue to find customers if the price is right.

More than 50% of 2010 global PV panel production was based in China.

China's Renewable Energy sector grows more attractive each year

China's Renewable Energy sector continues to provide business and investment opportunities as government support increases and technologies mature compared to conventional solutions. However, renewable energy remains disadvantaged by higher capital and energy generation costs, while barriers to market access and intense competition in many areas create challenges. Of all of China's Renewable Energy subsectors, the wind power market is the most attractive, due to favorable subsidies and cost structures. Solar, while showing promise, is still underdeveloped in China as technology costs are currently high and subsidies have not been introduced on a large scale. Bioenergy is also less attractive than wind, due to the small scale of adoption, feedstock supply risks and the difficulty securing project permits.

30. Li, Junfeng, et al., China Wind Power Report 2007 (Beijing, China: China Environmental Science Press, 2007)
31. Note: the 70% local content requirement was dropped in late 2009.
32. Bradsher, Keith, "To Conquer Wind Power, China Rewrites the Rules," New York Times, Dec. 14, 2010, www.nytimes.com
33. China Greentech Initiative analysis; Partner and Strategic Advisor discussion during China Greentech Initiative Renewable Energy Working Session, Dec. 2010
34. Alberts, Larry and Francois Tibi, Sunrise in the East: China's Advance in Solar PV—and the Competitive Implications for the Industry (Hong Kong: Boston Consulting Group, 2010); "Solar Photovoltaic (PV) Supply Chain—Global Market Size and Company Analysis of Polysilicon, Wafers, PV Cells and Solar Modules to 2015," *Renewable Energy World, Feb. 1, 2011, www.renewableenergyworld.com*

The China Greentech Initiative developed a Market Attractiveness Assessment (MAA) to evaluate the wind and solar power subsectors on six criteria: government support, addressable market size, solution attractiveness, five-year market growth potential, market accessibility and profit opportunity. Information on the Market Attractiveness Assessment methodology is found in the Research Methodology chapter.

Renewable Energy Market Attractiveness Assessment—Wind Power

Assessment Criteria	Attractiveness	Explanation
Government Support	●	■ Wind power prioritized in 12th Five-Year Plan with a target of 70 GW of added capacity between 2011 and 2015 (for a total of more than 110 GW installed capacity) ■ Feed-in tariffs continue to incentivize onshore wind development ■ Policies in place to promote offshore wind industry
Addressable Market Size	●	■ Largest installed wind power capacity in the world with 44.7 GW ■ Installed capacity expected to more than triple by 2020 ■ Offshore wind resources estimated at 750 GW
Solution Attractiveness	◑	■ Cost of energy production roughly double coal-fired power per kilowatt hour (US$ 0.08/kWh for onshore wind compared to US$ 0.04/kWh for coal) ■ Offshore wind energy costs double onshore costs (US$ 0.16/kWh) ■ Costs declining rapidly
Five-Year Market Growth Potential	◔	■ Wind power capacity will grow to meet the 12th Five-Year Plan target of 70 GW of added capacity between 2011 and 2015, although yearly growth may be slower than in 2010 ■ China will likely exceed 2015 target, which would translate into higher market growth rates ■ Rapid growth of offshore wind power capacity expected
Market Accessibility	◕	■ SOEs developed 90% of all onshore wind power projects, making it difficult for private developers to compete ■ All four offshore wind projects in first concession round won by SOEs ■ Domestic turbine producers supply more than 80% of local market, many of which are SOEs ■ 70% local content rule for wind farms dropped in 2009 to allow more foreign market participation
Profit Opportunity	◑	■ Dominance of SOEs as primary buyers limits profits for solution providers ■ High competition drives price down ■ Differentiation opportunities moderate for onshore and higher for new offshore wind market ■ Threat of substitutes moderate as onshore wind is still more expensive than conventional energy ■ Threat of substitutes for offshore wind high as costs much higher than onshore wind ■ Increasingly supportive government policies (feed-in tariffs) and improving cost structures allow for profitability, particularly for private developers and operators

Market Attractiveness Assessment Legend

Government Support	Addressable Market Size	Solution Attractiveness
● Highest priority	● Very large	● Advantaged
◕ High priority	◕ Large	◕ Attractive
◑ Medium priority	◑ Medium	◑ Emerging
◔ Low priority	◔ Limited	◔ Disadvantaged
○ No priority	○ Niche	○ Unavailable
Five-Year Market Growth Potential	**Market Accessibility**	**Profit Opportunity**
● Very rapid	● Fully open	● Superior
◕ Rapid	◕ Open with restrictions	◕ Above average
◑ Medium	◑ Partially limited	◑ Average
◔ Slow	◔ Limited	◔ Limited
○ Very slow	○ Restricted	○ Challenging

Source: China Greentech Initiative analysis

Wind power

China's wind power sector benefits from strong government support and a large addressable market size, which will continue to help grow wind power capacity in the coming years. Market accessibility is improving, although companies still face many challenges and profit opportunities for equipment manufacturers and five-year market growth potential remain limited.

By 2010 over 80% of wind power technology was sourced from private domestic producers.

Government support for wind power is rated as *highest priority,* due primarily to nationwide FiTs introduced in 2009 and high installation targets for 2015 and 2020. The government is also prioritizing offshore wind for development, with the release of offshore wind regulations in early 2010.

The addressable market size is rated *very large*, as China has some of the most plentiful wind power resources of any country. China has between 1,000 and 2,380 GW of exploitable wind resources, primarily in the North and West, as well as off the southeastern coast.[35]

Wind power solution attractiveness is seen as *emerging*, as wind is still roughly double the cost of conventional energy generation per kilowatt hour and subsidies are still needed to ensure profitability of wind farms. Solution attractiveness is expected to increase in the coming years with decreases in technology and power generation cost structures.

Five-year market growth potential is *slow*, primarily because China's wind power market began growing at a rapid rate in the mid-2000s, continuing through to 2010. Annual added wind power capacity is not expected to surpass 2010 additions of 18.9 GW. The current target of 70 GW of new wind power capacity set in the 12th Five-Year Plan will see a total installed capacity of 110 GW by 2015, although this may be surpassed as solution attractiveness increases.

Wind power market accessibility has improved in recent years, though by 2010 over 90% of wind farms were developed by SOEs and over 80% of wind power technology was sourced from private domestic producers. This is due primarily to the lower costs of domestic companies and a perceived preference for domestic products in certain provinces. Offshore wind farm projects to date have also been developed exclusively by majority-owned domestic companies using Chinese technology. The market therefore is seen as *open with restrictions.*

Wind power profitability in China in the coming three years is seen as *average*. Developers and operators have benefited from decreasing capital costs and increasing energy conversion efficiencies but are hurt by higher indirect capital costs and interest rates. The profitability of wind farms is also affected by site construction conditions, transmission line costs and strength of available wind resources. Meanwhile, high competition intensity and few opportunities for differentiation limit profit opportunities for wind power equipment manufacturers. While the operating margins of listed manufacturers have been among the highest in the world, significant price pressure exists in China in a consolidating industry with many new entrants. Many foreign manufacturers, who have localized by building factories in China, have become the biggest exporters of turbines produced in China.

35. Wu Qi, "Chinese wind chief argues for offshore 'postponement'," Windpower Monthly, Jul. 8, 2010, www.windpowermonthly.com

Renewable Energy Market Attractiveness Assessement—Solar Power		
Assessment Criteria	**Attractiveness**	**Explanation**
Government Support	◕	■ Solar power target of 5 GW (likely to be revised to 10 GW) of new capacity in 12th Five-Year Plan, for a total installed capacity of more than 5.8 GW by 2015 ■ Provincial feed-in tariffs in Jiangsu, Zhejiang and Shandong ■ Policies exist to support grid connection
Addressable Market Size	●	■ China has limited installed solar electricity generation capacity but rich resources and application potential (large area of rooftops, buildings, deserts) offer extensive opportunities
Solution Attractiveness	◔	■ Cost of energy production more than two times higher than coal-fired power per kilowatt hour (depending on location of solar power project) ■ Costs declining rapidly (latest projects awarded tariffs of less than RMB 1/kWh)
Five-Year Market Growth Potential	●	■ Capacity will grow very rapidly from 800 MW of installed capacity in 2010 to meet the 2015 target between 2011 and 2015
Market Accessibility	◑	■ Large-scale solar power project developers and operators are primarily SOEs ■ Manufacturers are mostly private domestic companies ■ No restrictions apply to foreign companies, but they have little market penetration to date due to higher equipment and operation costs and perceived preference of domestic companies
Profit Opportunity	◔	■ Buyer power of SOE project developers limits profits for manufacturers ■ High competition intensity of domestic manufacturers drives price down ■ Differentiation limited for utility-scale projects, moderate for small-scale private projects ■ Threat of substitutes high as solar electricity generation costs are higher than most other energies (including biomass and wind power) ■ Increasingly supportive government policies and improving cost structures will allow for profitability in longer term

Market Attractiveness Assessment Legend

Government Support	Addressable Market Size	Solution Attractiveness
● Highest priority	● Very large	● Advantaged
◕ High priority	◕ Large	◕ Attractive
◑ Medium priority	◑ Medium	◑ Emerging
◔ Low priority	◔ Limited	◔ Disadvantaged
○ No priority	○ Niche	○ Unavailable
Five-Year Market Growth Potential	**Market Accessibility**	**Profit Opportunity**
● Very rapid	● Fully open	● Superior
◕ Rapid	◕ Open with restrictions	◕ Above average
◑ Medium	◑ Partially limited	◑ Average
◔ Slow	◔ Limited	◔ Limited
○ Very slow	○ Restricted	○ Challenging

Source: China Greentech Initiative analysis

Solar power

China's solar power sector may experience rapid growth in the coming years as it benefits from increasing government support and a large addressable market size. Market accessibility is still challenging, while solution attractiveness and profit opportunities are limited due to the high cost of solar power.

Government support for solar power is rated as *high priority*, as a result of the 12th Five-Year Plan target of 5 GW (possibly to be revised to 10 GW) of added capacity between 2011 and 2015. China currently has less than 1 GW of solar power capacity, so this represents a dramatic increase in government support. Much of this new capacity will be installed in 13 Renewable Energy Development Zones, which the government announced in December 2010. Government support permeates down to local levels as well: Jiangsu, Zhejiang and Shandong provincial governments have all implemented favorable FiTs for rooftop solar installations.

Addressable market size is seen as *very large*, due to the large-scale applicability of solar power solutions. China has abundant solar resources, particularly in the North and West (although grid connection issues do exist in these areas) and expansive building and rooftop space for solar applications.

Solar power is still a very niche market in China. It is more expensive per kilowatt hour than conventional energy solutions, resulting in a solution attractiveness rating of *disadvantaged*. Costs have come down dramatically in recent years, due to steadily increasing production volumes, energy conversion efficiencies and raw materials supply. Solar power solution attractiveness ratings will only improve in the coming years.

Over the next 15 years, China may add more total electricity generation capacity than the entire 2010 capacity of the U.S.

Five-year market growth potential for solar power in China is rated as *very rapid*. By 2015, the government targets 5 GW of new solar power generation capacity. Officials have suggested that this target will be upwardly revised by 100% to 10 GW. Although overall capacity continues to be on a small scale compared to wind and hydropower, targeted growth rates reveal China's intention to develop its domestic solar market.

Although no rules explicitly restrict access to China's solar market, it receives a *partially limited* rating due to the prominence of SOEs in solar power project development and operation. As in the early days of the onshore wind industry, the economics for initial investors in solar power projects are unfavorable; as a result, it is difficult for private companies to compete with SOEs. Large-scale projects were initially made available to manufacturers and their partners to assure demand for domestic equipment during a drop-off in European solar subsidies; however, most large-scale projects have been developed by SOEs, with opportunities for private domestic and foreign firms limited instead to small-scale projects. Preference for strong domestic incumbents, such as Suntech, Yingli and Trina Solar is also apparent. These companies have favorable cost structures and can produce some of the world's cheapest solar cells and panels, making it difficult for market entrants to compete.

Profit opportunity for China's solar subsector in the coming three years is rated as *limited*. Strong buyer power of the SOEs (the primary technology buyers) and intense competition among solar producers drive prices down, although they are still significantly higher than conventional power generation costs. Differentiation opportunities for large-scale projects are also limited, given preference for low-cost, domestically-produced crystalline silicon solar panels. However, improving policy and technology cost structure trends indicate that profit opportunities will rise in the medium- to long-term.

The path ahead

China has turned to renewable energy out of a desire to improve environmental conditions, strengthen energy security and gain global market share. China may add more total electricity generation capacity over the next 15 years than the entire 2010 capacity of the U.S.[36] While the government knows that it cannot rely solely on conventional energy sources, growth of this magnitude would also be difficult to satisfy with renewable energy alone. New technologies and increased political willpower will pave the way for all types of renewable energy solution adoption in China, though this will not guarantee market opportunities for all stakeholders. Companies should be aware of the many challenges. As the first concession rounds for utility-scale solar and offshore wind show, SOEs and domestic incumbents will continue to dominate renewable energy project development.[37] Companies with strong local connections, such as joint venture partnerships with Chinese companies, and low-priced products and services, will be the most competitive in the years ahead.

36. China Greentech Initiative analysis; Partner and Strategic Advisor discussion during China Greentech Initiative Renewable Energy Working Session, Dec. 2010

37. Howell, Thomas, China's Promotion of the Renewable Electric Power Equipment Industry (Washington, D.C.: Dewey & LeBoeuf LLP, 2010)

China's Domestic Solar Market Emerges

Opportunity Assessment

China plans to boost its solar capacity 20-fold by 2020 to 20 GW, including more development in western China with technologies beyond the crystalline silicon (c-Si PV) solutions China has favored thus far[38].

China is already the world leader in solar panel manufacturing and is poised to enter a new phase: developing domestic solar power generation capacity. In early concession rounds, western regions have been favored for large-scale projects using primarily domestically-produced crystalline silicon PV panels. Thus far, China's state-owned power generation companies are the most active project developers, while private companies have focused on smaller installations in eastern provinces and high-tech development zones. As technology and power generation costs decline, it is likely that China will install a mix of solar technologies to achieve its solar power generation target of 20 GW or more by 2020, including thin film PV and CSP.

Two-thirds of China's land area receives more than 1,750 kilowatts per square meter of solar radiation annually.

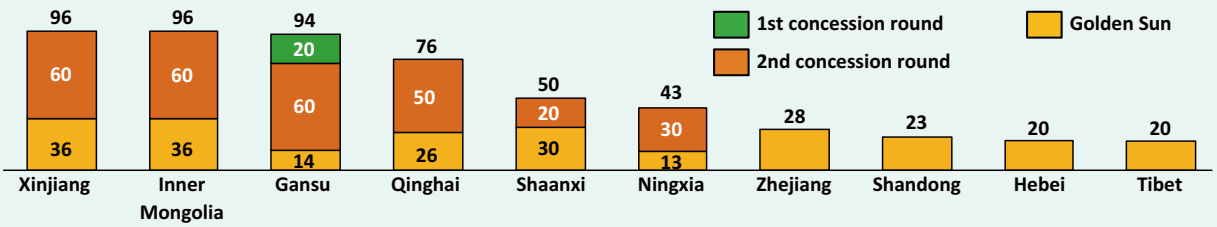
China's solar power installation market begins cautiously

Just 10 years ago, China's solar market consisted of a few small manufacturers supplying panels to remote villages too far from the grid to access electricity. At that time, only 20 MW of solar power was installed across China.[39] From these humble beginnings China's solar PV producers grew to become the world's largest. For example, Trina Solar, now the third biggest solar panel manufacturer in the world by volume, opened its factory doors in 1997 to sell solar panels to many of these village-scale projects, and now produces more than 1 GW of solar panels per year.[40]

Since solar currently costs more than wind power per kilowatt hour, China's government has been reluctant to subsidize solar power generation on a large scale.[41] Nevertheless, Chinese manufacturers managed to grow in size to supply foreign markets, where their products were very price competitive. Catalyzed by the financial crisis and recent reductions in European subsidies that resulted in an oversupply of panels in the market in 2009, China's central government has finally moved to create a domestic market.

China's domestic solar power installations began to grow in earnest in 2010, following the second solar concession round that saw 13 utility-scale projects totaling 280 MW put up for bid. This effectively doubled China's installed solar power capacity to roughly 800 MW.[42] The bidding results hint at how the market may develop in the coming years—the projects are all in remote western provinces, which feature wide open spaces and abundant solar resources. Two-thirds of China's land area receives more than 1,750 kilowatts per square meter per year of solar radiation.[43] Provinces such as Qinghai and Gansu, currently among China's less-developed areas, will be home to some of China's most advanced solar power stations. Farmers and nomads, will now live next to huge fields of solar panels sending electricity to China's power-hungry cities in the East.

National Utility-Scale Solar Power Projects by Selected Chinese Provinces, MW, 2010



Source: Li, Keith, China Environmental: Staking a Claim in China's Green Rush, CIMB, Sector Initiation (Hong Kong: CIMB, 2010)

38. Note: Along with the 2015 target, the 2020 target may be raised in the near future.
39. Liang, Chih-heng, "Overview of China's solar PV policies," DigiTimes Research, Nov. 10, 2010, www.digitimes.com
40. Osborne, Mark, "Trina Solar module shipments top 1.06 GW in 2010: capacity to reach 1.9 GW mid-year," *PV Tech, Feb. 23, 2011, www.pv-tech.org*
41. Rotman, David, "Praying for an Energy Miracle," Technology Review, March/April 2011, www.technologyreview.com
42. China Greentech Initiative analysis
43. Li Junfeng, Review on China's Solar PV Market (Beijing, China: Chinese Environment Press, 1999)

Meanwhile in eastern China, the Solar Roofs Program and provincial-level FiTs in Jiangsu and Shandong are helping put solar power on the roofs and walls of buildings. The Solar Roofs Program reduces critical component costs by up to 50% (from roughly RMB 34.3 per Watt to RMB 17 per Watt or US$ 5.28 per Watt to US$ 2.62 per Watt) and can reduce the payback period by half. The installation of solar applications will be a priority at the newly created Renewable Energy Development Zones, and in a nod to local industry, the government located the zones near China's solar PV production bases, such as Baoding, home of Yingli, and Xinyu, home of LDK Solar.[44] These zones and China's many other low-carbon demonstration areas and eco-cities present the most promising opportunities for new market entrants and private project developers.

Following the wind sector's example, early projects help determine an appropriate solar power tariff that is attractive to developers and affordable for the government. Tariffs awarded so far do not allow for a favorable return on investment. However, if a FiT is established in the future, it will likely be higher; as panel prices continue to decline, project economics will become more attractive.[45] China wants to avoid overcapacity and prospecting in the market, as seen in Europe after FiTs were established, and proceeds cautiously with solar subsidies. Advisors to national power regulators have suggested the government will study price dynamics in other markets for at least a year before it introduces FiTs.[46]

Low-cost, proven solar PV technology preferred

China has long favored traditional crystalline silicon (c-Si) PV panels, while thin film PV, the main alternative to c-Si, has struggled to gain a foothold amongst producers. Chinese manufacturers continue to focus on crystalline silicon (over 90% of production is c-Si) because of its relative technological simplicity, proven track record and accessible local supply chain. Developers and investors like its high energy conversion efficiencies, low cost and bankability (credibility, quality and cost advantages).[47]

China's crystalline silicon solar producers grew rapidly in 2010, hoping to capture market share in European and U.S. markets and added 6.4 GW of cell and panel manufacturing capacity. Of the 10 companies that experienced the largest worldwide production capacity growth, seven were Chinese. One such company, LDK Solar, added 1.4 GW of solar cell and panel production capacity.[48] Founded in 2005, the company initially focused solely on crystalline wafers, but vertically integrated from polysilicon production to panel supply in order to keep pace with other Chinese competitors. By 2010 volume, LDK Solar became one of the top ten panel suppliers in the world.[49] Keeping it company in the top ten were four other Chinese companies, only one of which was in the top ten six years ago.[50]

Given China's strong domestic c-Si manufacturing base and preference for low-cost technology, the China Greentech Initiative does not anticipate drastic changes in the technologies used in solar installations in the near future. Worldwide and in China, thin film lost popularity in 2010 as c-Si PV has become more competitive. This may change in the medium to long term, however, as thin film technologies and CSP solutions become more efficient and less expensive. CSP could be particularly relevant for utility-scale applications in China, as it has higher energy conversion efficiencies than c-Si (up to 30% compared to around 16%) and greater cost-reduction potential.[51]

44. 中华人民共和国财政部, "财政部等四部门联合部署推进国内光伏发电规模化应用工作," [Ministry of Finance, "Ministry of Finance and four other ministries gather to promote large-scale, domestic deployment of solar PV"] Dec. 2, 2010

45. "China Profits from Solar Policy as Europe Backpedals," Bloomberg, Feb. 14, 2011, www.bloomberg.com

46. Ibid.

47. China Greentech Initiative analysis: Partner and Strategic Advisor discussion during China Greentech Initiative Renewable Energy Working Session, Dec. 2010

48. "Chinese PV companies dominate solar manufacturing spending in 2010," SolarServer, Nov. 24, 2010, www.solarserver.com

49. "Company Profile," LDK Solar, www.ldksolar.com, accessed on Mar. 10, 2011

50. Prometheus Institute, Who Manufactured Photovoltaic Modules Globally in 2004? (Cambridge, MA: Prometheus Institute, 2005)

51. OECD/IEA, Technology Roadmap: Concentrating Solar Power (Paris, France: International Energy Agency, 2010)

Top 10 Solar Panel Producers Globally, 2010

Company	Country of Origin	Production Capacity in MW, 2010
1. Suntech Power	China	1,800
2. First Solar	U.S.	1,400
3. Yingli Green Energy	China	1,061
4. Trina Solar	China	1,060
5. Canadian Solar	Canada	803
6. Hanwha SolarOne	China	798
7. Q-Cells	Germany	474
8. REC	Norway	412
9. LDK Solar	China	361
10. SHARP Solar	Japan	210

Source: China Greentech Initiative analysis

A major factor in the rising competitiveness of crystalline silicon PV is the declining price of polysilicon, the main raw material used in solar cells. China used to depend on importing expensive polysilicon, which limited producers' ability to cut costs. However, China doubled polysilicon production capacity from 2009 levels to approximately 40,000 tons in 2010, supplying 50% of its total demand.[52] Production expansion in China and elsewhere resulted in a dramatic drop in the silicon price from US$ 350 per kilogram in October 2008 to US$ 60 per kilogram in mid-2010. Solar producers have also become vertically integrated, often acquiring polysilicon production capabilities, which coupled with decreased raw material price volatility enables Chinese producers to cut their already low production costs even further. Some of the cheapest Chinese-made panel currently sell for US$ 1.85 per Wp, far lower than the worldwide average of US$ 3.29 per Wp.[53]

Public sector plays leading role

Promoting solar power costs governments hundreds of millions of dollars in financial support globally. But China's government sees investment opportunities in the sector, for just as in the wind power sector, China's SOEs dominate solar power project development. In the second solar concession round, held in the summer of 2010, SOEs won all 13 of the projects by underbidding private developers. The tariffs awarded to these projects ranged from RMB 0.7 to 1.09 per kilowatt hour (US$ 0.11-0.17 per kilowatt hour), too low to guarantee a 10% return on investment. But SOEs, with their large balance sheets and ability to forgo short-term profits for long-term gains, are uniquely suited to these early projects.[54]

The Chinese government also extends support to its domestic solar producers through financial incentives and low-interest loans. The most notable assistance in 2010 came in the form of large credit lines from China Development Bank to the country's top solar panel producers. Suntech, Yingli, Trina Solar, JA Solar and LDK Solar received a combined total of RMB 203 billion (US$ 31.2 billion) in loans for increasing production capacity and expanding overseas operations. This could double global solar cell production capacity and allow these companies to gain even larger shares in important markets.[55] Take California for example: the 2007 to 2016 California Solar Initiative provides US$ 2.17 billion in rebates for rooftop solar panels totaling nearly 2 GW.[56] Thus far, Chinese producers have supplied 39% of the projects. Yingli, which

52. "Entry standards for polysilicon plants rise," People's Daily, Feb. 16, 2011, www.english.people.com.cn
*53. "*Module Pricing" *Solarbuzz, www.solarbuzz.com, accessed on Mar. 1, 2011*
54. China Greentech Initiative analysis: Partner and Strategic Advisor discussion during China Greentech Initiative Renewable Energy Working Session, Sept. 2010
55. Woody, Todd, "From California, Chinese Solar Maker Looks East," New York Times, Mar. 3, 2010, http://green.blogs.nytimes.com
56. "California Solar Initiative," Go Solar California, www.gosolarcalifornia.ca.gov, accessed on Feb. 28, 2011

only entered the California market in 2009, has so far provided 17.5% of the panels, more than any other company in the program.[57] SunPower, the largest non-Chinese supplier, only supplies 6.3% of the California Solar Initiative. Chinese solar companies will only become more competitive in markets across the world as their production capacities grow and costs fall.

China's Wind Market Heads to Sea

Opportunity Assessment

As a new government priority, China's offshore wind market is poised for takeoff; however, since offshore wind is more expensive to develop than China's still abundant onshore resources, the market represents a paradox for investors.

In 2010 China built the world's first offshore wind farm outside of Europe.

China's offshore wind market began in 2009 with the construction of the 102 MW Shanghai Donghai Bridge Offshore Wind Farm, but government targets envision swift growth to 30 GW installed capacity by 2020. China is also the first country to focus on intertidal wind (wind farms built on mud flats between tide levels).[58] Offshore wind capital costs in China are expected to be roughly double onshore costs, yet the first concession round held in 2010 for four projects totaling 1 GW showed low bid prices—insufficient, it appears, for profitable ownership. Despite this, these projects may be subsequently awarded higher tariffs by the government to ensure profitable operation, just as with the early onshore wind farms.[59] Given the numerous policy and technical uncertainties, risk-averse developers are not well-suited for the China market; only aggressive positioning and significant risk-taking is likely to allow success for developers. For international service and equipment suppliers, the market may be favorable, but due to pricing constraints there appear to be few opportunities for foreign turbine manufacturers.

The dawn of China's offshore wind market

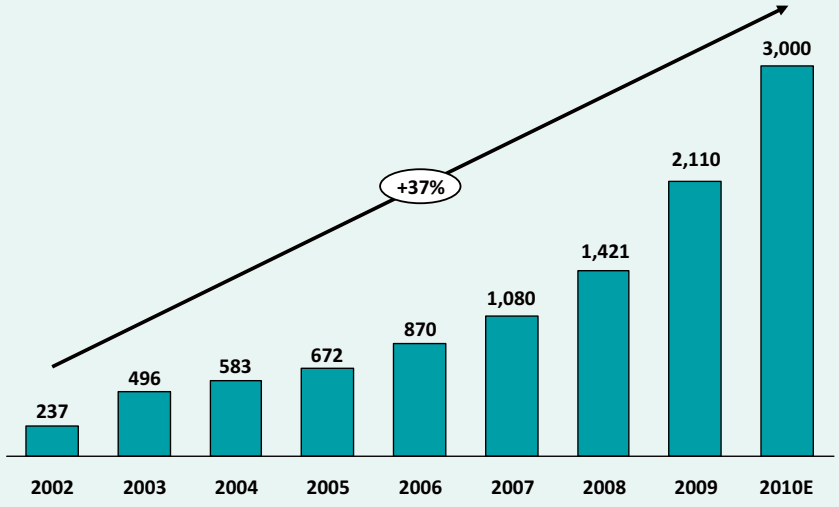
Offshore wind, a much more technically challenging and expensive form of wind power than onshore, was until recently limited to northern Europe. By 2010, roughly 3 GW of offshore capacity had been installed worldwide, with the U.K., Denmark and the Netherlands together accounting for 88% of capacity.[60] China emerged onto the scene in July 2010 by completing the world's first offshore wind farm outside of Europe. The unveiling of this 102 MW project was timed to coincide with the World Expo in Shanghai. In keeping with China's ambition to show its technical expertise, the project was developed entirely by Chinese companies, none of which had previous offshore wind experience. Sinovel, at the time China's largest wind turbine manufacturer, supplied 34 3-MW wind turbines; the newly formed Shanghai Donghai Wind Power Generation Company developed the project.[61]

The passing of the Interim Measures on Management of the Development and Construction of Offshore Wind Power on January 22, 2010 was the first specific regulatory guidance for offshore wind development and was jointly developed by the National Energy Administration and the State Oceanic Administration. The measures specified that the concession scheme would be used for offshore wind projects and that developers must be at least 50% Chinese-owned.[62] The central government also instructed coastal provinces to prepare offshore wind development plans that would enable China to meet its stated 30 GW offshore wind target by 2020.

57. Woody, Todd, "California's solar power increasingly Chinese made," Grist, Jan. 18, 2011, www.grist.org
58. World Bank, China: Meeting the Challenges of Offshore and Large-Scale Wind Power: Strategic Guidance (Washington, D.C.: Asia Sustainable and Alternative Energy Program, World Bank, 2010, 16)
59. China Greentech Initiative interviews
60. Fichaux, Nicolas, et al., Oceans of Opportunity: Harnessing Europe's Largest Domestic Energy Resource (Brussels, Belgium: European Wind Energy Association, 2009); World Bank, China: Meeting the Challenges of Offshore and Large-Scale Wind Power: Strategic Guidance (Washington, D.C.: Asia Sustainable and Alternative Energy Program, World Bank, 2010)
61. "Global Offshore Wind Farms Database," 4C Offshore, www.4coffshore.com, accessed on Nov. 6, 2010
62. 国能新能[2010]29号,国家能源局和国家海洋局, "海上风电开发建设管理暂行办法,"[NEA, SOA, "Interim Measure for the Management of the Development and Construction of Offshore Wind Power"] Jan. 22, 2010

In the short term, much of China's offshore wind development will happen in the intertidal zone before developers venture out to deeper waters. China has elected to pioneer intertidal wind because of the strong wind resources provided by its vast, mid-coast mudflats, as well as its clear cost advantages. In the construction of intertidal wind farms, the turbine foundations sit above the water line at low tide, and their structure more closely resembles onshore wind turbines than offshore. Proximity to shore and existing transmission lines negate the need to lay expensive undersea electricity cables. Intertidal wind farms also do not require specialized cranes and vessels for installation and can be accessed directly from shore. The challenge for China is to develop the industry itself and to address soft soil conditions and potential land-use conflicts with local residents.[63]

Global Cumulative Installed Offshore Wind Capacity, MW, 2002-2010



Source: World Bank, China: Meeting the Challenges of Offshore and Large-Scale Wind Power: Strategic Guidance (Washington, D.C.: Asia Sustainable and Alternative Energy Program, World Bank, 2010)

China's first offshore wind concession round was held in October 2010 in Jiangsu Province, one of China's wealthiest areas. Four projects were put up for bid with a combined capacity of 1 GW. Partnerships between state-owned power generators and large Chinese wind turbine producers won all four of the bids. Because the government required that all bids come from majority-owned Chinese companies, few foreign firms participated in the concession round, unwilling to risk losing money on early-stage projects. Domestic manufacturers, on the other hand, were willing to sell turbines at or below cost to gain valuable experience and better position themselves in the international offshore turbine market. Prior to the bidding round, Goldwind, Sinovel and Sewind all opened wind turbine manufacturing plants in Jiangsu; each producer subsequently won the bid for the project closest to their plant.[64]

High costs, low tariffs

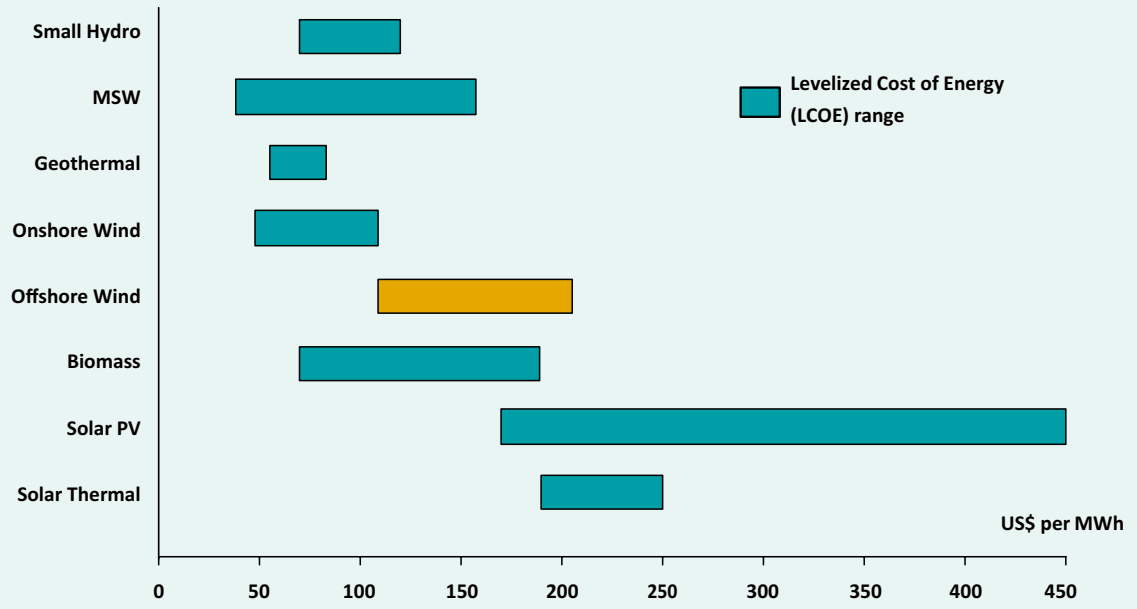
Although project costs are higher, northern European countries have turned to offshore development for its superior wind resources and for the lack of onshore projects to develop. Offshore wind can be more than twice as high as onshore wind with higher operating and maintenance costs as well as hostile environmental conditions. Larger turbines, complex foundations, expensive substations, undersea cables and the need for specialized cranes and vessels during installation account for higher capital costs. Energy production costs are also higher: US$ 109 to 205 per megawatt hour for offshore

63. China Greentech Initiative interviews
64. China Greentech Initiative analysis

versus US$ 48 to 109 per megawatt hour for onshore.[65] Developers can justify these costs because offshore wind typically has higher capacity factors.[66] In the U.K., onshore capacity factors average 28.2% while offshore capacity factors can be as high as 40%.[67]

European offshore wind tariffs reflect offshore wind's higher costs: in the U.K. the FiT is RMB 1.4 per kilowatt hour (US$ 0.22 per kilowatt hour). By contrast, China's first concession round awarded tariffs ranging from RMB 0.62 to 0.73 per kilowatt hour (US$ 0.09 to 0.11 per kilowatt hour), or less than 50% of the U.K. price.[68] With rates that were only RMB 0.1 to 0.2 per kilowatt hour (US$0.02-0.03 per kilowatt hour) higher than offshore tarrifs, only SOEs could compete.

Comparison of Levelized Cost of Energy for Various Renewable Energies, US$ per MWh, 2010

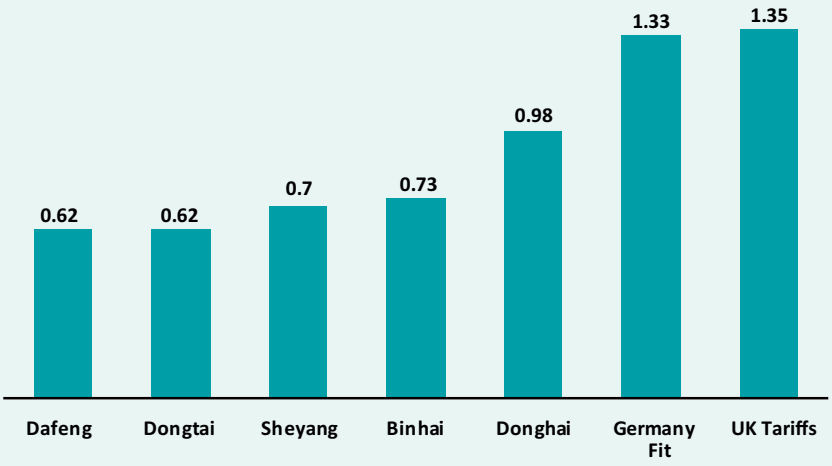


Source: World Economic Forum, Green Investing 2010: Policy Mechanisms to Bridge the Financing Gap (Geneva, Switzerland: World Economic Forum, 2010); China Greentech Initiative analysis

Factoring in additional environmental and technical challenges, these tariffs look even lower. Environmental conditions can wreak havoc on wind turbines. The salt water environment and exposure to more extreme weather strain the moving parts, requiring more frequent maintenance and replacement. Additionally, in southern China where offshore wind resources are strongest, the threat typhoons pose to turbines cannot be ignored.[69]

65. World Economic Forum, Green Investing 2010: Policy Mechanisms to Bridge the Financing Gap (Geneva, Switzerland: World Economic Forum, 2010)
66. Note: The U.K. Energy Research Center defines capacity factor as: the maximum ratio of generated power to rated power, representing the maximum number of load hours per year independent of actual utilization.
67. "BWEA Briefing on UK Wind Capacity Factors," RenewableUK, www.bwea.com, accessed on Feb. 28, 2011; The Offshore Valuation Group, The Offshore Valuation: A Valuation of the UK's offshore renewable energy resource (Wales, U.K.: The Offshore Valuation Group and the Public Interest Research Centre, 2010)
68. Pu Jun, "High Bids Garnered for Offshore Wind Power Projects," Caixin Online, Oct. 12, 2010, www.english.caing.com
69. Alberts, Larry and Ting Yin, East Wind: Prospects for Equipment Manufacturers in China's Burgeoning Wind-Power Sector (Hong Kong: Boston Consulting Group, 2010)

Offshore Wind Power Tariffs in China and Europe, RMB per kWh, 2010



Source: Pu Jun, "High Bids Garnered for Offshore Wind Power Projects," Caixin Online, Oct. 12, 2010, www.english.caing.com

Caution advised for market entry

Regardless of the location, offshore wind remains a daunting investment for developers, in large part because turbines have yet to prove they have been designed to reliably withstand harsh marine environments.[70] They tend to fail at higher rates offshore due to the extreme technical and environmental challenges.[71] Furthermore, financing offshore wind farms can be much more difficult than onshore due to their larger size and higher technical construction and operating complexity.[72]

As China seeks to develop its domestic offshore wind capabilities, space for foreign participants appears limited. Even if the majority-owned requirement is eliminated, foreign manufacturers are not likely to achieve large market share due to the high price sensitivity of developers. Some also suggest that China's offshore wind resources are weaker than estimated. If this is true, lower than anticipated capacity factors offshore may result in a limited lifespan for the industry.

China's Distributed Renewable Energy (DRE) Leadership and Potential

Opportunity Assessment

China is a leading player in distributed renewable energy with significant capacity in small hydropower, household biogas digesters and rooftop solar water heating. However, barring grid improvements, more advanced and cost-effective energy storage and subsidies, additional DRE technologies such as small wind and rooftop solar PV will not reach their full potential.

China's push for rural electrification in previous decades promoted DRE technologies for the first time. More recently, China has established policies and regulations to promote the subsector further, despite the high capital cost of newer DRE technologies. Government subsidies can offset costs up to 50% in some areas and development has been mostly government funded and driven, although private financing models have been used successfully in wealthier urban areas for distributed rooftop solar.

70. Jackson, Matthew, "How can the offshore wind industry overcome O&M obstacles?" Renewable Energy Focus, Jan. 1, 2009, www.renewableenergyfocus.com
71. China Greentech Initiative analysis; Partner and Strategic Advisor discussion during China Greentech Initiative Renewable Energy Working Session, Dec. 2010
72. Bakhareva, Alina, "Integration of the Banking Sector into the Offshore Wind industry," Frost & Sullivan, Sep. 1, 2010, www.frost.com

Distributed Renewable Energy Definition

The China Greentech Initiative defines distributed renewable energy (DRE) as renewable energy that is generated on-site or near the energy consumer, and is usually small-scale. Solutions can be deployed in urban or rural environments and can be grid-connected or off-grid. The scope of our research covered small hydropower,[1] small wind, solar PV (including building-integrated photovoltaics), solar water heaters, small-scale biomass power, biogas and micro-combined heat and power (CHP).

1. Note: China defines small hydropower as 50 MW capacity and below, which is higher than the generally accepted definition of 10 MW capacity and below

Long DRE track record

China's renewable energy history began just after the founding of the People's Republic. Beginning in 1950, small hydropower stations (under 6 MW in capacity) were built in rural regions and grew in number to supply 50% of rural electricity by 2002.[73] The rural population in 2002 was 60% of China's population, meaning small hydropower supplied a staggering 385 million people with electricity.[74] Between 1980 and 2000, the earliest solar, wind and bioenergy applications were introduced particularly in China's most remote reaches. Many nomads and herders were given solar PV panels and micro-wind turbines, gaining access to electricity for the first time.

Though talk about China's renewable energy leadership has centered on large-scale projects in recent years, China also leads the world in many DRE applications. Their low cost (equivalent or lower than coal-fired electricity per kilowatt hour produced) and suitability to rural areas without grid access have made them popular with local governments and planners. More expensive DRE technologies, such as small wind and rooftop solar PV, will not reach their full potential without technology improvements, stronger government subsidies or significant reductions in costs that would make them competitive with conventional power sources.

Looking ahead, small hydropower and solar water heaters show the most potential for continued growth. China is planning to double its solar water heating capacity by 2020, from 145 million square meters today to an impressive 300 million square meters. If achieved, solar water heaters would cover an area equivalent to more than five Manhattans put together. Building-integrated photovoltaic (BIPV) applications are also expected to rapidly expand in the long-term. With 40 billion square meters of floor space predicted to be built in China in the next 20 years, the expansion of low-cost BIPV applications represents real opportunities.[75]

The Brightness Program: Helping Electrify Rural Areas with Renewable Energy

China's Brightness Program brought electricity to rural residents using renewable energy across 50% of the country. The program, which concluded in 2010, was the world's largest DRE project for rural areas: in the space of 10 years, 1.3 million people gained access to electricity through 200 MW of micro-hydropower, 20 MW of solar PV and 840 kW of small wind.[1] Domestically-produced equipment supplied the majority of these systems, which helped to create and grow China's domestic solar PV industry. Trina Solar supplied 39 solar generating systems to Tibetan villages in 2003, becoming the first private company to participate in the program.[2]

Today, only 8 million people in China remain without access to electricity. This is less than 1% of the total population, compared to more than 50% in 1950. The International Energy Agency estimates that by 2015, China will have reached full electrification.[3] In this 60-year span, at least 500 million people (many of whom live in extremely remote areas) gained access to electricity.

1. National Renewable Energy Laboratory, Renewable Energy in China, Township Electrification Program, Factsheet (Golden, Colorado: National Renewable Energy Laboratory, 2004)
2. "Milestones," Trina Solar, www.trinasolar.com, accessed on Mar. 1, 2011
3. International Energy Agency, 2010 World Energy Outlook (Paris, France: International Energy Agency: 2010)

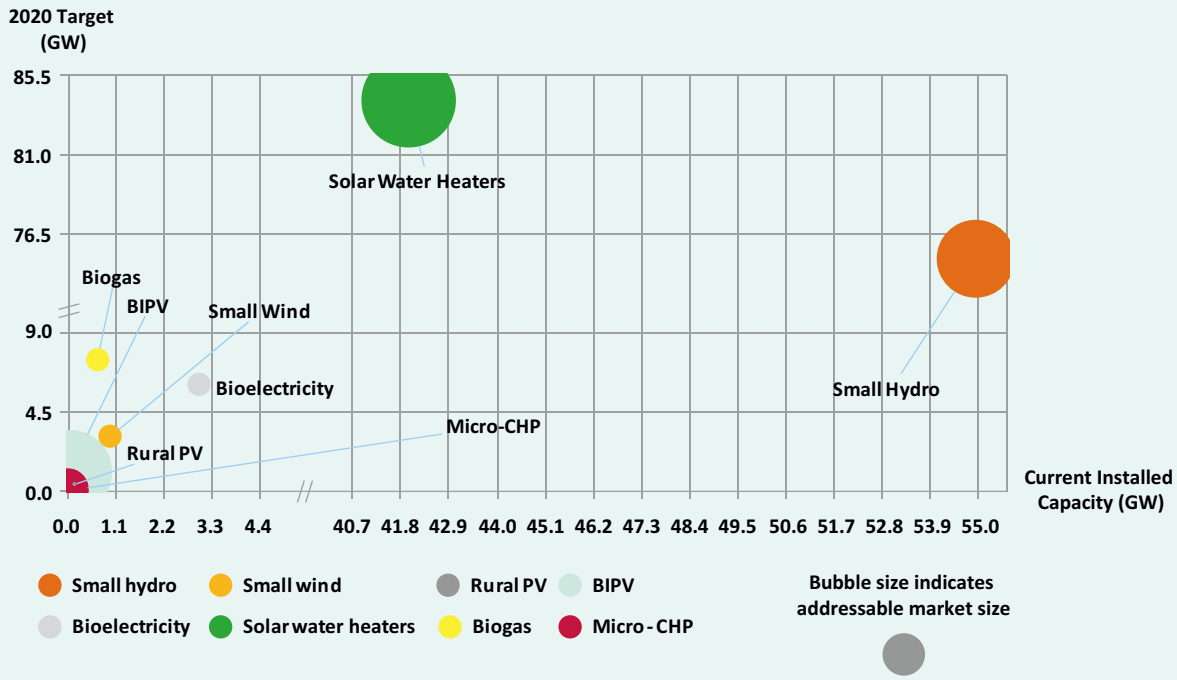
73. Pan, Jiahua, et al., Rural Electrification in China 1950-2004: Historical Processes and Key Driving Forces, Working Paper #60 (Palo Alto, California: Stanford University, 2006)
74. "China's Population, 1969-2006," Chinability, www.chinability.com, accessed on Mar. 5, 2011
75. McKinsey Global Institute, Preparing for China's Urban Billion (Shanghai, China: McKinsey Global Institute, 2008)

Without stronger subsidies, DRE adoption will remain limited

Not all types of DRE solutions are price competitive with conventional energy. Solar PV electricity currently is unaffordable without subsidies, costing RMB 1.5 to 3 per kilowatt hour (US$ 0.23 to 0.46 per kilowatt hour). The government recently introduced subsidies for distributed and centralized solar PV projects, on the other hand. One clear victory in China's rooftop solar PV sector was the completion of the solar station on the roof of Shanghai's newest railway station. At 6.7 MW in capacity, it is the largest solar rooftop station in the world, covering an area of 61,000 square meters.[76]

Other high-cost DRE solutions, such as small wind power, micro-CHP and small-scale biomass energy, will struggle to grow without further government financial support (unless they are able make costs competitive with conventional energy). Low-interest loans, tax incentives and subsidized tariffs are available in some cases, but these measures are insufficient to provide positive investment economics.

Addressable Market Size for Distributed Renewable Energy Solutions Given 2020 Targets, Current Installed Capacity and Resource Potential

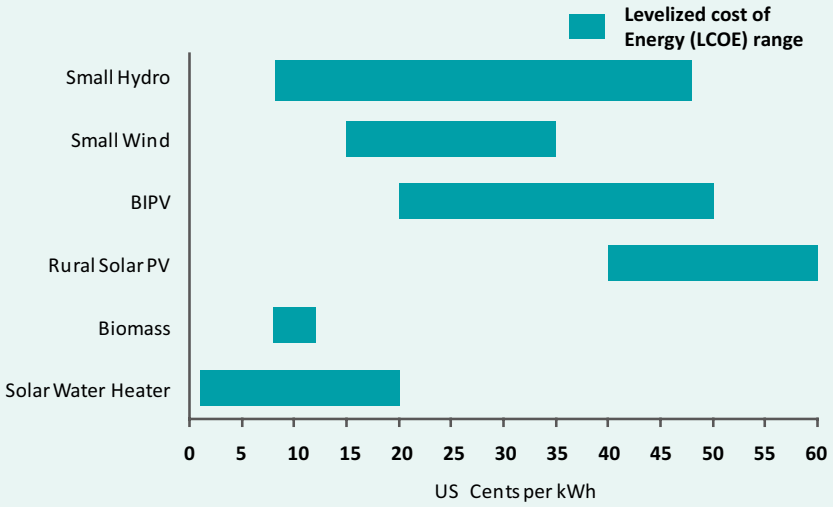


Note: 1. Potential for micro-CHP is based on commercial/institutional applications in five provinces identified by The Potential for Clean DE and CHP in China by the World Alliance for Decentralized Energy, 2010 (actual potential for China is higher);
2. Bioelectricity potential based on an available resource base of 300 millioin tons of agricultural residues per year;
3. Biogas potential is based on an available resource base of 60 billion cubic meters of animal waste per year for village or household-scale biogas

Source: China Greentech Initiative analysis

76. Qian, Yanfeng, "Huge solar station starts operation," China Daily, Jul. 19, 2010, www.chinadaily.com.cn

Levelized Cost of Energy for Distributed Renewable Energy Production
US cents per kWh, 2010



Source: "Distributed Power Generation," Solarbuzz, accessed on Nov. 10, 2010, www.solarbuzz.com

If all DRE solutions surveyed were developed fully, China could add at least 270 GW of electricity generation.

Large potential remains

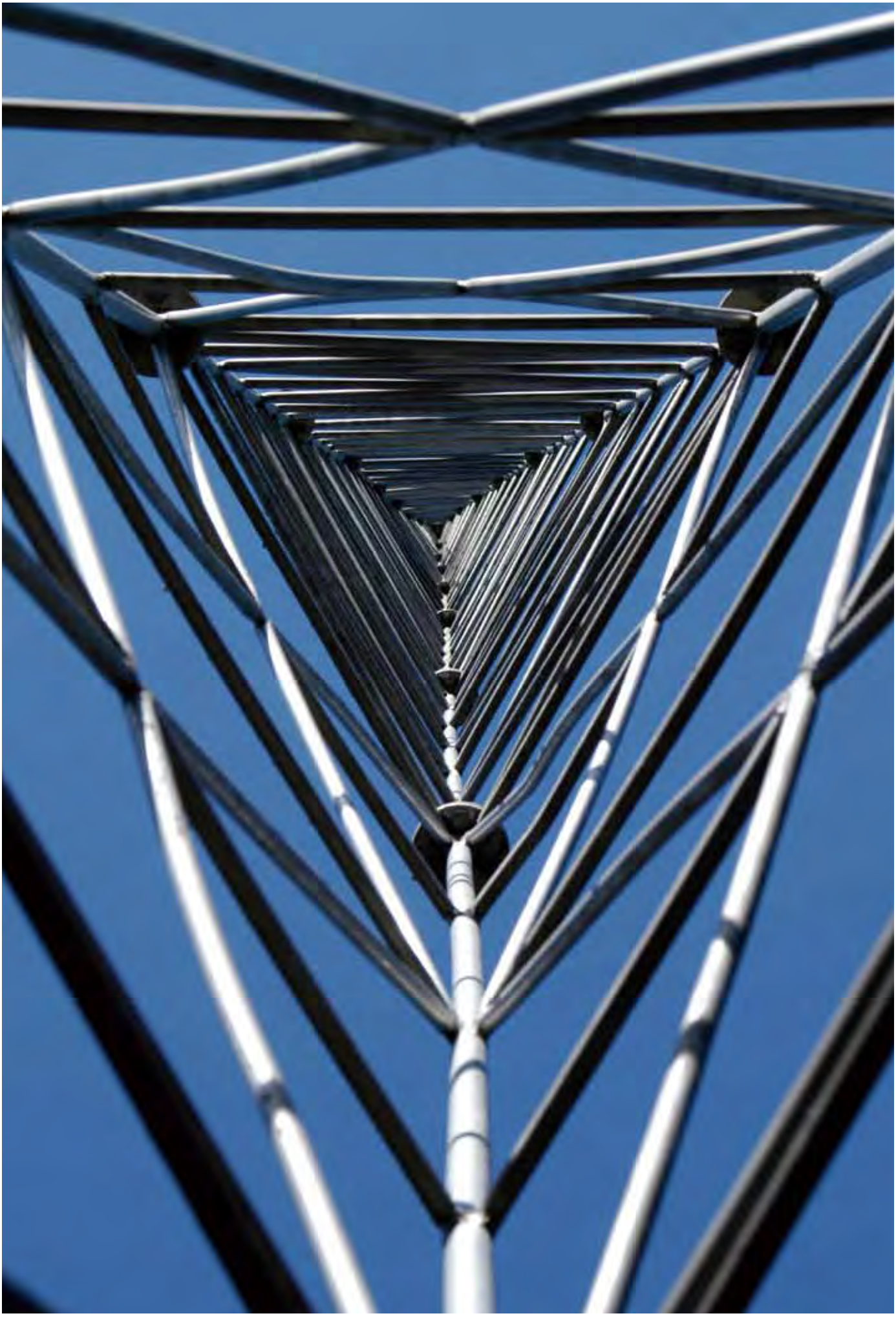
A truly distributed energy system, using conventional and renewable energy sources and allowing households to sell electricity back to the grid, remains elusive in China. Many DRE technologies are still too expensive, and the existing infrastructure was not developed to support DRE. Intelligent grid networks (including micro-grids), smart meters, energy storage and standards for all of these components must be improved before DRE can be applied on a large scale. China is not unique in facing these challenges as grid utilities across the world often resist DRE applications, hoping to avoid the resulting loss of revenues from more efficient energy use.

While the infrastructure and the subsidies are not yet in place, the technologies are; therefore, the gap between installed capacity of DRE solutions and addressable market size is large. If all DRE solutions surveyed were developed fully, China could add at least 270 GW of electricity generation.[77] Rural biogas production currently utilizes seven billion cubic meters, less than 20% of available waste resources. Rural villages and households across China produce 60 billion cubic meters of human and animal waste each year that could be turned into biogas for cooking and heating.[78] While less than 100 MW of BIPV exists worldwide today, it has great potential; if applied to only 20% of China's existing rooftop space, BIPV applications could produce 100 GW of electricity.[79]

Renewable Energy Opportunities for 2011

This chapter provides an update of China's Renewable Energy sector and three Opportunity Assessments prioritized by the China Greentech Initiative's partners and advisors in 2010. As the sector evolves, participants in the China Greentech Initiative Partner Program will continue to collaborate on additional opportunity areas. The first topic in 2011 covers China's solar PV supply chain, with emphasis on opportunities for upstream and downstream integration, cost reduction and deeper foreign project participation. Other topics may include waste-to-energy, onshore wind farm project development and onshore wind farm operational efficiency. The China Greentech Initiative will also continue to track the evolution of China's Renewable Energy sector.

77. Note: Potential for micro-CHP is based on commercial/institutional applications in 5 provinces identified by The Potential for Clean DE and CHP in China by the World Alliance for Decentralized Energy, 2010 (actual potential for China much higher)
78. Zhang, Qingfeng, et al., Rural Biomass Energy 2020: Cleaner Energy, Better Environment, Higher Rural Income, People's Republic of China (Beijing, China: Asian Development Bank, 2010)
79. Kan, Sichao, Chinese Photovoltaic Market and Industry Outlook (Part 1) (Beijing, China: IEEE, 2010)



Electric Power Infrastructure

State Grid's ambitious plan to invest RMB 3.45 trillion (US$ 530 billion) to build a smart grid by 2020 ensures that China will be one of the world's largest smart grid markets in the years to come; however, the industry's monopolistic structure poses challenges for market entrants.

China's overstretched electricity grid faces a daunting challenge: efficiently powering the nation's staggering economic growth as the energy mix diversifies. Ambitious renewable energy and energy efficiency targets, as well as growth projections for electricity demand, require a more powerful and advanced grid than exists today. State Grid, the world's largest utility and provider of 80% of China's electricity, released its Smart Grid Plan in 2009. China Southern Grid, responsible for the remaining 20% of electricity in six provinces, will take direction from State Grid's plan. Laying out a roadmap from now until 2020, the plan will make China one of the world's largest smart grid markets. Smart grid solution providers, however, must prepare for difficult market conditions, where low-cost solutions and strong relationships with local grid companies define success.

This chapter begins by providing an overview of Electric Power Infrastructure sector developments since the publication of *The China Greentech Report 2009*. It then summarizes the three Opportunity Assessments the China Greentech Initiative developed with its partners and advisors throughout 2010.

- State Grid's Smart Grid Plan
- Connecting Intermittent Power to the Grid
- Technology Preferences in the Smart Meter Market

The China Greentech Initiative's partners and advisors prioritized each of these Opportunity Assessments as critical to the growth of China's Electric Power Infrastructure 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 the organizations participating in the China Greentech Initiative Partner Program. The chapter concludes with an outlook on additional opportunities and issues in the Electric Power Infrastructure sector that the China Greentech Initiative plans to explore in 2011.

The writing of this chapter was led by Claire N. Nelson (聂凯怡), based upon strategic research deliverables completed by Rachel Xiao (肖凝) of the China Greentech Initiative's Electric Power Infrastructure sector research team.

Electric Power Infrastructure Sector Definition

The China Greentech Initiative defines Electric Power Infrastructure as "smart" electric grids and networks which deliver power to users on demand in an efficient and reliable way, 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

State Grid's investment plan provides 11-year smart grid roadmap

Behind China's glittering cities and expansive factory floors is an overstretched grid network straining to keep it all in motion. In recent decades, China's electricity demand has grown rapidly. Between 2000 and 2009, China's electricity demand soared 110% to 3.4 trillion kilowatt hours, more than the demand in non-OECD Central America, South America, the Middle East and Africa combined.[1] Generation capacity grew from 318 GW in 2000 to nearly 1,000 GW by the end of 2010, with coal supplying 70% of capacity. The grid network has struggled to keep pace with such astonishing growth. Between 2002 and 2006, rapid economic growth fueled by heavy industry and urbanization caused severe electricity shortages in eastern China.[2] Many provinces suffered industrial power blackouts that imposed heavy economic losses. Some estimate that the power shortages between 2000 and 2005 resulted in economic losses of over RMB 1 trillion, or the equivalent of 10% of China's GDP in 2001.[3] This has prompted heroic efforts by the government in recent years to boost power supply and transmission capabilities.

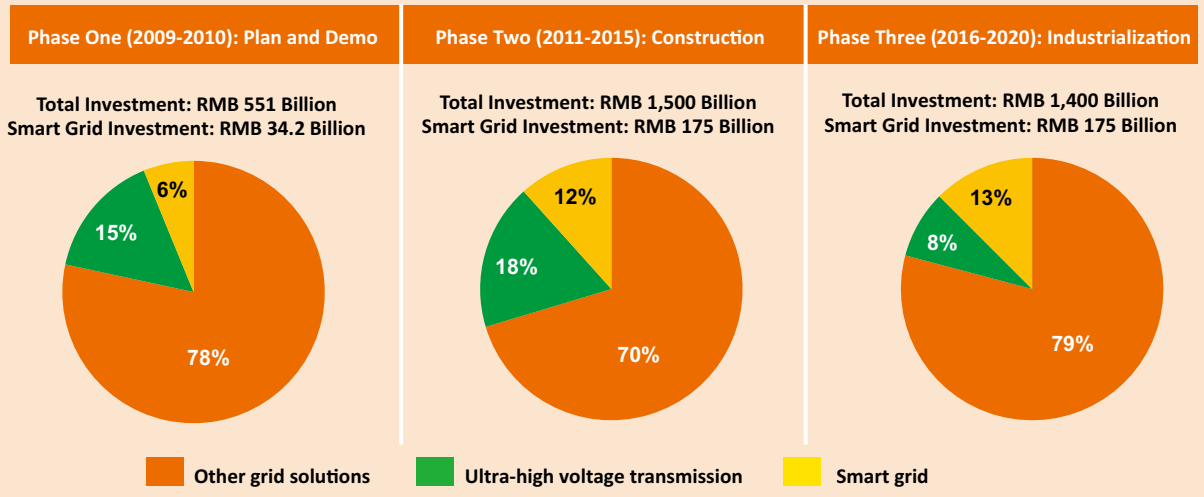
By some estimates, power shortages between 2000 and 2005 resulted in economic losses of over RMB 1 trillion, or the equivalent of 10% of China's GDP in 2001.

Aside from rapid growth, geography further complicates China's electricity network picture. Between 800 to 3,000 kilometers separate China's energy resources in the North and West of the country from its electricity demand centers in the South and East.[4] More than 80% of coal and hydro resources, and nearly 100% of onshore wind resources, are located in remote regions. China's grid networks cannot transmit that magnitude of electricity. In the case of coal, China relies heavily on road and rail transportation to ship coal where it is needed. For hydro and wind power, electric transmission is the only option.[5] Transporting coal by road was blamed for causing two record-breaking traffic jams in the summer of 2010: one stretched 100 kilometers, while the other lasted a full month. In both events, overloaded trucks carrying coal on the same highway from Inner Mongolia to the port city of Qinhuangdao in Hebei caused gridlock and outrage.[6]

China's economic growth is expected to continue to grow rapidly. Even though the carbon intensity of GDP may fall 40 to 45% by 2020, energy use and carbon emissions will continue to rise, with the International Energy Agency predicting China's electricity demand will triple by 2035.[7] Although China may not again experience electricity blackouts like those of the early 2000s, expanding energy infrastructure remains a monumental task. Also of concern to grid networks are China's plans to transform the way it produces and consumes electricity: by 2020 renewable energy is targeted to account for 15% of energy production, combined heat and power systems may supply 400 GW of electricity, and up to 5 million electric vehicles may ply the roads.

1. Energy Information Agency, Country Analysis Briefs, China (Washington, D.C.: Department of Energy, 2010, 16)
2. Feng Yikun, "Power Shortages Worse Next Year," China.org.cn, Dec. 9, 2003, www.china.org.cn
3. Bo, Kong, An Anatomy of China's Energy Insecurity and its Strategies (Richland, WA: Pacific Northwest Center for Global Security, 2005, 4)
4. Lu, Adrian, A Primer on the (Strong) Smart Grid and its Potential for Reducing GHG Emissions in China and the United States (Beijing, China: Natural Resources Defense Council, 2010)
5. Ibid.
6. Hook, Leslie, "Chinese drivers blame economy for gridlock," Financial Times, Aug. 26, 2010, www.ft.com
7. International Energy Agency, 2010 World Energy Outlook (Paris, France: International Energy Agency, 2010, 50)

State Grid's Smart Grid Plan in China, billions RMB, 2009-2020



Sources: State Grid, State Grid Plan Final Report (Beijing, China: State Grid Corporation of China, 2009); China Greentech Initiative analysis

These new technologies, particularly renewable energies, challenge the grid in multiple ways. Intermittence is one problem—wind and solar only produce power when the wind blows and the sun shines. Another issue is their location in western China far from cities. Intermittent renewable energy sources require bi-directional communication with the grid, as well as new and more advanced approaches to electricity transmission and consumption.[8]

In 2009, the State Grid Corporation released an 11-year, RMB 3.45 trillion (US$ 530 billion) investment plan for the completion of a strong and smart grid.[9] The plan focuses on improvements across the value chain, especially building the ultra-high voltage (UHV) backbone of the grid. Eleven percent of the investment, or RMB 387 billion (US$ 59.5 billion), is earmarked for smart grid solutions.[10] Premise, dispatch and substation solutions will be prioritized, receiving nearly 75% of the total smart grid investment.[11] The investments will be finalized in the 12th Five-Year Plan, then rolled out in three phases, with the majority of construction to be completed by 2015 (see State Grid's Smart Grid Plan Opportunity Assessment later in this chapter for details). China Southern Grid is also in the process of developing its own smart grid plan, likely modeled on State Grid's plan.[12]

The impact of planned grid investments is truly staggering. State Grid estimates that these investments could help abate 2020 carbon emissions by 1.65 billion metric tons per year by increasing electricity transmission efficiency, allowing for integration of low-carbon energy sources, enabling the use of electric vehicles, and other mechanisms.[13] This amount of carbon emissions roughly equals Russia's total carbon emissions in 2009. The plan also has the potential to create the world's largest smart grid market. As evidence of its commitment to these grid improvements, China spent more in 2010 on smart grid solutions than any other country: China's smart grid expenditure of RMB 47.5 billion (US$ 7.3 billion) just edged out the U.S.'s RMB 46.2 billion (US$ 7.1 billion), and dwarfed investments in any other market.[14] Japan was the third largest market with only RMB 5.5 billion (US$ 849 million) invested. Further,

8. McKinsey & Company, McKinsey on Smart Grid (McKinsey & Company, Number 1, Summer 2010)
9. 国家电网，"国家电网智能化规划总报告."[State Grid, "State Grid Smart Grid Plan Final Report"] Feb. 2010
10. Ibid.
11. China Greentech Initiative analysis
12. China Southern Power Grid, http://www.csg.cn, accessed on Sep. 5, 2010; China Southern Power Grid, 2009 CSR Report (Guangzhou, China: China Southern Power Grid, 2010,35)
13. Lu, Adrian, A Primer on the (Strong) Smart Grid and its Potential for Reducing GHG Emissions in China and the United States (Beijing, China: Natural Resources Defense Council, 2010); "World carbon dioxide emissions data by country: China speeds ahead of the rest," Guardian, www.guardian.co.uk, accessed on Mar. 5, 2011
14. "Top 10 Countries for Smart Grid Investment," Zpryme Research and Consulting, Nov. 9, 2010, www.gereports.com

some analysts predict China's smart grid markets will grow to RMB 130 billion (US$ 20 billion) per year by 2015, including construction of ultra-high voltage transmission lines. The size of the planned investment has prompted the interest of solution providers around the world.[15]

China's Grid: More Than Just a Smart Grid

The definition of smart grid varies widely. The European Technology Platform, a industry-led research forum, defines smart grid as "electricity networks that can intelligently integrate the behavior and actions of all users connected to it—generators, consumers and those that do both—in order to efficiently deliver sustainable, economic and secure electricity supplies."[1] China's definition is broader and includes technologies that many consider to fall under conventional grid infrastructure. For example, China labels ultra-high voltage (UHV) transmission lines as smart grid, and in the past year, State Grid has begun to refer to all of its grid improvements as "smart grid." While many may argue with the validity of this claim, the fact remains that even under a more limited definition of smart grid, by size, China is still the undisputed market leader.

1. "SmartGrid Definition," *European Technology Platform, www.smartgrids.eu, accessed on Mar. 4, 2011*

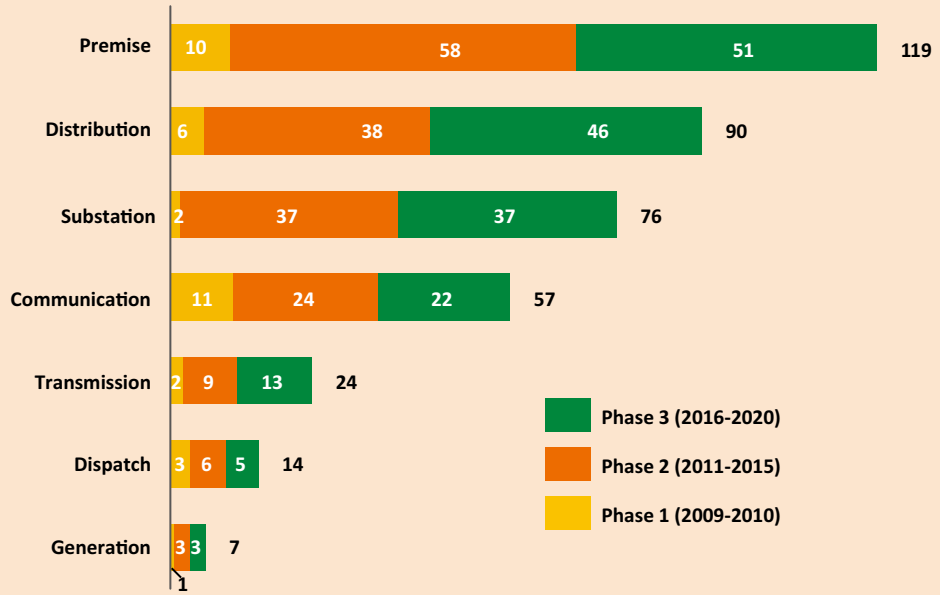
Solutions for building a "smart grid"

Whether or not they represent smart grid technologies, many solutions in State Grid's Smart Grid Plan will help reduce carbon emisions and increase the use of cleaner energy. China's plan devotes resources across four greentech solution areas for Electric Power Infrastructure—loss reduction, smart grid, energy storage and access solutions—to help connect new sources of energy to the grid. Solutions in the distribution and premise stage of the value chain receive the largest share of the planned investment, accounting for more than 50% of the RMB 387 billion total.[16] Other areas, including transmission and communications, will also receive substantial support.

Perhaps China's most ambitious grid project is a plan to build a UHV transmission network to link power generated in the North and West with demand in the East. UHV lines efficiently transmit power over long distances and alleviate curtailment, which occurs when power is wasted because it cannot be transmitted to where it is needed. In Inner Mongolia in 2009, for example, 12 GW of electricity generation capacity (much of which was wind powered) was curtailed.[17] UHV has many advantages versus conventional 500 kilovolt (kV) lines: 40% lower line losses, lower project costs and better reliability.[18] China currently has two UHV lines that can transmit power up to 2,500 kilometers. One is an 800 kV direct-current line extending from Sichuan to Shanghai; the other, the world's first 1,000 kV alternating current line, originates in Shanxi and ends in Hubei. By 2015, China plans to construct 40,000 kilometers of UHV lines with an investment of RMB 500 billion (US$ 77 billion). No other country has plans to develop UHV on this scale.[19] In contrast, China Southern Grid has expressed doubts about the technological benefits of UHV direct current (DC), and has no near-term development plans.[20]

15. McKinsey & Company, McKinsey on Smart Grid (McKinsey & Company, Number 1, Summer 2010, 19)
16. China Greentech Initiative analysis
17. Lu, Adrian, A Primer on the (Strong) Smart Grid and its Potential for Reducing GHG Emissions in China and the United States (Beijing, China: Natural Resources Defense Council, 2010)
18. 中国电力出版社, *"*智能电网知识读本*," [Smart Grid Knowledge],"*智能电网技术*,"[Smart Grid Technology] Apr. 2010*
19. Bai, Jim and Aizhu Chen, "China top grid firm says to further develop UHV tech," Reuters, Jan. 28, 2011, www.reuters.com
*20."*南方电网:特高压交流项目仍有待论证*"[CSG, "Skeptical about UHV DC"], BJX, Sept. 29, 2010, www.news.bjx.com*

State Grid's Investment Allocation in China's Smart Grid, billions RMB, 2009-2020 (RMB 387 billion in total)



Sources: State Grid, State Grid Plan Final Report (Beijing, China: State Grid Corporation of China, 2009); China Greentech Initiative analysis

Renewable energy challenges the grid not just because of its geographical location but also because of its intermittent nature. Wind and solar applications can only produce energy when weather patterns allow, requiring back-up solutions to ensure power supply when renewable energy is unavailable. UHV can help to some extent by allowing transmission of power from other locations. Other technologies also show promise, such as better resource prediction capabilities, adjustable power transmission, power regulation through energy storage and operating reserves, and active and reactive power control systems. These are described in more detail in the Connecting Intermittent Power to the Grid Opportunity Assessment later in this chapter.

In terms of end-user demand for electricity, State Grid has identified 61 solutions for development of its smart grid, including advanced metering systems (discussed in the Technology Preferences in China's Smart Meter Market Opportunity Assessment), smart dispatch supporting systems and storage systems. State Grid is planning to supply some of these solutions itself. The electric vehicle charging station example shows that China's grid companies can be competitive in demand-side applications as well as transmitting power.

China's monopolistic grid market challenges market entrants

China's state-dominated grid market can be an intimidating business arena for private companies, whether foreign or Chinese. Since the 2002 Power Reform Act created the monopolistic power grid structure, State Grid and China Southern Grid have controlled 100% of the market. As such, companies hoping to enter China's electric power sector only have two potential customers. Success depends on understanding these companies' incredibly complex organizational and bidding structures. Success also depends on close relationships with all levels of the organization (see the State Grid Smart Grid Plan Opportunity Assessment later in this chapter for more details on organizational structure).[21] Not surprisingly, domestic companies are better equipped in this respect and occupy dominant supplier positions in the market. For instance, the top ten companies supplying the grid with smart meters were large domestic incumbents.[22]

21. China Greentech Initiative analysis
22. 长城证券, "国家电网2010统一招标大盘点"[Greatwall Securities,"State Grid Central Bidding 2010"], Nov. 12, 2010

China's Grid Companies Winning Race for Electric Vehicle (EV) Charging Station Market

China has clear aspirations to be the world leader in new-energy vehicles. In the 12th Five-Year Plan, new-energy vehicles are listed as one of the seven Strategic Emerging Industries, and a pilot program in 25 cities promotes and subsidizes EV purchases. If China has 1 million EVs on the road by 2015, as targeted in the 12th Five-Year Plan, the country will need major new EV infrastructure.[1] EV charging stations provide battery swapping service and on-site charging services. They can also help the grid lessen peak loads by charging batteries at night when electricity demand and prices are lower.[2] China's grid companies hope to capture much of the emerging EV charging station market. State Grid built 75 charging stations in 27 cities across China in 2010, including the country's largest station to date in Linyi, Shandong Province.[3] China Southern Grid also built three charging stations in 2010 and leads in developing charging station standards.[4] It is by no means a given that China's grid companies will dominate the EV charging station market: China's oil giants Sinopec and CNOOC reportedly also plan to build their own charging stations.[5] However, since they have not yet begun building, they are likely to lose early-mover advantage to the grid companies.

1. McKinsey & Company, McKinsey on Smart Grid (McKinsey & Company, Number 1, Summer 2010, 19)
2. "SGCC Promote Battery Replacement," China Finance, Jan. 9, 2011, www.cfi.net.cn
3. "China constructs largest electrical vehicle charging station," People's Daily, Jun. 24, 2010, www.english.peopledaily.com.cn
4. "CSG Competes for EV Leadership," China News, Aug. 23, 2010, www.chinanews.com
5. "China constructs largest electrical vehicle charging station," People's Daily, Jun. 24, 2010, www.english.peopledaily.com.cn

According to companies with first-hand experience, State Grid places more importance on price than any other factor. In the State Grid project bidding process, companies report that price accounts for 60% of the decision, followed by technology and other criteria. However, price is not the only factor at work. Some suggest grid companies source 80% of their equipment from domestic suppliers to strengthen local capabilities.[23] State Grid appears to follow the Government Procurement Law, which states that government entities should give preferential treatment to domestic products in certain strategic industries, including clean energy.[24] China's Ministry of Commerce released a statement that state-owned enterprises (SOEs) do not qualify under the Government Procurement Law, provoking much debate in the last year. Nevertheless, grid companies' procurement policies remain opaque, and many industry participants sense that preference for domestic solutions persists.[25]

Preference for domestic products, whether real or imagined, does not exclude all foreign players from the grid market in China. China's ambitious smart grid plans will require new technology and solutions. Domestic companies lack experience and technology in some important value chain segments, creating openings for new private and foreign companies. Some foreign companies are seizing these opportunities and making China's grid sector more international than ever before.

A more international Chinese grid market

With China's announcements of large investment plans and increasing talk of smart grid, foreign governments and companies are eager to get involved. In March 2011, the U.S. Trade and Development Agency announced a US$ 660,000 (RMB 4 million) grant to State Grid's Electric Power Research Institute (EPRI) to pilot smart grid demand response management systems.[26] The U.S. China Energy Cooperation Program (ECP), established as part of bilateral clean energy agreements and initiatives announced during President Obama's 2009 visit to China, funds the grant. One of the purposes of the ECP is to create business opportunities for Chinese and U.S. companies promoting U.S. clean energy technology in China. Honeywell International

23. China Greentech Initiative analysis
24. McGregor, James, China's Drive for "Indigenous Innovation" A Web of Industrial Policies (Beijing, China: APCO Worldwide, 2010)
25. China Greentech Initiative analysis
26. Department of Energy, Report on U.S.-China Clean Energy Cooperation (Washington, D.C.: U.S. Department of Energy, 2011)

will supply automated demand response, advanced energy management and sub-metering systems to the smart grid project to help EPRI study how energy use can be managed and reduced in buildings through technology.[27]

China's grid companies have forged a variety of commercial partnerships with large foreign smart grid suppliers. GE currently works with State Grid and the Chinese Academy of Sciences on smart grid standards, announcing together in early 2011 that they will work with the city of Yangzhou to develop and roll-out end-to-end smart grid solutions. By 2012, the project plans to have GE smart grid solutions installed across Yangzhou, including advanced metering, distribution automation, and in-home monitoring displays.[28] IBM, through its newly opened Energy & Utilities Solutions Lab in Beijing, collaborates with State Grid's EPRI to develop and pilot an optimized distribution networking planning platform.[29] The company expects to generate more than US$ 400 million in smart grid revenues in China by 2014.[30] Siemens, Accenture, Intel, HP and ABB have also announced deals in China's grid market.

Chinese grid companies becoming more international

Just as foreign companies are eager to enter China's power grid markets, China's grid companies are expanding into foreign markets. State Grid took its first real step out of China by winning a US$ 3.95 billion deal in 2007 as part of a consortium to manage the electric power grid of the Philippines for a 20-year period.[31] State Grid now owns 40% of the Philippines National Grid Corporation (NGCP) and is considering smart grid options for the Philippines network.[32] More recently, the State Grid has turned to Brazil for new investment opportunities. In 2010, State Grid bought seven Brazilian electricity distribution companies for US$ 989 million and electricity transmission rights in southeast Brazil for 30 years (with 20-year extension possible). It will supply power to Brasilia, Sao Paulo and Rio de Janeiro, and expects to see annual profits of US$ 110 million.[33]

China Southern Grid is also looking past China's borders for investment opportunities into power generation and transmission. In 2010, China Southern Grid secured approval for a US$ 1.75 billion project to build and operate two 600 MW coal-fired power plants in southern Vietnam, representing China's largest investment in Vietnam to date.[34] This represents China Southern Grid's first power generation project since the Power Reform Act of 2002. The reforms prevent China's grid companies from managing power generation projects in China, but the Vietnam project shows their willingness to undertake generation projects abroad.[35]

China's Smart Grid market, one of the world's largest, remains challenging in the short term

China's smart grid market, one of the world's largest, remains challenging for most companies in the short term given limited market accessibility and intense competition.

China's smart grid market has become one of the world's largest, and will continue to grow rapidly in the coming years to meet China's 2020 low-carbon energy targets. State Grid's substantial investment of RMB 387 billion (US$ 59.5 billion) over the next 10 years attracts the most prominent international smart grid solution providers and small domestic entrants alike. The market's monopolistic structure, however, presents challenges for solution providers. Strong influence by China's two electricity

27. "Honeywell to Implement China's First Smart Grid Project for Managing Energy Use in Buildings," Press Release, Honeywell, www.honeywell.com, accessed on Mar. 5, 2011
28. Leeds, David, "GE Gets its Smart Grid Foot in a Very Large Door: China," Greentech Media, Jan. 11, 2011, www.greentechmedia.com
29. "IBM Unveils Energy & Utilities Solutions Lab in China," Press Release, IBM, www-03.ibm.com, accessed on Mar. 23, 2010
30. Moresco, Jim, "The Next Hot Smart Grid Market? China," *GigaOm, Jan. 11, 2010, www.gigaom.com*
31. Landingin, Roel and Richard McGregor, "China State Grid group wins Philippine auction," Financial Times, Dec. 12, 2007, www.ft.com
32. Velasco, Myrna, "China's State Grid Eyes Upgrading Options," Manila Bulletin, Sept. 19, 2010, www.mb.com
33. Duce, Jim, "China State Grid Completes Purchase of Brazil Electricity Assets," Bloomberg, Dec. 22, 2010, www.bloomberg.com
34. "China's Coal-Fired Power Plant in Vietnam Got Nod from Government," Caijing, Aug. 27, 2010, www.caijing.com.cn
35. "CSG invests in Vietnam," *SASAC, Aug. 27, 2010, www.chinaequip.gov.cn*

providers on smart grid technology adoption favors low-cost, domestic incumbents. Market entrants must navigate the complex organizational structures of the two grid companies and localize production processes to be competitive.

The China Greentech Initiative developed a Market Attractiveness Assessment (MAA) to evaluate the smart grid solution market on six criteria: government support, addressable market size, solution attractiveness, five-year market growth potential, market accessibility, and profit opportunity. Information on the Market Attractiveness Assessment methodology can be found in the Research Methodology Chapter.

Electric Power Infrastructure Market Attractiveness Assessment—Smart Grid

Assessment Criteria	Attractiveness	Explanation
Government Support	●	■ Smart grid solutions prioritized in State Grid's investment plan ■ Increased electricity tariffs support grid connection to renewable energy ■ RMB 387 billion (US$ 59.5 billion) allocated for smart grid solutions between 2009 and 2020 by State Grid
Addressable Market Size	◕	■ Large annual addressable market size for smart grid solutions as China upgrades already extensive grid networks ■ All electricity meters in China (500 million) will be replaced by 2015 by automatic meter reader AMR technology
Solution Attractiveness	◑	■ Solution attractiveness varies across the value chain, with most solutions still more expensive than conventional alternatives ■ Grid standards are in development and will make smart grid solutions more attractive
Five-Year Market Growth Potential	●	■ State Grid targets large investment into smart grid solution adoption between 2009 and 2020, which will result in very rapid growth across all portions of the value chain ■ otal investment in smart grid solutions by 2015 will be RMB 209 billion
Market Accessibility	◑	■ Strong state influence over the sector with SOEs State Grid and Southern Grid as only electricity providers ■ Sector technically open to foreign participation, but grid companies seem to favor domestic suppliers based on low price and track record
Profit Opportunity	◔	■ State Grid and Southern Grid are the only buyers and make procurement decisions based on price and track record ■ Competition intensity is high, but top suppliers to the value chain are often concentrated ■ Differentiation opportunities low for all smart grid solutions given price sensitivity of buyers ■ Threat of substitutes low, particularly for top suppliers ■ Increasingly supportive government targets and State Grid's Smart Grid Plan will grow the market, but domestic incumbents with low-cost solutions will be primary beneficiaries

Market Attractiveness Assessment Legend

Government Support	Addressable Market Size	Solution Attractiveness
● Highest priority	● Very large	● Advantaged
◕ High priority	◕ Large	◕ Attractive
◑ Medium priority	◑ Medium	◑ Emerging
◔ Low priority	◔ Limited	◔ Disadvantaged
○ No priority	○ Niche	○ Unavailable
Five-Year Market Growth Potential	**Market Accessibility**	**Profit Opportunity**
● Very rapid	● Fully open	● Superior
◕ Rapid	◕ Open with restrictions	◕ Above average
◑ Medium	◑ Partially limited	◑ Average
◔ Slow	◔ Limited	◔ Limited
○ Very slow	○ Restricted	○ Challenging

Source: China Greentech Initiative analysis

Smart grid solutions

China's smart grid market receives highest priority from the government and has rapid five-year maket growth potential and a large addressable market size. Solution attractiveness is emerging and market accessibility is partially limited. Profit opportunities are also limited given the nature of China's monopolistic grid markets.

Government support for smart grid solutions is rated as *highest priority*, due to State Grid's impressive 11-year Smart Grid Plan. Smart grid solutions are also included in China's new energy development plan, which will pump RMB 5 trillion into cleaner energy development and necessary grid upgrades by 2020.

The addressable market for smart grid solutions in China is considered *large*. China's extensive grid networks, which are growing rapidly to meet new electricity demands, present opportunities for adoption of smart grid solutions all along the Electric Power Infrastructure value chain.

Smart grid solution attractiveness is rated as *emerging* as many solutions still carry a cost premium over conventional solutions. For example, foreign-produced advanced metering infrastructure (AMI) solutions cost more than RMB 650 per unit, while domestically-produced and simpler automatic meter readers (AMRs) cost as little as RMB 180. China will install AMR in the coming years before it switches to more expensive AMI, by which time the price will have fallen. EPRI is also developing 79 new smart grid standards, which will make smart grid solutions increasingly attractive.

China's new energy development plan will pump RMB 5 trillion into cleaner energy development and necessary grid upgrades by 2020.

Five-year market growth potential for smart grid solutions is *very rapid*, given development in the subsector that will result from State Grid's Smart Grid Plan. RMB 209 billion will be invested in smart grid solutions between 2009 and 2015.

Market accessibility is *partially limited* due primarily to the strong state influence on the sector. These companies show a preference for large domestic incumbent suppliers in their procurement process, making it difficult for new domestic and foreign companies to gain market share. There are no legal restrictions on foreign participation, however, and firms with strong relationships to the grid companies can secure partnerships.

Smart grid profitability in China in the coming three years is *limited.* The two major buyers, State Grid and China Southern Grid, exercise strong buyer power over smart grid solution adoption in China and choose technologies based on price, track record, and quality. The grid companies' extreme price sensitivity limits opportunities for product differentiation, particularly for more expensive, and usually foreign, firms. Competition intensity along the smart grid value chain is also high, limiting profits for market entrants and concentrating profits among large, established incumbents. Opportunities for smart grid solutions will increase in the longer term, however, as government investment grows and smart grid technology cost structures improve.

The path ahead

China's grid markets, backed by substantial government support and investment, will experience rapid growth in the coming years. Growth will create market opportunities for solution providers throughout the Electric Power Infrastructure value chain, particularly for transmission and dispatch, storage, and demand side management solutions. In order to tap opportunities, companies must understand and be prepared to navigate China's monopolistic grid market and its two major providers: State Grid and China Southern Grid. Both companies, with their complex organizational structures, typically favor local, low-cost incumbents; however, recent agreements between new market entrants and China's grid companies show that the market is open to innovative and flexible companies.

State Grid's Smart Grid Plan

Opportunity Assessment

Distribution and consumption are the best opportunities for private solution providers in the State Grid 11-year Smart Grid Plan, due to openness and budget.

State Grid's Smart Grid Plan covers every region and every technology. Distribution will account for RMB 119 billion (US$ 18 billion) and consumption for RMB 89 billion (US$ 14 billion), together over half the smart grid investment total, with these sectors relatively open to private involvement. Recent centralization of the sector transferred most procurement decisions to the central level, leaving only distribution and consumption decisions under the purview of provincial power bureaus. Private firms seeking to promote their smart grid products and services must engage deeply with central and local levels of the grid companies.

State Grid's comprehensive investment plan offers opportunities

State Grid announced its much-anticipated Smart Grid Plan on May 21, 2009. The plan, which covers three phases between 2009 and 2020, is expected to contribute 1% to China's annual GDP growth through 2015.[36]

The first phase (2009-2010) was devoted to planning and demonstration projects. To date, two rounds of demonstration projects have been launched, testing 25 smart grid technologies. Priority technologies included energy storage, renewable energy integration, and electric vehicle charging stations.[37]

The second phase (2011-2015) will focus on construction of UHV transmission lines and dispatch infrastructure, as well as development of operating controls and interactive service systems. By 2015, State Grid hopes to have completed wide-scale adoption of smart grid technologies.

The third and last phase (2016-2020) will see the completion of China's smart grid, including the adoption of technology and equipment standards developed by State Grid. The majority of the investment will be allocated in the second and third phases of the plans (RMB 1,400-1,500 billion in each phase) for projects in the populous north, east and central regions of China.[38]

China currently lacks smart grid standards; therefore, development of technology and management standards is a first phase priority. State Grid hopes that its standards will be adopted on a national level, which will give it a leg up in the international market for smart grid technology.[39] The company has identified 93 necessary smart grid standards: only 14 of these standards already exist, while 17 will be completed by early 2011, and 62 are under development or are yet to come.[40] State Grid's Electric Power Research Institute (EPRI) is responsible for developing standards, sometimes with the assistance of international companies. GE, IBM, the Chinese Academy of Science and State Grid recently signed a memorandum of understanding to jointly develop smart grid standards for China.[41]

State Grid's Smart Grid Plan is expected to contribute 1% to China's annual GDP growth through 2015.

The name of State Grid's Smart Grid Plan creates misleading assumptions as to the proportion of investment that will go to smart grid technologies and services. Only 11% of the RMB 3.45 trillion will go towards smart grid solutions, or RMB 387 billion, although some experts told the China Greentech Initiative that this amount could be much higher in the coming years.[42] In contrast, a slightly larger amount, RMB 500 billion, will be used to construct a vast UHV transmission network.[43] Although many countries do not consider UHV transmission lines to be part of a smart grid,

36. Liu, Yiyu, "Smart grid project generates local buzz," China Daily, Jun. 6, 2010, www.chinadaily.com.cn
*37. 陈静思, "第二批16项目试点 智能电网技术标准或5月公布"[Chen, Jingsi, "*Second Batch of Demonstration Projects in 16 Areas"*] Sohu, Apr. 23, 2010, www.business.sohu.com*
38. 国家电网, "国家电网智能化规划总报告,"[State Grid, "State Grid Smart Grid Plan Final Report"] Feb. 2010
39. Liu, Yiyu, "State Grid, GE to create smart grid standards," China Daily, Jan. 11, 2011, www.chinadaily.com.cn
40. 国家电网, "国家电网智能化规划总报告,"[State Grid, "State Grid Smart Grid Plan Final Report"] Feb. 2010
41. "Smart Grid Standards Link with International Levels," Xinhua, Aug. 16, 2010, www.xinhua.net;
42. 国家电网, "国家电网智能化规划总报告,"[State Grid, "State Grid Smart Grid Plan Final Report"] Feb. 2010
43. Liu, Yiyu, "State Grid, GE to create smart grid standards," China Daily, Jan. 11, 2011, www.chinadaily.com.cn

China sees them as a major contributor to regional integration of grids and use of renewable energy.[44] Nevertheless, the plan targets 141 smart grid solutions, most of which are in premise, distribution and substation areas, accounting for more than 80% of the total investment.

State Grid ranked eighth on the Global Fortune 500 list in 2010.

The China Greentech Initiative analyzed each portion of the value chain to determine solution attractiveness based on three criteria: market projection (total planned investment by 2020), market openness (degree of openness to private domestic and foreign players), and market attractiveness (economic attractiveness of smart grid solutions compared to conventional solutions). The findings indicate that distribution and consumption solutions are the most attractive for companies. These areas will receive RMB 118.5 billion and RMB 89.2 billion in investment respectively, and are handled at the provincial and local levels, which are more accessible for market entrants. While not yet the industry standard, smart grid distribution and consumption solutions show promise of overtaking conventional solutions in the near future.[45]

Southern Grid has yet to publish a smart grid plan, but pilot projects underway suggest that a plan will be published which closely resembles State Grid's plan. Pilot projects include solar power stations, electric vehicle charging stations, and UHV transmission lines. The plan will likely emphasize connecting and transmitting energy resources in the West, particularly hydropower, to eastern load centers. Grid improvements at Southern Grid are on-going as well, with 11.5 GW of UHV lines added by 2010 and RMB 91.5 billion (US$ 14.1 billion) invested in grid construction in 2009.[46]

The imperative of understanding grid companies

China's State Grid, wholly owned by the central government State-owned Assets Supervision and Administration Commission (SASAC), is truly a force with which to be reckoned. As one of the world's largest companies, the State Grid ranked eighth on the Global Fortune 500 list in 2010 (moving up from 15th place in 2009).[47] It owns 80% of China's electric grid assets, provides electricity to over one billion customers and employs almost 900,000 people.[48] With RMB 1.2 trillion (US$ 184 billion) in revenues in 2010, State Grid dwarfs other major utilities. Electricité de France (EDF), with US$ 91 billion in revenues and Duke Energy, with US$ 14 billion in revenues, while among the world's largest energy utilities, do not come close to matching State Grid.[49]

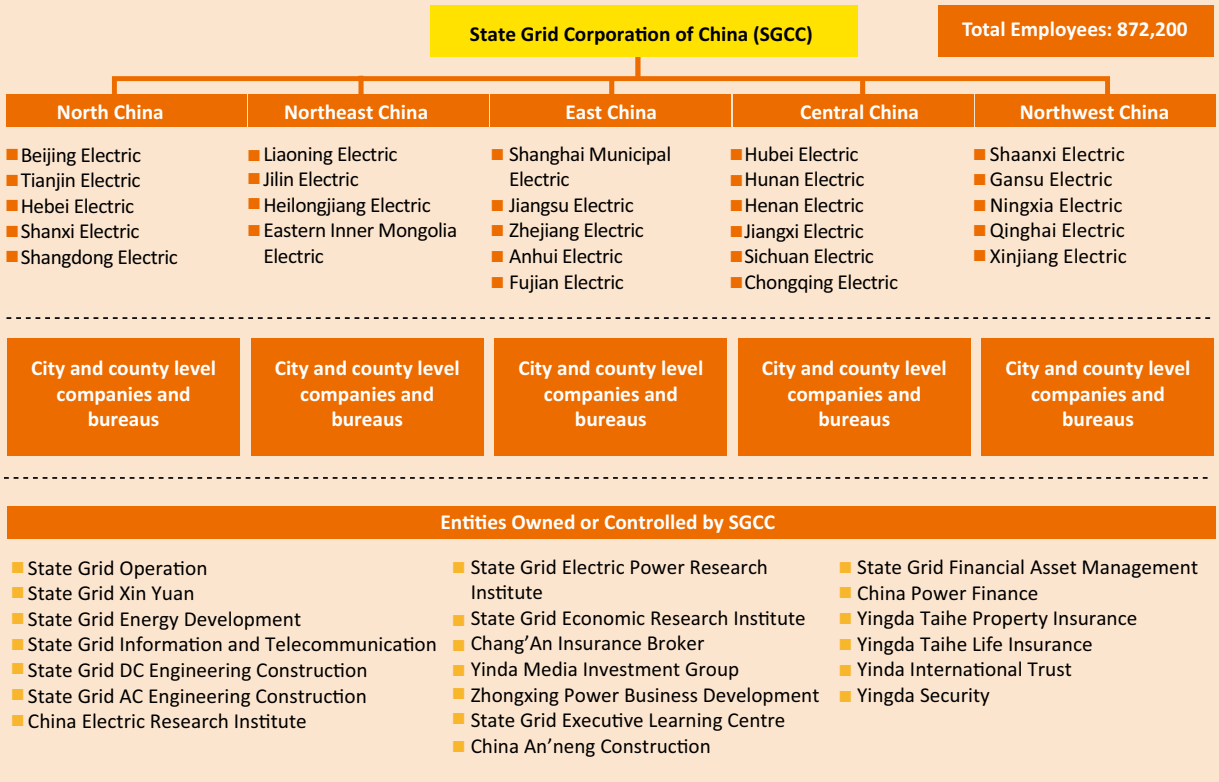
Not surprisingly, State Grid has a complex organizational structure that solution providers must understand if they hope to access market opportunities. The company has 51 subsidiaries and local organizations in every province. Major decisions are made throughout the organization at central, regional and provincial levels, making it difficult for solution providers to know where to focus their efforts. China Southern Grid is similarly complex: it has eight primary central departments that oversee seven provincial subsidiary companies, three branch companies, and three affiliated units. Making matters more complicated, State Grid is one of four major shareholders of China Southern Grid, with a 25% share along with the Guangdong Provincial Government (38.4% share), China Life (32%), and the Hainan Provincial Government (3.2%).[50]

China's grid companies were created through the 2002 Electric Power System Reform Plan, which completely changed the power generation landscape in China. The State Power Corporation controlled all aspects of power generation and transmission until the reforms, when it was split into five power generation companies (Huaneng, Datang, Guodian, Huadian and China Power Investment Group, which are now known as the Big Five) and two transmission companies, State Grid and China Southern Power Grid. These reforms followed on the heels of power sector liberalizations in

44. Lu, Adrian, A Primer on the (Strong) Smart Grid and its Potential for Reducing GHG Emissions in China and the United States (Beijing, China: Natural Resources Defense Council, 2010)
45. China Greentech Initiative analysis
46. China Southern Power Grid, http://www.csg.cn/, accessed on Sep. 5, 2010; China Southern Power Grid, 2009 CSR Report (Guangzhou, China: China Southern Power Grid, 2010, 35)
47. "Global 500" Fortune Magazine, accessed on Mar. 6, 2011, www.money.cnn.com
48. McKinsey & Company, McKinsey on Smart Grid (McKinsey & Company, Number 1, Summer 2010, 18)
49. Electricite de France, Consolidated Financial Statements (Paris, France: EDF, Dec. 31, 2010); China Greentech Initiative interview
50. China Southern Power Grid, http://www.csg.cn/, accessed on Sep. 5, 2010

other countries in the 1990s, including the U.S., Russia, and other Asian nations.[51] The hope was that a more competitive market would translate into higher efficiency and lower costs in the power sector.

State Grid's Ownership and Organizational Structure



Sources: State Grid, 2008 Corporate Social Responsibility Report of State Grid Corporation (Beijing, China: State Grid, 2009); China Greentech Initiative analysis

State Grid was allocated 80% of the electricity transmission market, with the rest controlled by Southern Grid.[52] Subsequent reforms divided sector responsibilities: the National Development and Reform Commission (NDRC) handles price setting, the State-Owned Assets Supervision and Administration Commission does asset restructuring, and the State Electricity Regulatory Commission coordinates market development. The difficulties coordinating these three regulatory bodies, each with its own priorities and overlapping responsibilities, may slow the pace of future power sector reforms. Some suggest China's electric grid sector may experience further liberalization, by restructuring the two monopolies into provincial entities, but this is unlikely in the short term.[53]

Relationships needed with all levels of grid organizations

Distribution and consumption solutions, as noted above, are currently the most attractive investment areas in China's smart grid value chain. This is partly because decisions on these solutions can be made primarily at the provincial and local levels, where decision-makers are more open to private company participation, particularly with domestic companies and through forming joint ventures.[54] Although all levels of the organizational structure provide input on annual investment plans and key projects, provincial level subsidiaries set budgets and manage procurement for distribution and consumption projects. City and county-level bureaus occasionally

51. Asia Pacific Energy Research Centre, Electricity Sector Deregulation in the APEC Region (Tokyo, Japan: Asia Pacific Energy Research Centre, 2000)
52. 国务院,"电力体制改革方案" [State Council, "Electric Power System Reform Plan"] Feb. 10, 2002
53. China Greentech Initiative analysis
54. Ibid

provide procurement input as well.[55] This highlights why greentech solution providers need to understand and form relationships with all levels of the grid organizations, from central headquarters down to the city bureaus.

Connecting Intermittent Power to the Grid

Opportunity Assessment

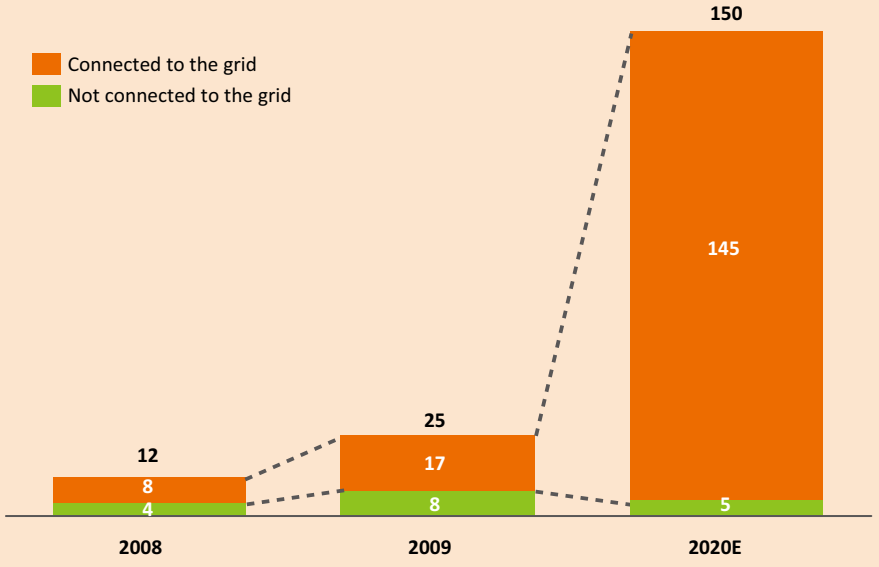
State Grid has largely addressed the problems with wind farm connections from 2008 to 2009, but still cannot absorb intermittent energy in some regions, requiring new solutions such as UHV construction to transport power elsewhere.

State Grid has made notable progress connecting wind farms: despite huge growth in new wind installations since 2008, nearly all wind farms are now connected to the grid, compared to only two-thirds in 2008. The problem has shifted to excess intermittent supply, because the windiest regions cannot absorb significant power fluctuations without posing problems for grid stability and reliability. New UHV power lines will partially address the problem by shifting power elsewhere, as will management tools that maintain grid stability, such as active and reactive power flow control and low-voltage ride-through (LVRT) technology. China lags behind other countries in one critical area: accurately forecasting intermittent resources.

China's great strides to address renewable energy connection losses

Difficulties connecting China's wind power capacity to the grid remains of perennial concern in the Renewable Energy sector. Remarkable growth in wind power capacity, doubling every year between 2005 and 2009, has positioned China as the world's largest wind power producer in the world. Yet China's grid networks have struggled to keep pace with that growth. As a result, an estimated 30% of wind power was wasted in 2009.[56] There are two main reasons for this: lack of *grid connection* due to poor coordination between relevant developers and regulators primarily at the county and provincial level, and lack of *grid connectivity* due to the intermittent nature of wind power.[57]

China Wind Power Connection, GW, 2008-2020E



Source: Shu Yinbiao, "'12 Five- Year' Electricity and Energy Sector Transition Development," State Grid (presentation given at the 2020 Energy, Economy, Development Forum, China, Oct. 31, 2010)

55. Chan, Angello and Edwin Chen, China Power Grid Sector (Hong Kong: Credit Suisse, 2007)
56. Li, Junfeng, et al., 2010 China Wind Power Outlook (Beijing, China: CREIA, Greenpeace, 2010)
57. China Greentech Initiative analysis

Interviews with grid officials revealed one surprise: grid connection problems were the primary cause of such high wind power losses. As one government official told the China Greentech Initiative: "The greatest challenge of connecting wind electricity to the grid is the management of conflicts of interests, followed by people's perception and technology."[58] The enthusiasm of central government targets and local government wind farm approvals outpace grid construction plans. In most cases, wind farms not connected to the grid did not obtain the required permits before construction.

Meanwhile, even though the Renewable Energy Law mandates connection with all renewable energy sources, the law lacked sufficient incentives for grid companies to connect to wind farms.[59] This resulted in the passage of Renewable Energy Law Amendments in 2009. The new rules require grid companies to supply a certain portion of their electricity from non-hydropower renewable energy (similar to a renewable portfolio standard) instead of being required to purchase all renewable energy generated. Grid companies will also now be directly compensated for costs of integration, and non-compliance measures have been strengthened.[60]

By the end of 2010, nearly 100% of completed wind farms were grid-connected.

Due to these legal changes and other efforts, China has made great strides in connecting wind power capacity to the grid. By the end of 2010, nearly 100% of completed wind farms were grid-connected.[61] These efforts must continue as China adds a minimum of 11 GW of wind power capacity per year to meet its 150 GW target by 2020.[62] State Grid plans to keep losses to only 4% of total capacity by 2020, which will result in a minimum of 144 GW of grid connected wind power capacity.[63]

Improving renewable energy grid connectivity on a national level requires installation of advanced solutions

The largest remaining obstacle for wind power is its variability, or intermittency, and the strain this puts on the grid. One grid operator told the China Greentech Initiative, "We only have one aim—that wind power will become a grid-friendly, high-quality energy source that is predictable, controllable and has resistance to disturbances."[64]

Unlike coal and hydropower, which can produce stable power on demand, wind and solar are weather dependent and produce uneven frequencies. For stable grid connectivity, intermittent power requires better prediction (weather forecasting and management of back-up power or operating reserves), dispatch (power transmission and distribution) and management (electricity stability control). The 12th Five-Year Plan targets regional grid integration through construction of 40,000 kilometers of UHV transmission lines by 2015.[65] Currently, a large proportion of wind power is wasted as oversupply. These UHV lines and other transmission technologies, will allow grid operators to transfer excess wind and other types of power produced in oversupplied areas to high demand centers.

Energy management solutions, such as storage, active and reactive power flow control and LVTR will enhance the ability of the grid to absorb increasing amounts of renewable energies. Energy storage technologies, which can store excess power and discharge it when required, are still at an early stage and prohibitively costly. Of the nine types available today, pumped storage, compressed air, and batteries appear most practical—particularly lithium-ion battery technology.[66] Further development is needed for broad adoption. Synchronized active and reactive power compensation systems could also ease grid connection with intermittent power sources by ensuring stable electricity frequencies. Active power controls and reactive power adjustment technologies are also at an early

58. China Greentech Initiative interview
59. Finamore, Barbara, "China Renews its Commitment to Renewable Energy," Natural Resources Defense Council, Feb. 1, 2010, www.switchboard.nrdc.org
60. Ibid.
61. Shu, Yinbiao, Deputy General Manager, State Grid, speech at conference: 2020 "Energy, Economy, Development" Forum (Autumn), Topic: "12 Five- Year Plan Electricity and Energy Sector Transition Development," Beijing, China, Oct. 31, 2010
62. "PR China," *Global Wind Energy Council, www.gwec.net, accessed on Mar. 7, 2011*
63. China Greentech Initiative interview
64. Ibid.
65. Bai, Jim and Aizhu Chen, "China top grid firm says to further develop UHV tech," Reuters, Jan. 28, 2011, www.reuters.com
66. 中国电力出版社, *"智能电网知识读本," [Smart Grid Knowledge],"智能电网技术," [Smart Grid Technology] Apr. 2010*

stage in China, but are necessary for large-scale integration of renewable energies into the grid. Finally, LVRT technologies allow wind and solar farms to remain connected to the grid when voltage drops off, in turn protecting turbines and the grid against disturbances.[67] Increasingly, wind turbines come equipped with these energy management technologies.[68]

China lags behind other countries in one critical area: forecasting intermittent resources

Poor prediction capabilities limit effective grid connectivity with renewable energy in China, perhaps more than any other factor. Intermittent renewable energy requires expensive back-up thermal power reserves when not producing energy, which can take up to 48 hours to coordinate. The result is significant power wastage. Better weather prediction capabilities can eliminate this by telling operators exactly when to turn on back-up power sources.

China relies on prediction models developed by EPRI and other universities, which are less accurate than those used by international counterparts.[69] Live tracking of individual wind turbines and solar panels, along with sophisticated weather forecasts, allow for more efficient power production. Current technologies can predict power generation output by five-minute intervals up to 72 hours in advance.[70] In the future, China may require wind and solar farms to install advanced prediction and monitoring tools such as these. This may create substantial market opportunities for prediction technology providers.

Technology Preferences in the Smart Meter Market

Opportunity Assessment

Although China will roll out 50 to 60 million Automatic Meter Reader (AMR) meters in 2011, more sophisticated Advanced Meter Infrastructure (AMI) is yet to come; at present, the meter market is only open to a handful of experienced players.

China's smart meter roll-out poses a paradox for solution providers. On one hand, China's decision to implement AMR now due to low cost means that the country could require another round of new, more sophisticated AMI meters as early as 2015. On the other hand, China's meter market is restricted to a handful of players already present, and this seems unlikely to change in the near future. Grid companies rely on suppliers with low prices, a quality track record, local after-sale customer service, and relationships with internal grid company departments. Attitudes on smart meters are another factor. The China Greentech Initiative's interviews and working sessions revealed a sharp disagreement on the value of smart meters; many local players believe that China does not need expensive foreign technology, while others believe they could more efficiently manage and reduce energy use.

The Short Lifespan of AMR Meters May Create a Near-Term Market for More Advanced Meters

China requires automatic meter readers installed today to have a product lifespan of 10 years.[1] An AMR installed in 2010, therefore, should last until 2020, but our interviewees suggest otherwise. According to industry experts, many AMRs on the market today will malfunction in four to five years, requiring replacement of at least 300 million meters by 2015. At this time, grid companies may begin a transition to AMI, creating another vast market for smart meter suppliers.[2] This raises questions about the quality of current AMR suppliers and AMR installation targets.

1. 王晓明, "大量超龄电（水）表无人体检," [Wang, Xiaoming, "Large amount of old electricity and water meters unchecked"] Strait Consume, Mar. 10, 2005
2. China Greentech Initiative interviews and analysis

67. Ibid.
68. China Greentech Initiative analysis
69. 中国电力出版社,"智能电网知识读本," [Smart Grid Knowledge],"智能电网技术,"[Smart Grid Technology] Apr. 2010
70. "Large scale integration of wind energy into electrical grids," Global Wind Energy Council, www.gwec.net, accessed on Mar. 7, 2011

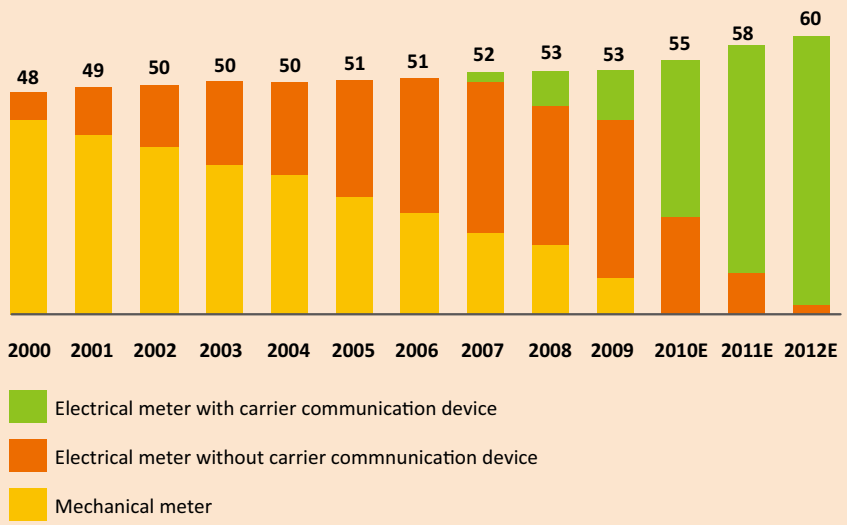
China's smart meter market is growing as mechanical meters are replaced

Most homes in China still record electricity use with outdated mechanical meters. Over 95% of China's roughly 500 million meters for electricity, water, and gas are mechanical, requiring utility employees to enter homes to manually record use.[71] China's smart grid plans require a shift in the way the country transmits and uses electricity. This involves modernizing the entire electric power value chain, including introducing smart meters.

Smart meters are often defined as electricity monitoring devices with two-way communication capabilities, allowing utilities and customers to analyze energy use. China's definition varies slightly, including both readers and infrastructure. The more simple AMRs simply transmit information about electricity use to utilities, while AMI allows for real-time data analysis for utilities and consumers. AMI is still at an early stage in China, however, and will likely not be introduced until after 2015.

In the next five years (2011-2015), China plans an impressive roll-out of automatic meter readers under State Grid's Smart Grid Plan. In 2010, China began AMR distribution with as many as 55 million units installed. Yearly installations will increase to 60 million meters in 2011.[72] By 2015, State Grid and China Southern Grid expect to have replaced all mechanical meters with AMR, supported by an investment of RMB 72.9 billion (US$ 11.2 billion).[73] In 2010, the majority of AMR meters installed by State Grid were one-phase, suited to residential applications, as opposed to three-phase meters, which are typically used for industrial purposes. Three-phase meters will gain market share in the coming years, however, with predictions of nearly 50% of the market in 2011.[74] These plans will create a huge market for meters, albeit a relatively closed one. State Grid, the main customer for electricity meters in China, prefers low-cost, incumbent suppliers, making market entry for new companies extremely difficult.

AMR Demand in China, millions of units, 2000-2012E



Sources: China International Capital Corporation, 即将进入全面建设期的中国智能电网 *(China is about to Build a Smart Grid], (Beijing, China: CICC, 2010); China Greentech Initiative analysis*

71. Cox, Michael, China 'Smart Meter' Industry Primer: Multi-Year Upgrade Cycle Continues (Minneapolis, MN: PiperJaffrey, 2010)
72. 北京易观网络信息咨询有限公司, "中国电子式电能表行业发展现状及趋势研究报告," *[Eguan, China Electricity Meter Industry Development] 2010, 15*
73. Li, Min and Wendy Wang, Electronic Equipment & Services (Hong Kong: Yuanta, 2010)
74. Ibid.

Grid procurement favors low-cost meter incumbents

Although China's smart meter market will experience incredible growth in the coming years, few domestic or international companies stand to benefit. Top suppliers for meters in China share similar traits as large Chinese companies offering a range of low-cost products. Most of them have established reputations with grid companies and offer local after-sale customer service. All of these factors make market entry for new companies difficult. With just a few exceptions, the supplier mix remains stable with Sanxing, Wasion, and Holley Metering occupying the top three spots in 2010.[75]

State Grid Smart Meter Suppliers by Market Share, 2009 and 2010

Rank	2009	2010	Market Share as of November 2010
1	Jiangsu Linyang Electronics Co.	Ningbo Sanxing Electric	20%
2	Wasion Group	Wasion Group	12%
3	Ningbo Sanxing Electric	Holley Metering	9%
4	Holley Metering	Shenzhen Clou Electronics	8%
5	Hangzhou PAX Electronic Technology	XJ Group	7%
6	Shenzhen Clou Electronics	Ningxia LGG Instrument	7%
7	Shanghai Wellsun	Shenzhen Haoningda Meters	7%
8	Hangzhou Xili Watthour Meter Manufacture	Zhejiang Chint Instrument and Metering	6%
9	CNELE	Hangzhou PAX Electronic Technology	5%
10	Not available	Beijing Fugen Intelligent Meter	4%

Sources: 长城证券, *"国家电网2010统一招标大盘点," [Greatwall Securities, "State Grid Central Bidding 2010"] (China: Nov. 12, 2010); China Greentech Initiative analysis*

China's smart meter procurement processes are the dominant forces shaping the market. Despite regulatory oversight from four agencies (NDRC, China Electric Instrument Association, General Administration of Quality Supervision, Inspection, and Quarantine, and the National Institute of Metrology), the decision-making power ultimately lies with State Grid and China Southern Grid, the only smart meter customers in China. Each company has its own process: State Grid decides procurement at the central level while Southern Grid delegates it to the provincial level.[76] Both companies emphasize price and quality (despite speculation that meters will malfunction after half their expected lifespan). In State Grid's procurement process, for example, bids are assessed based on price (45% weight), quality (45% weight) and bankability of company (10%).[77] State Grid also requires that suppliers obtain quality approval certification to be eligible for bidding. The certification, given by EPRI, has to be renewed every two years. Additionally, meters must include 20 functions, including pre-payment and carrier communication features.

Attitudes towards advanced smart meters vary

The China Greentech Iniative's interviews with experts revealed a surprising divergence of opinions on smart meters. While many believe in the ability of smart meters to help reduce China's energy use, others in China argue that more advanced meters are simply too expensive and not suitable for China's networks. Foreign

75. 长城证券,*"国家电网2010统一招标大盘点" [Greatwall Securities, "State Grid Central Bidding 2010"] Nov. 12, 2010*
76. 中国国际招标网,*"电监会:直购电要形成机制" [Forming a Mechanism for Direct Purchase of Electricity] http://www.chinabidding.com, accessed on Sep. 22, 2010*
77. China Greentech Initiative analysis

companies, for example, believe they can offer advanced smart meters that would more effectively monitor and reduce electricity use than meters currently in use in China. A typical foreign-produced smart meter has a wider range of functions, including two-way communications and user pattern analysis.

Those arguing against the need for this level of technological sophistication in the China market list price as one factor, but also highlight other reasons. Meters costing over RMB 650 are not considered necessary, when Chinese meters can be installed for RMB 180. Others cite anecdotes of public outcry against smart meters in some U.S. states as a reason to remain cautious. For example, some U.S. customers suspect smart meters of increasing their power bills. Others complain about the deleterious health effects from smart meters—like cell phones, the meters transmit signals electromagnetically. Some towns in California even have banned smart meters, even though the state mandates their installation.[78]

Local and low-cost products key to market entry

As State Grid and Southern Grid's procurement processes show, the most important criteria for new market entrants are local operations and low-cost products. Domestic and foreign private companies hoping to enter the market should pursue vertical integration, expand geographic coverage, and invest in research and development to improve product quality. Foreign companies should additionally customize products for the Chinese market, form joint venture partnerships, develop relationships with local grid company bureaus and engage in pilot projects wherever posssible.[79]

Electric Power Infrastructure Opportunities for 2011

This chapter provides an update of China's Electric Power Infrastructure sector and three Opportunity Assessments prioritized by the China Greentech Initiative's partners and advisors in 2010. As the sector evolves, participants in the China Greentech Initiative Partner Program will continue to collaborate on additional opportunity areas. The first topic in 2011 covers energy storage for grid connectivity improvement, focusing on the impact of dispatch and wind power on storage solutions selection and implementation. Other topics may include commercial opportunities with State Grid and Southern Grid along the Electric Power Infrastructure value chain, such as storage, electric vehicle charging stations, distribution, and UHV. The China Greentech Initiative will also continue to track the overall evolution of China's Electric Power Infrastructure sector.

78. "Smart Meters Get Pushback Because of Electromagnetic Field Concerns," Sustainable Business, Jan. 7, 2011, www.sustainablebusiness.com

79. China Greentech Initiative analysis

Steve Bale

Green Building

China's green building market has more than doubled every year since 2005, but remains only a fraction of its potential size. Numerous challenges impede growth, yet companies with a nuanced understanding of this complex, rapidly-growing market can position themselves to become future industry leaders.

Given the pace and scale of urbanization, China needs to improve building efficiency to meet energy and environmental goals. Green buildings can play a substantial role but the sector faces many challenges. There is no common industry definition for green building and standards are unclear. Although the economics of green building are favorable in China, builders are reluctant to pursue green building projects due to misaligned incentives between developers, owners and tenants. Enforcement may be improving for building energy codes but lags in other areas. Despite these and other challenges there are still attractive opportunities for international and domestic companies.

This chapter begins by providing an overview of Green Building sector developments since the publication of *The China Greentech Report 2009*. It then summarizes the three Opportunity Assessments the China Greentech Initiative developed with its partners and advisors throughout 2010:

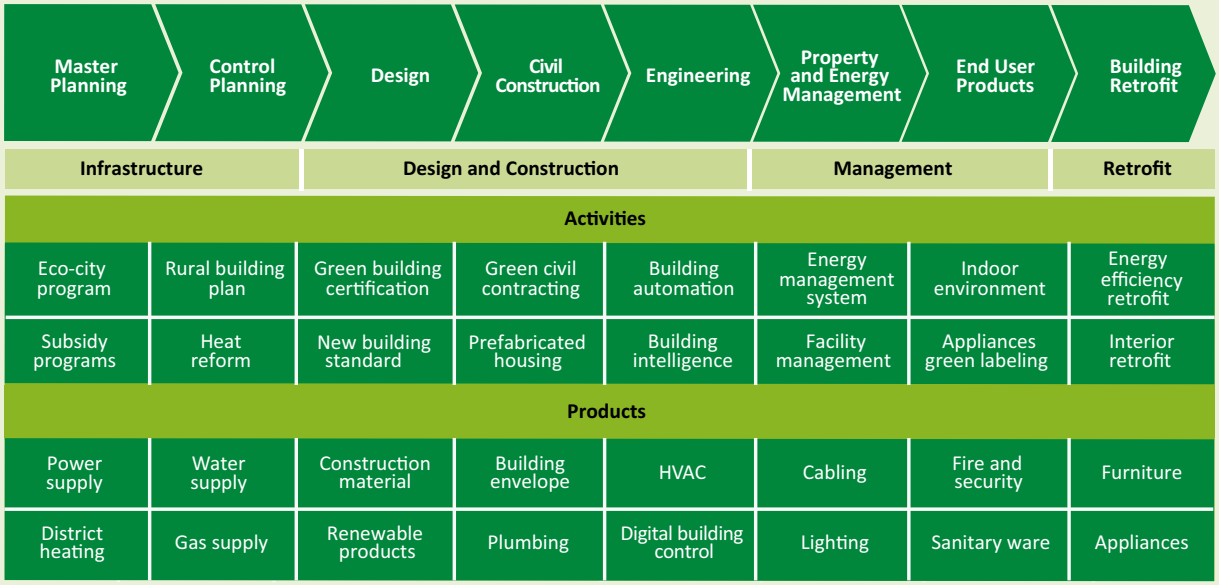
- Expanding the Building Energy Efficiency Retrofit Market through Energy Service Companies (ESCOs)
- Accelerating Green Building Materials Adoption Through Supply Chain Practices
- Rapidly Improving Markets for Sustainable Indoor Environment Solutions

The China Greentech Initiative's partners and advisors prioritized each of these Opportunity Assessments as critical to the growth of China's Green Building 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 the organizations participating in the China Greentech Initiative Partner Program. The chapter concludes with an outlook on additional opportunities and issues in the Green Building sector that the China Greentech Initiative plans to explore in 2011.

The writing of this chapter was led by Ran Tao (陶然), based upon strategic research deliverables completed by Ran Tao (陶然) and Sebastian Tang (汤化峻) of the China Greentech Initiative's Green Building sector research team.

Green Building Sector Definition

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.



Source: China Greentech Initiative analysis

Market Update

China's urbanization creates unprecedented challenges for the environment

Since the late 1970s, the Chinese government has focused on economic growth and alleviating poverty, birthing vibrant cities and a growing consumer society. Recently, as China's huge cities frequently confront resource limitations, the government has recognized the need for more efficient and sustainable buildings. Unlike countries that industrialized earlier, China has the chance to marry sustainable development with rapid growth. China's rapid urbanization has seen more people than the entire U.S. population migrate into cities since 1980, and China's urban population is expected to grow by a similar figure by 2025. Continued economic growth relies on urbanization, since Chinese cities generate 75% of GDP despite having approximately 50% of the population.[1] To meet demand, China adds over two billion square meters of new floor space to its building stock annually, representing half the world's construction market.[2] If current trends hold, by 2030 over one billion people will live in China's cities, more than 220 Chinese cities will have over one million inhabitants (compared with 35 in Europe today), and cities will account for 95% of GDP.[3]

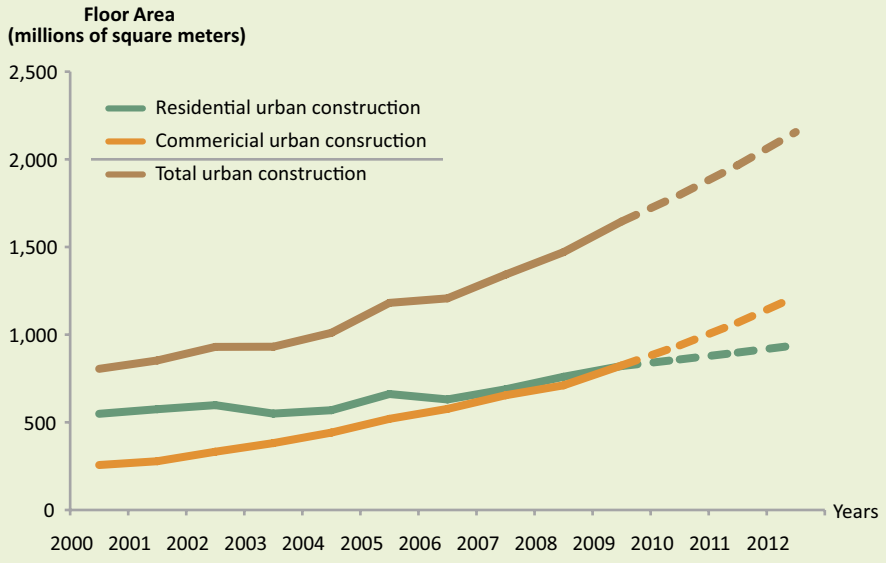
Adding over two billion square meters of floor stock annually, China represents half the world's construction market.

This unprecedented growth translates to enormous strain on natural resources and the environment. While building energy consumption per square meter in China is lower than in industrialized nations—on average it is only a quarter of U.S. building consumption—city-dwellers consume more than three times as much electricity as rural residents.[4] As China's economy expands, demand also rises for modern heating and cooling, larger refrigerators and more powerful electronic appliances, often meaning higher energy consumption.[5] Official figures attribute 19% of China's current

1. Woetzel, J. et al., Preparing for China's Urban Billion (Shanghai, China: McKinsey Global Institute, 2009)
2. National Bureau of Statistics of China, China Statistical Yearbook, 2000-2009 (Beijing, China: National sBureau of Statistics of China, 2010)
3. Woetzel, J. et al., Preparing for China's Urban Billion (Shanghai, China: McKinsey Global Institute, 2009)
4. Fung, J. et al., From Gray to Green: How Energy-Efficient Buildings Can Help Make China's Rapid Urbanization Sustainable (US: The Boston Consulting Group; Natural Resources Defense Council, 2009)
5. 中国工程院院士,建筑学院教授，"中国建筑能耗现状及节能途径分析,"[Chinese Academy of Engineering, "Current Energy Consumption in Chinese Buildings and Energy Solution Analysis"] (Beijing, China: Chinese Academy of Engineering, 2009)

total energy consumption to buildings, while other studies on day-to-day operations of residential and commercial buildings place the figure at anywhere from 25% to over 30%.[6] These figures exclude the energy and resources used to create buildings: materials extraction, manufacturing, distribution and construction. By 2030, urban China is forecasted to account for 20% of global energy consumption.[7]

China's Annual Urban Floor Area Construction
millions of square meters, 2000-2012



Source: National Bureau of Statistics of China, "China Statistical Yearbook, 2000-2010"

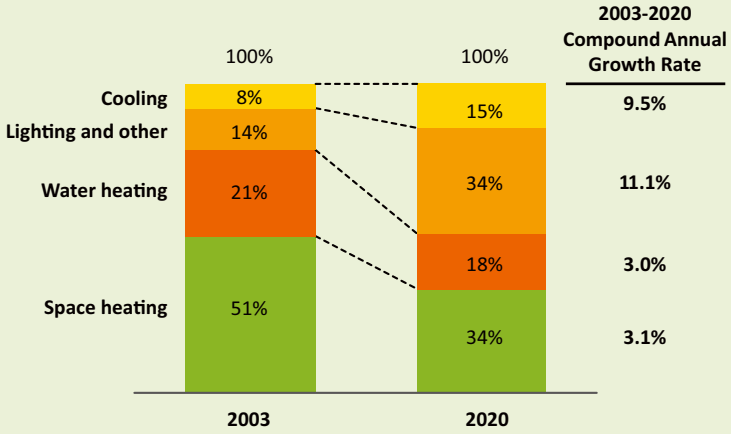
Since coal and other fossil fuels dominate China's electricity production, building electricity use represents a substantial share of greenhouse gas (GHG) emissions. In 2005, the buildings and appliances sector was responsible for 1.1 billion metric tons, or 16% of China's total GHG emissions.[8] To address existing and new energy and environmental policy goals, it will be critical to adopt sustainable development. Growing cities will require vast tracts of land and a staggering amount of infrastructure to satisfy energy supply, building and transit needs. These demands will exacerbate environmental problems such as congestion, water scarcity, air pollution and arable land depletion, straining China's environmental and social fabric.

Green building provides a sustainable alternative

Developing green buildings can help countries grow sustainably without sacrificing comfort or economic growth; their objective is to conserve natural resources and minimize harm to the environment throughout the building life cycle. The building sector in China is known for poor durability, wasteful energy use and low environmental quality. Developers generally build for speed and will often do anything to maximize profit, even if it means compromising building quality.[9] An average Chinese building lasts 25-30 years, compared with 74 years in the U.S. and 132 years in the U.K.[10] Inefficient energy use spurred the Chinese government to launch a costly initiative to redress heat loss in northern district-heating pipelines in 2008, where primary energy consumption for heating buildings can be twice as high as energy consumption at the buildings themselves.[11]

6. Fridley, D. et al., China's Building Energy Use (Berkeley, CA: Lawrence Berkeley National Laboratory, 2007)
7. Woetzel, J. et al., Preparing for China's Urban Billion (Shanghai, China: McKinsey Global Institute, 2009)
8. Bressand, F. et al., Leapfrogging to Higher Energy Productivity in China (Shanghai, China: McKinsey Global Institute, 2007)
9. "Not Built to Last: China's Overused Wrecking Ball," Time, Nov. 10, 2010, www.time.com
10. "'Most homes to be demolished in 20 years," China Daily, Aug. 07, 2010, www.chinadaily.com.cn
11. Kerschberger, Alfred, "Drei Pilotprojekte zur energieeffizienten Sanierung von Mehrfamilienhäusern in Nordchina," [Three pilot projects on energy efficiency refurbishment of apartment buildings in Northern China], Sino-German Technical Cooperation – Energy Efficiency in Existing Buildings Project Output (Beijing, China: GTZ, 2010)

China's Energy Consumption in Buildings by Use, percent, 2003 and 2020



Note: Percentages are rounded to the nearest whole number

Source: Zhou, N., et al., The Reality and Future Scenarios of Commercial Building Energy Consumption in China (US: Ernest Orlando Lawrence Berkeley National Laboratory, 2007); 江亿, *"*中国建筑能耗现状及节能途径分析*," [Jiang Yi, Chinese Academy of Engineering, "Current Energy Consumption in Chinese Buildings and Energy Solution Analysis"] 2009*

Green building solutions offer a range of environmental and social benefits. For example, using window glazing to reflect solar radiation, installing vegetated roofing or switching to high-performance insulation materials such as expanded polystyrene (EPS), extruded polystyrene (XPS) and polyurethane (PUR) are all methods that can improve the building envelope. Installing energy efficient T-series light fixtures or using compact fluorescent (CFL) and light emitting diode (LED) bulbs reduces electricity use. Using technologies such as high-efficiency pumps in heating, ventilation and air conditioning (HVAC) systems enhances overall energy performance. Not only do these solutions deliver energy savings, but together they can also reduce 980 million tons of carbon equivalent, or 50% of the sector's 2030 forecast.[12] In addition to superior environmental performance, sustainable indoor environments offer higher comfort, better ventilation and more natural light, resulting in improved health, higher productivity and lower rates of absenteeism among employees. In the U.S., case studies have shown that companies using green building offices can achieve productivity gains of 11-15% as well as 5% reductions in absenteeism.[13] Green offices can also enhance the appeal of a company to prospective employees and contribute to higher retention rates of top talent.[14]

China's green building market is still in nascent stages

China's first green building demonstration project, Beijing's Agenda 21 building, achieved certification under the internationally recognized U.S. Leadership in Energy and Environmental Design (LEED) rating standard in 2005.[15] Housing offices for China's Ministry of Science and Technology (MOST), the building incorporates green building solutions such as an insulating roof garden, locally sourced construction materials, and automatic lighting. Since then, green building floor area in China has more than doubled every year to over 7.3 million square meters in 2010.[16] However, this still amounts to less than 0.5% of annual new construction floor space in urban China.[17]

12. McKinsey & Company: China's green revolution. Prioritizing technologies to achieve energy and environmental sustainability (Shanghai, China: McKinsey & Company, 2009)
13. Fung, J. et al., From Gray to Green: How Energy-Efficient Buildings Can Help Make China's Rapid Urbanization Sustainable (Beijing, China: The Boston Consulting Group and Natural Resources Defense Council, 2009)
14. Ibid.
15. "China's First Green Office Building," NRDC, www.china.nrdc.org, accessed on Mar. 3, 2011
16. "LEED Projects and Case Studies Directory," USGBC, www.usgbc.org, accessed on Nov. 13, 2010; "Announcement of Green Building Label Project Names," MOHURD, www.mohurd.gov.cn, accessed on Nov. 17, 2010; National Bureau of Statistics of China, China Statistical Yearbook, 2000-2009 (Beijing, China: National Bureau of Statistics of China, 2010)
17. Ibid.

China's Potential Environmental Impact from Green Building

If all buildings in China achieved energy savings comparable to the country's first green building, the environmental impact would be equivalent to any of the following:

Notes: Based on 2015 energy use and assuming 70% and 55% energy savings for commercial and residential buildings respectively; includes operating efficiencies only; excludes residential applicance usage

Source: Zhou, N. et al., The Reality and Future Scenarios of Commercial Building Energy Consumption in China (US: Ernest Orlando Lawrence Berkeley National Laboratory, 2007); 江亿, *"* 中国建筑能耗现状及节能途径分析*," [Jiang Yi, Chinese Academy of Engineering, "Current Energy Consumption in Chinese Buildings and Energy Solution Analysis"] 2009*

The number one reason cited for weak adoption of green building solutions is low awareness.

Lack of awareness is one of many factors that contribute to low market penetration for green building solutions in China. In conjunction with RCC China, a market intelligence firm for the Chinese construction industry, the China Greentech Initiative conducted a 2009 survey on green building attitudes among Chinese building professionals. The number one reason cited for weak adoption of green building solutions is low awareness or lack of understanding.[18] A standard definition for "green building" has yet to emerge in China, with the term having different meanings for different building industry stakeholders. In 2006, the Ministry of Housing and Urban-Rural Development (MOHURD) released China's Green Building Evaluation System, known as the 3-Star system, which was modeled upon the U.S. LEED rating system. While the two systems address similar sustainability principles and share common characteristics, they have different interpretations in areas such as green building material requirements.[19] More than twice as many Chinese building professionals were aware of the 3-Star system versus LEED in 2009.[20] However, multinational corporations are more likely to pursue LEED certification for their commercial

18. China Greentech Initiative analysis
19. China Greentech Initiative interviews
20. China Greentech Initiative analysis

properties due to its recognition and acceptance among international audiences. The lack of clear industry definitions and competing green building standards contribute to market uncertainty, continuing to hinder growth.

Misaligned incentives also constrain the market. While green buildings may offer environmental and financial benefits, these benefits are spread unevenly among value chain stakeholders, distorting the incentive to build green. The decision to build is often decoupled from the decision to own, occupy or rent, giving developers little incentive to invest in more costly energy efficient technologies that deliver savings to future building occupants. For example, HVAC contractors are compensated for the systems they install, not for downsizing systems to reflect future building use or incorporating energy conservation technologies to reduce future energy bills. However, some innovative business models are emerging in China to address misaligned value chain incentives, which are described in the Expanding the Building Energy Efficiency Retrofit Market Opportunity Assessment.

The MOST demonstration office uses 70% less energy, 40% less water and avoids emitting 1,700 metric tons of carbon emissions per year.

Green building makes economic sense

The Green Building market is viable in China only if there is enough demand for products, services and solutions that may cost more initially compared with conventional alternatives. Encouragingly, evidence suggests that green building economics in China are favorable for stakeholders: consumers are increasingly willing to pay more for green buildings, the cost premium for developers can be modest, and savings can translate into short payback periods for owners. In addition, as China continues to reduce the carbon intensity of its economy, studies show that building energy efficiency is the least costly carbon abatement strategy available, giving the government a strong incentive to promote green building.[21]

As incomes and living standards rise and awareness improves, consumers are demanding more durable, safe and healthy buildings. Green buildings stand out by offering better occupant safety, health and comfort.[22] In the 2009 China Greentech Initiative green building survey, the majority of Chinese building professionals believed that buyers were willing to pay up to a 20% premium for green buildings.[23] In the U.S., green buildings generate 10-15% more profit and have occupancy rates that are 4% higher than conventional buildings.[24]

While green buildings do have an upfront cost premium, the average additional cost to build green is estimated to be approximately 2% internationally.[25] In China, however, the actual cost premium is subject to debate: some estimates place the premium as high as 9-14% (due to the low cost of conventional building construction, the relative immaturity of the green building materials market and other factors), while low-end estimates suggest the premium is 4-5%.[26] These divergent estimates reflect a lack of reliable green building cost data, illustrating the need for greater monitoring, verification and transparency for the financial performance of green buildings. Beyond the initial outlay, green building technologies have the ability to reduce operational costs, which can translate to shorter payback periods. The MOST demonstration office uses 70% less energy, 40% less water and avoids emitting 1,700 metric tons of carbon emissions per year compared to conventional buildings.[27] Gains in efficiency deliver operational savings in excess of RMB 800,000 (US$ 123,000) per year, which will allow the building to recoup initial green building investment in about six years.[28] Similarly, an international survey of green buildings suggests they reduce

21. Fung, J. et al., From Gray to Green: How Energy-Efficient Buildings Can Help Make China's Rapid Urbanization Sustainable (Beijing, China: The Boston Consulting Group and Natural Resources Defense Council, 2009)
22. Lal, Abhishek and Qian Yingchu, "Green Building Trends in China," BusinessForum China, Apr. 2007, www.bdchina.de
23. China Greentech Initiative analysis
24. Fung, J. et al., From Gray to Green: How Energy-Efficient Buildings Can Help Make China's Rapid Urbanization Sustainable (Beijing, China: The Boston Consulting Group and Natural Resources Defense Council, 2009)
25. Kats, Greg, Greening Our Built World: Costs, Benefits, and Strategies (Washington, D.C.: Island Press, 2009)
26. 孙大明 等,"国内绿色建筑的造价成本调查和分析" [Sun, D. M. et al., "Investigation and Analysis on Construction Cost of Green Building in China"] www.chinagb.net, accessed on Apr. 18, 2008; Fung, J. et al., From Gray to Green: How Energy-Efficient Buildings Can Help Make China's Rapid Urbanization Sustainable (Beijing, China: The Boston Consulting Group and Natural Resources Defense Council, 2009)
27. "China's First Green Office Building," NRDC, www.china.nrdc.org, accessed on Mar. 3, 2011
28. Ibid.

energy use by 33% on average, resulting in a six-year energy-savings payback.[29] Case studies in China show that green building premiums can be as low as 2-4% with payback periods between two to four years, illustrating that achieving higher performance is possible.[30]

Cost Premiums and Payback Periods of LEED Projects in China

Project	Cost Premium (%)	Energy Savings	Simple Payback Period (Year)	LEED Status
Plantronics Factory (Suzhou)	2.5%	Combined savings of RMB 580,000 thousand per year	2.3	Pre-certified Gold
Plantronics Office (Suzhou)	3.2%		3.6	Pre-certified Silver
Tongji United Plaza (Shanghai)	3.2%	RMB 482, 193 thousand per year	4	LEED CS Silver

Source: Wang Hong, "Building Green for Greener Companies," EMSI China, http://www.docin.com, accessed on Mar. 9, 2011; EMSI, "EMSI China LEED Project List," http://www.emsi-green.com.cn, accessed on Mar. 9, 2011

Not only can builders profit from selling green buildings and end-users benefit from associated cost savings, but green buildings also make sense for the overall economy. Every metric ton of carbon equivalent saved through building energy efficiency generates a net benefit of RMB 461 (US$ 71) per year, the largest return on investment for any sector.[31] Conversely, industrial and power sector mitigation techniques require relatively large capital expenditures and involve highly specific technologies. Creating energy-efficient green buildings achieves energy and emissions targets more efficiently than many other mitigation strategies.

Government actively supports green building

Every metric ton of carbon equivalent saved through building energy efficiency generates a net benefit of RMB 461 (US$ 71) per year, the largest return on investment for any sector.

The Chinese government recognizes the importance of the building sector in meeting its energy and environmental goals. In the "Ten Key Projects" initiative released in 2004, a multi-billion RMB program to support and finance energy-saving projects across China, energy efficiency and conservation in buildings accounted for 40% of the emissions reduction target.[32] In the 11th Five-Year Plan, the government identified six priorities for improving building efficiency in its broader strategy to achieve a 20% reduction in energy intensity.[33] The 11th Five-Year Plan also mandated that new buildings use 50% less energy when compared to the existing building stock by 2010, with a more ambitious target of 65% for major cities such as Beijing, Shanghai and Tianjin.[34] Throughout the 11th Five-Year Plan, the government made progress on number of ambitious policies, programs and incentives targeting the building sector, including the following:

- Compliance with national building energy codes has increased as regulators step up enforcement to achieve energy savings, rising from 5% or less in 2001 to almost 100% in 2010 for building design and construction in urban areas.[35]

29. Kats, Greg, Greening Our Built World: Costs, Benefits, and Strategies (Washington, D.C.: Island Press, 2009)
30. Wang Hong, "Building Green for Greener Companies," EMSI China, Mar. 23, 2008, www.docin.com; EMSI, "EMSI China LEED Project List," http://www.emsi-green.com.cn, accessed on Mar. 11, 2011
31. Note: the following formula was used to calculate net benefit: annual cost savings less annual amortization of initial capital expenditure/annual metric tons of CO_2 abated; Fung, J. et al., From Gray to Green: How Energy-Efficient Buildings Can Help Make China's Rapid Urbanization Sustainable (Beijing, China: The Boston Consulting Group; Natural Resources Defense Council, 2009)
32. National Development and Reform Commission (NDRC), Implementation Suggestions of Ten Key Energy-Conservation Projects during the Eleventh Five-Year Plan (Beijing, China: NDRC, 2006)
33. "Building Energy Codes," ChinaFAQs, www.chinafaqs.org, accessed on Mar. 1, 2010
34. Ibid.
35. Lawrence Berkeley National Laboratory, 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)

- The central government launched a program to reform urban district heating in northern China in 2008. To date, 150 million square meters of building area have undergone improvements which include installation of heat meters and thermal control equipment.[36]
- MOHURD launched an energy management program in 2007 covering government office buildings and commercial buildings larger than 20,000 square meters. As part of the program, 150 out of 774 public buildings in Beijing had undergone energy audits by 2009.[37]
- The National Development and Reform Commission (NDRC) began promoting energy efficient lighting products in 2007. Sixty-two million efficient compact fluorescent (CFL) and light-emitting diode (LED) lamps were distributed across China in 2008, achieving an estimated 3.2 billion kWh in energy savings.[38] While distribution has been impressive, mercury contamination from the improper disposal of energy efficient lamps can undermine their environmental value.
- To promote building-integrated renewable energy, MOHURD issued guidelines and subsidies in 2009 for rural and urban demonstration projects.[39]
- NDRC and the Ministry of Finance (MOF) announced the first subsidies for the energy efficiency retrofit market in June 2010, offering funding to Energy Service Companies (ESCOs) to execute energy management contracts.[40]

Energy quotas may be introduced for large public buildings.

The 12th Five-Year Plan will build upon the progress of the 11th Five-Year Plan in energy and the environment. Building energy savings will continue to contribute to new reduction targets for energy intensity and carbon emissions. The 65% energy reduction target for new buildings already active in select municipalities will extend to the rest of the country.[41] The government will step up enforcement of national building energy codes beyond urban areas, where substantial progress has been made, to rural areas where compliance still lags.[42] Energy quotas may be introduced for large public buildings, effectively capping energy consumption for buildings already under MOHURD's energy management program for large public buildings. New Materials, which includes advanced construction materials, has been named one of seven Strategic Emerging Industries that will receive subsidies to stimulate innovation and adoption.[43] Eco-cities and related urban development principles will likely grow in importance as the government continues to wrestle with urbanization. New targets set forth in the 12th Five-Year Plan should help the green building market grow, though many challenges will remain.

Green Building markets have enormous potential but vary in attractiveness

As shown by the three Green Building Opportunity Assessments completed by the China Greentech Initiative in 2010, energy efficiency is the most attractive Green Building market, with building energy performance standards and energy efficiency retrofit targets supporting strong growth. The market for sustainable building materials is still in its infancy. Weak enforcement of standards and sourcing practices

36. 中华人民共和国住房和城市建设部, *"*我国建筑节能潜力最大的六大领域及其展望,*" [Ministry of Housing and Urban-Rural Development, "Six Key Development Areas in Energy Saving for Buildings"] Apr. 8, 2010*

37. Ibid.

38. Lawrence Berkeley National Laboratory, 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)

39. 中华人民共和国住房和城市建设部,*"*关于组织申报2010年可再生能源建筑应用城市示范和农村地区县级示范的通知*," [Ministry of Housing and Urban-Rural Development, "Applications for BIRE demonstration projects in urban and rural areas"] May 10, 2010*

40. 中华人民共和国财政部、发改委, *"*合同能源管理项目财政奖励资金管理暂行办法,*" [NDRC, MOF, "Interim Measures on Management of Financial Incentive Funds for Energy Management Contracting Projects"] Jun. 2010*

41. Lawrence Berkeley National Laboratory, 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)

42. Ibid.

*43.*中华人民共和国国务院, *"*国务院关于加快培育和发展战略性新兴产业的决定,*" [The General Office of the State Council, PRC"Decision on Accelerating Growth and Development of Strategic Emerging Industries"] Oct. 10, 2010*

that overlook environmental principles are serious challenges, translating into limited opportunities for private companies. Targets in the 12th Five-Year Plan including more stringent building energy codes and stronger support for advanced building materials will continue to accelerate the adoption of green building solutions.

The China Greentech Initiative developed the Market Attractiveness Assessment (MAA) to evaluate the energy efficiency and sustainable materials markets on six criteria: government support, addressable market size, solution attractiveness, five-year market growth potential, market accessibility, and profit opportunity. Information on the Market Attractiveness assessment methodology can be found in the Research Methodology chapter.

Strong government support boosts market attractiveness for energy efficiency solutions

While China's building energy codes have become tougher and the energy efficiency retrofit market has almost quadrupled in size over the last five years, the near-term potential of energy efficiency solutions still remains unclear.

Energy efficiency

Government support for building energy efficiency is rated *high priority*. Energy reduction targets for new buildings will rise from 50% to 65% and energy quotas will likely be introduced for large public buildings in the 12th Five-Year Plan. While the first subsidies for ESCOs were introduced in 2010, they are still too small to make a substantial impact.

There is a *very large* addressable market size for building energy efficiency in China. If all potential adopters implemented existing energy efficiency technologies, the addressable market size is estimated to be over RMB 500 billion (US$ 77 billion). China adds over two billion square meters of new construction floor space annually, while northern urban heating reform and retrofits of large public buildings support the market for existing buildings.

Solution attractiveness is rated *average*. Green building cost premiums range between 2-14% with typical payback periods between two to six years in China. Government standards place a high emphasis on the energy performance of new buildings, while strong targets, policies and subsidies promote building energy efficiency retrofits.

If all potential adopters implemented existing energy efficiency technologies, the addressable market size is estimated to be over RMB 500 billion (US$ 77 billion).

There is *very rapid* five-year growth potential for energy efficiency in China. Compliance with national building energy codes rose from 5% or less in 2001 to almost 100% in 2010 for new construction in urban areas. Building energy efficiency retrofit targets in the 12th Five-Year Plan should be similar to those included in the 11th Five-Year Plan, suggesting ESCOs should maintain historical growth rates of approximately 40% in the near term.

Market accessibility is rated as *open with restrictions*. Building energy efficiency is generally open to private companies. However, there may be some restrictions for government and residential buildings, where domestic developers are generally preferred over foreign companies.

Profit opportunities for private companies are rated as *average*. Buyers are fragmented, perhaps with the exception of government contracts. High specialization in energy solutions allows ESCOs to enjoy niche markets and form direct relationships with private owners; however, low electricity rates prevent energy efficiency solution suppliers from offering competitive prices. While government targets for building energy efficiency retrofits are strong, the first subsidies for ESCOs released in 2010 have generally been too small to make a major difference. Energy efficiency retrofit solutions require high upfront investment but ESCOs can help absorb some of the financial risk. Boosted by strong government support, the market for energy efficiency should become more attractive in the medium term.

Green Building Market Attractiveness Assessment—Energy Efficiency		
Assessment Criteria	**Attractiveness**	**Explanation**
Government Support	●	■ Energy reduction targets for new buildings will rise from 50% to 65% ■ Energy quotas will likely be introduced for large public buildings ■ First subsidies for ESCO use were introduced in 2010
Addressable Market Size	◕	■ Market size is estimated to be over 500 billion RMB if all potential adopters used energy efficiency technologies today ■ China adds over two billion square meters of new construction floor space annually ■ Northern urban heating reform and retrofits of large public buildings support the market for existing buildings
Solution Attractiveness	◑	■ Green building cost premiums range between 2-14% with typical payback periods between two to six years in China ■ Government targets, policies and subsidies promote ESCOs
Five-Year Market Growth Potential	●	■ 12th FYP building energy efficiency targets should be similar to 11th FYP targets ■ ESCOs should maintain historical growth rates of roughly 40%
Market Accessibility	◑	■ Building energy efficiency is generally open to private companies whereas there may be some restrictions for government buildings ■ NDRC and MOF have shortlisted foreign ESCOs to receive incentives
Profit Opportunity	◔	■ Buyer power is not concentrated but suppliers have less of an advantage for government-owned buildings ■ ESCOs have direct relationships with building owners and enjoy niche markets ■ Low electricity rates prevent suppliers from being able to offer competitive solutions ■ While government targets for buildings energy efficiency retrofits are strong, the first subsidies for ESCOs released in 2010 are generally too small ■ Energy efficiency retrofit solutions require high upfront investment but ESCOs can help absorb some of the financial risk

Market Attractiveness Assessment Legend

Government Support	Addressable Market Size	Solution Attractiveness
● Highest priority	● Very large	● Advantaged
◕ High priority	◕ Large	◕ Attractive
◑ Medium priority	◑ Medium	◑ Emerging
◔ Low priority	◔ Limited	◔ Disadvantaged
○ No priority	○ Niche	○ Unavailable

Five-Year Market Growth Potential	Market Accessibility	Profit Opportunity
● Very rapid	● Fully open	● Superior
◕ Rapid	◕ Open with restrictions	◕ Above average
◑ Medium	◑ Partially limited	◑ Average
◔ Slow	◔ Limited	◔ Limited
○ Very slow	○ Restricted	○ Challenging

Source: China Greentech Initiative analysis

The market for sustainable materials has enormous potential but growth is slow

Although green building demand is rising in China, green building materials only represent approximately 5% of the total market. The proper integration and installation of sustainable materials also affects the efficacy of green building systems. Incomplete standards, poor enforcement of existing regulations, and supply chain practices that ignore the environment slow the growth of this embryonic market in the near term.

Sustainable materials

Government support for green building materials is rated as *medium priority*. In the 12th Five-Year Plan, New Materials, which includes advanced construction materials, has been named as a Strategic Emerging Industry that will receive public funding.

There is a *very large* addressable market size for sustainable materials in China. Although market penetration is still in early stages, the addressable market size is estimated to be over 600 billion RMB (US$ 92 billion) if all potential adopters used sustainable materials in new and existing buildings today.

The addressable market size for sustainable solutions is over 600 billion RMB (US$ 92 billion).

Solution attractiveness is rated *emerging*. Chinese developers prefer to use cheaper conventional materials rather than more costly green building options. Lagging enforcement of environmental standards across the green building materials supply chain does not support market uptake. Upstream building material suppliers have narrow operating margins and view environmental compliance as an extra cost.

The five−year market growth potential for sustainable materials is *rapid*. Although data on the green building materials market in China are lacking, the quickening rate of green building certifications in China is an instructive proxy, more than doubling each year. While aggressive 12th Five-Year Plan targets for building energy performance will boost green building materials demand, better enforcement of standards across the supply chain is needed.

Market accessibility is seen as *open with restrictions*. Private companies generally have good market access, but domestic developers who dominate the residential market often show a preference for domestic building material suppliers. Due to quality issues, multinational corporations often turn to costly foreign suppliers of green building materials, contributing to higher green building costs in China.

There appears to be *limited* profit opportunities for companies in sustainable materials. Domestic developers choose between numerous supplier bids and make decisions based on price, often at the expense of quality and compliance with standards. Suppliers are small and fragmented while quality issues weaken the value proposition of their products. Environmental certification for many green building materials is met with doubt by industry stakeholders. The proliferation of small suppliers creates heavy competition, which drives down profitability. Government policies targeting sustainable building materials are virtually nonexistent and no reliable resources exist for developers and suppliers of legitimate green building materials to identify one other. The sustainable materials market in China is extremely fragmented and the government needs to step up enforcement to promote growth.

Green Building Market Attractiveness Assessment—Sustainable Materials		
Assessment Criteria	**Attractiveness**	**Explanation**
Government Support	◑	■ New Materials (which mentions advanced construction materials) has been named as a Strategic Emerging Industry that will receive public funding in the 12th FYP
Addressable Market Size	●	■ Market size is estimated to be over 600 billion RMB if all potential adopters used sustainable materials
Solution Attractiveness	◑	■ Developers do not source more costly green building materials due to lagging enforcement and quality issues ■ Upstream building material suppliers have narrow operating margins and generally see environmental compliance as an extra cost
Five-Year Market Growth Potential	◕	■ Certified green building floor space has been growing at a 137% CAGR since 2005 ■ Aggressive 12 FYP targets for building energy performance will boost green building material demand ■ Better enforcement of standards across the green building materials supply chain is needed
Market Accessibility	◕	■ Private companies have good market access ■ Domestic developers dominate the residential market and show a preference for domestic building material suppliers ■ Multinational corporations often turn to costly foreign suppliers of green building materials
Profit Opportunity	◔	■ Domestic developers choose between numerous supplier bids and make decisions primarily based on price ■ Suppliers are small and fragmented while quality issues weaken the value proposition of their products ■ Numerous small suppliers mean heavy competition in the market ■ Environmental certification for green building materials is met with doubt by industry stakeholders ■ Government policies targeting sustainable building materials are virtually nonexistent ■ No reliable resources exist for developers and suppliers of legitimate green building materials to identify one another

Market Attractiveness Assessment Legend

Government Support	Addressable Market Size	Solution Attractiveness
● Highest priority	● Very large	● Advantaged
◕ High priority	◕ Large	◕ Attractive
◑ Medium priority	◑ Medium	◑ Emerging
◔ Low priority	◔ Limited	◔ Disadvantaged
○ No priority	○ Niche	○ Unavailable
Five-Year Market Growth Potential	**Market Accessibility**	**Profit Opportunity**
● Very rapid	● Fully open	● Superior
◕ Rapid	◕ Open with restrictions	◕ Above average
◑ Medium	◑ Partially limited	◑ Average
◔ Slow	◔ Limited	◔ Limited
○ Very slow	○ Restricted	○ Challenging

Source: China Greentech Initiative analysis

The path ahead

China has the opportunity to leapfrog unsustainable development patterns and green building is a crucial part of the solution. Green buildings can benefit developers and owners economically, leading to higher profits, lower costs and greater customer satisfaction; however, many obstacles remain: lack of awareness, conflicting definitions, and misaligned incentives. China's government has already promoted building energy efficiency, and will continue to do so in the 12th Five-Year Plan. Subsidies introduced to date are modest and awareness is still low—policies enacted thus far are a start, but

clearer incentives and better coordination will be needed. The market is in its infancy but findings from the Opportunity Assessments show how companies with a nuanced understanding of this complex, rapidly-growing market can get ahead of the curve.

Expanding the Building Energy Efficiency Retrofit Market through ESCOs

Opportunity Assessment

The market for building energy efficiency retrofits is expanding rapidly, as are government efficiency targets for existing buildings, yet current policies are insufficient, subsidies are still small, and ESCO solutions vary widely by market segment.

An Energy Services Company (ESCO) is a specialized business that provides energy efficiency solutions to industrial or commercial clients on a risk-reward basis over a specified payback period. ESCOs have great potential to improve energy efficiency, but their near-term potential in China is unclear. Over the last five years the building energy efficiency retrofit market has almost quadrupled as government policies support growth. The most important policies affecting ESCOs are targets for urban heating in northern China and energy management of large public buildings; however, progress in these programs is uneven and subsidies for ESCOs are too small to make a meaningful difference. Another challenge is that ESCO services vary widely by market segment. China Greentech Initiative research suggests the most attractive segments for ESCOs include government, SOEs, single-owner offices, supermarkets and hotels.

ESCOs help to address inefficiency challenges in China's buildings

Building quality in China historically has been low, contributing to energy efficiency as a major problem. Structures built in the three decades leading up to economic reforms in 1979 met basic needs but were not intended for long-term use.[44] In the following decades, the Chinese government focused on providing shelter for the burgeoning population as quickly as possible at the expense of quality.[45] Much of the residential property built before 1999 will have to be demolished and rebuilt over the next two decades, representing up to half of the existing building stock in China today.[46] Inefficient coal-fired boilers and district heating pipelines for buildings in northern China contribute to profligate energy waste. In addition, negligence in building maintenance has led to widespread moisture damage and leaky building envelopes across the region. Urban northern China accounts for 40% of total energy consumption while only representing 10% of the nation's living area. [47] All of these issues illustrate the need for policies and services to address energy inefficiency more effectively.

To tackle these challenges in China's existing building stock, the central government actively promotes the building energy efficiency retrofit market. Retrofits can be done directly by the building owner or host, or indirectly through an ESCO. The Chinese government has identified ESCOs as a way to achieve its ambitious energy efficiency goals, issuing a number of policies to spur growth.[48]

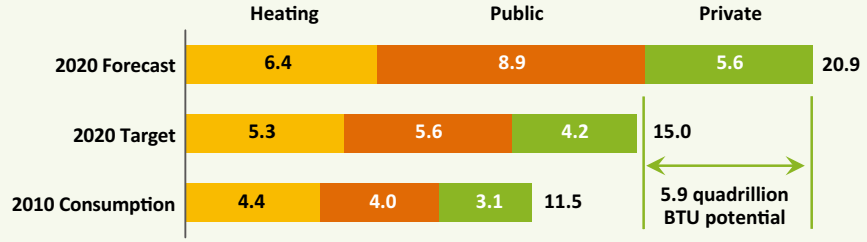
The building energy efficiency market is growing rapidly

With 40% annual growth since 2005, the market for building energy efficiency retrofits has almost quadrupled in size, with investment reaching RMB 6.1 billion (US$ 938 million) in 2009.[49] Yet relative to the addressable market size the industry is in its infancy. Plans call for a reduction in building energy consumption by 5.8 quadrillion

44. "Most homes' to be demolished in 20 years," China Daily, Aug. 07, 2010, www.chinadaily.com.cn
45. "Not Built to Last: China's Overused Wrecking Ball," Time, Nov. 10, 2010, www.time.com
46. "Most homes to be demolished in 20 years," China Daily, Aug. 07, 2010, www.chinadaily.com.cn
47. Kerschberger, Alfred, "Drei Pilotprojekte zur energieeffizienten Sanierung von Mehrfamilienhäusern in Nordchina" [Three pilot projects on energy efficiency refurbishment of apartment buildings in Northern China], Sino-German Technical Cooperation – Energy Efficiency in Existing Buildings Project Output (Beijing, China: GTZ, 2010)
48. State Council , Accelerating the Implementation of Energy Management Contracting and Promoting the Development of the Energy Savings Services Industry (Beijing, China: State Council, 2010)
49. Energy Committee of China Energy Conservation Association, Annual Report on China Energy Service Industry (Beijing, China: EMCA, 2009)

BTUs, or 25% from the official 2020 forecast.[50] MOHURD estimates that the country will need to invest RMB 1.3 trillion (US$ 200 billion) in energy efficiency retrofits from 2010 to 2020 to achieve this target.[51] New government targets and policies should spur additional growth as China continues to incorporate existing building energy efficiency into its energy agenda.

China's Building Energy Consumption Forecast and Target
quadrillion BTUs, 2010 and 2020



Source: 清华大学建筑节能研究中心, "中国建筑节能年度发展研究报告, " *[Tsinghua University Construction Energy Saving Institute, "Annual Report on Construction Energy Saving Development in China"] 2010; MOHURD Minister Qiu Baoxing, "Issues relating to building energy efficiency" (presentation given at the press release after National Congress, 2007)*

ESCO solutions are diverse and vary widely by market segment

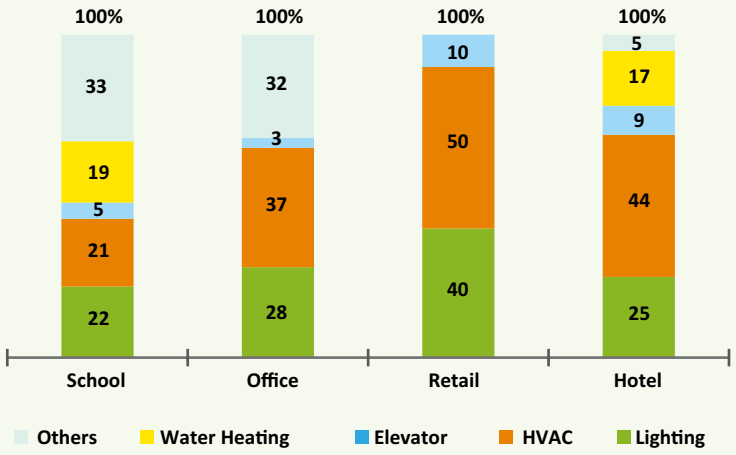
ESCOs offer a range of retrofit solutions which vary in suitability by geographic region and market segment. ESCO solutions are commonly divided into three groups. *Equipment solutions* cover turnkey heating, ventilating and air conditioning (HVAC), as well as lighting technologies; *service solutions* include on-site energy audits; *management solutions* include metering and monitoring. In northern climate regions, central heating systems account for 70% of all heating energy consumption, yet their average thermal efficiency is only 60%, leaving much room for improvement through energy efficiency retrofits.[52] Energy service solutions such as facility auditing, or energy management solutions like meter installation, are well-suited for this climate region. In contrast, equipment providers stand to benefit the most in southern regions where heating loads are met by small appliances such as electric heaters or air conditioners.

Similarly, the structure and rate of energy consumption in a building has important implications for the applicability of ESCO solutions, which vary significantly by building type. A survey of Shanghai and Beijing buildings showed retail stores use twice as much energy per square meter on average than most other building segments.[53] HVAC and lighting systems consume the most energy across all building types, but especially for retail, office and hotel spaces. ESCOs providing equipment solutions can target these building segments.

ESCO business models also influence the attractiveness of solution offerings. ESCOs can address incentive misalignment between building stakeholders by using contract types that optimally distribute financial risks and cost savings. ESCOs generally operate under either the Build Operate Transfer (BOT) or Energy Performance Contract (EPC) business models. The EPC model usually offers either shared savings or guaranteed saving plans to customers.[54] These models have different project financing, risk allocation and savings distribution implications for contract participants.

50. Tsinghua University Construction Energy Saving Institute, Annual Report on Construction Energy Saving Development in China (Beijing, China: Tsinghua University, 2010)
51. Qiu Baoxing, "Issues relating to building energy efficiency," MOHURD Minister (presentation given at the press release after national congress, 2007)
52. Jiang Yi, Current Energy Consumption in Chinese Buildings and Energy Solution Analysis (Beijing, China: Chinese Academy of Engineering, 2009)
53. Shanghai Statistics Bureau, Shanghai Statistical Yearbook, 2009 (Shanghai, China: Shanghai Statistics Bureau, 2009)
54. Note: In the Shared Savings model, the ESCO generally provides or arranges for most or all of the financing needed for the implementation of the project. The Energy Savings Performance Contract specifies the sharing of the cost savings between the Energy Savings Provider and the host facility over a period of time. The sharing of the payments is structured such that the Energy Savings Provider will recover its implementation costs and obtain the desired return on its investment within that period; in the Guaranteed Savings model, the customer generally takes the loan on its own balance sheet. The ESCO guarantees certain performance parameters (such as efficiency, energy savings, cost savings, and/or other performance parameters) in the Energy Savings Performance Contract, which specifies the methods for M&V, and payments are made once the project performance parameters have been confirmed.

Beijing's Energy Structure by Building Type, percent, 2009



Source: 清华大学建筑节能研究中心, "中国建筑节能年度发展研究报告," *[Tsinghua University Construction Energy Saving Institute, "Annual Report on Construction Energy Saving Development in China"] 2010*

Government programs support ESCO growth but progress is uneven

Given the enormous potential, the government is eager to cultivate the building energy efficiency retrofit market. The release of the 20% energy intensity reduction target in the 11th Five-Year Plan heralded new policies, and the pace of new energy efficiency policies has only quickened since then. The government released the first sector-specific subsidies in 2010, with the most relevant policies to the energy efficiency retrofit market including urban heating reform in northern regions, energy conservation in large public buildings, and the introduction of subsidies to promote ESCO use.

In 2008, the government mandated the retrofit of inefficient district heating systems covering 150 million square meters of building area across 15 provinces and 24 demonstration cities in northern China, to be completed by the end of the 11th Five-Year Plan period.[55] Retrofits include building envelope upgrades and heat meter installations at residences, and heat source and distribution network improvements. According to official tallies, 150 million square meters underwent retrofits by the end of 2010, ostensibly achieving targets set forth in 2008, but certain regions show inconsistent progress. Jilin is one of only three provinces that met provincial targets, pumping RMB 570 million (US$ 88 million) into retrofit projects in 2009 alone. Progress on heat meter installation targets leaves much to be desired: only 46 million square meters, or 10% of new construction area and 23% of floor space in demonstration cities have installed heat meters.[56]

The government more actively drives demand for ESCO solutions through its national program Energy Management of Government Office Buildings and Large-Scale Public Buildings. This program targets buildings that have at least 20,000 square meters of floor area and encompasses primary audits for main building components such as HVAC systems, secondary audits for building sub-systems like lighting, and data analysis platforms to gather information on energy use. To date, government departments in 24 provinces and cities have conducted audits of large government buildings. Energy management programs, including primary and secondary audits, are occurring in demonstration cities alongside a rollout of data analysis platforms.[57]

55. 中华人民共和国住房和城乡建设部、财政部,"关于推进北方采暖地区既有居住建筑供热计量及节能改造工作的实施意见,建科 *[MOHURD, MOF, "Advice on accelerating heat metering and energy efficiency retrofit in existing buildings in northern district heating regions, Jianke No.95"] 2008*

56. China Greentech Initiative analysis

57. 中华人民共和国住房和城乡建设部," 国家机关办公建筑和大型公共建筑能源审计导则," *[MOHURD, "Guide on Energy Audit of Government Building and Large Public Building"] 2007;* 省级建设厅,"省级能源审计暂行办法," *[Provincial Construction Bureau, "Temporary Methods for Energy Auditing in Provinces"] 2009*

For example, primary and secondary audits were completed for 150 out of 774 public buildings in Beijing by the beginning of 2009, and the China Academy of Building Research in Beijing currently operates a data analysis center.[58] This program opens up new opportunities for energy meter suppliers, although the average installation contract is no more than RMB 150,000 (US$ 23,077).[59] Metering provides the foundation for Energy Management Solutions (EMS), or software packages that analyze real-time energy consumption data and measure energy savings. EMS technology is easily integrated with building automation systems (BAS), but currently less than 5% of BAS systems in China include EMS.[60]

During the 12th Five-Year Plan period, the government will likely introduce a building energy quota to cap energy use in large public buildings. This will require more rigorous monitoring and data collection than the current program, creating new business opportunities for ESCOs. Shenzhen is expected to be the first city to launch this energy quota scheme, with Beijing and Shanghai to follow shortly after.

Investors can only expect to recover up to 7% of the upfront cost through subsidies on ESCO projects providing BAS solutions.

Existing subsidies for ESCOs are too small to matter

To implement policy objectives released by the State Council earlier in the year, NDRC and MOF issued incentives to promote ESCOs on June 3, 2010: Interim Measures on Management of Financial Incentive Funds for Energy Management Contracting Projects. Incentives for Energy Management Contracting (EMC) projects include subsidies covering all sectors, the ability to pledge fixed assets from energy efficiency retrofits for bank loans, tax exemptions and reductions, and clarification of accounting procedures.[61] In 2010, authorities shortlisted 461 eligible ESCOs.[62] Projects can receive RMB 240 (US$ 36.92) in central funding per avoided ton of coal equivalent, while provincial governments must provide at least an additional RMB 60 (US$ 9.23) per avoided ton of coal equivalent. Local governments are encouraged to supplement subsidies. Total project funding is a modest RMB 200 million (US$ 31 million) with a cap of RMB 3 million per year per project.[63]

Government incentives will likely have only a moderate impact on the ROI for energy efficiency retrofit investments. Investors can only expect to recover up to 7% of the upfront cost through subsidies on ESCO projects providing BAS solutions.[64] In addition, to meet minimum requirements in energy savings for program eligibility, retrofitted floor space must be very large: 12,000 square meters for universities, 6,667 square meters for offices, and 4,800 square meters for shopping malls. Other barriers exist for ESCOs: in Guangzhou for example, there have been instances where incentives are only given to locally-registered ESCOs.

Attractive building segments and technologies for ESCOs

ESCOs can substantially improve the energy efficiency of China's existing building stock, an increasing priority for the Chinese leadership. Energy service and management solutions may be more suitable for northern regions where heating systems are complex, whereas equipment providers may prosper more in southern climates where simple technologies can have a greater impact. Energy consumption patterns vary by building type, location and other factors, which also influence the suitability of ESCO solutions. Government and SOE facilities, single-owner offices, supermarkets, hotels, and data centers are attractive building segments for energy efficiency retrofits. These buildings consume huge amounts of energy, experience

58. 中国建筑科学研究院环境与节能研究院,"北京大型公建节能监测平台建设," *[Research Institute of Environment and Energy Saving, CABR, "Energy Auditing Platform Construction for Large Public Buildings in Beijing"] 2008*

59. 北京市建设委员会办公室," 关于做好大型公共建筑能源审计及用电分项计量工作的通知," *[Beijing Construction Commission Office, "Notification on Energy Audit and Secondary Energy Metering for Large Public Buildings"] 2008*

60. Yuan Li, BAS Market Report for China (China: BSRIA-Proplan, 2010)

61. 国务院办公厅,"关于加快推行合同能源管理促进节能服务产业发展意见," *[The General Office of the State Council, PRC, "Accelerating the Implementation of Energy Management Contracting and Promoting the Development of the Energy Savings Services Industry"] Apr. 2, 2010*

62. 财政部办公厅、国家发展改革委办公厅," 关于合同能源管理财政奖励资金需求及节能服务公司审核备案有关事项的通知（财办建*60*号）," *[MOF, NDRC, "Notification on Issues Relating to ESCO Subsidies and ESCO Certification Approval"] 2010*

63.中华人民共和国发改委、财政部,"合同能源管理项目财政奖励资金管理暂行办法," *[NDRC, MOF, "Interim Measures on Management of Financial Incentive Funds for Energy Management Contracting Projects"] Jun. 2010*

64. CICC, State Council Support Set to Fuel Growth Of Energy Management Companies (Beijing, China: CICC, Jun. 2010)

constant demand, and require technical assistance, and they usually have a single owner who is responsible for the energy bill, making it easier to implement retrofits.

Accelerating Green Building Materials Adoption through Supply Chain Practices

Opportunity Assessment

Incomplete industry standards and metrics, poor enforcement of existing regulations, and supply chain practices that ignore the environment define China's fledgling green building materials supply chain; however, sustainable sourcing practices and value chain partnerships offer opportunities for stakeholders.

Despite rising green building demand in China, green building materials currently represent only 5% of the total market. Building code enforcement is uneven, giving developers little incentive to source legitimate green building materials. Most upstream building materials suppliers are small-to-medium enterprises（SMEs）and family-owned businesses that may certify materials with authorities but don't always comply with requirements. Nevertheless, environmental criteria in sourcing and value chain partnerships offer opportunities for stakeholders to move the entire market forward.

Green Building Materials Supply Chain Definition

Environmental concepts such as green building, green building material and green supply chain are relatively new and not well-defined in the marketplace.[1] The China Greentech Initiative defines a "green building material" as having a net positive environmental impact over conventional alternatives. To assess the life cycle impact of building materials from raw material extraction through end-of-life recovery, we developed a model highlighting essential supply chain processes and their environmental implications.[2]

1. Ashenbaum, Bryan, "Green" Corporate Strategies: Issues and Implementation from the Supply Management Perspective (Tempe, AZ: CAPS Research, 2008)
2. Note: using the Supply-Chain Operations Reference-model (SCOR), a cross-sector industry standard for supply chain management developed by management consulting firm PRTM and endorsed by the Supply-Chain Council (SCC), the China Greentech Initiative created a model for the green building materials supply chain, highlighting essential supply chain processes and their environmental implications

China's Green Building material supply chain is embryonic

A mature market usually has a sophisticated supply chain. The U.S. has a relatively mature green building market whereas the China market is just beginning to develop. The difference is evident in the scale and composition of the green building materials supply chain in each respective country. China's green building materials market is one-third the size of the U.S. market in absolute terms and represents only 5% of the total materials market in China.[65] This difference in green building material availability contributes to the divergent average cost of green buildings in each country. Estimates suggest cost premiums average 2% in the U.S. while they can reach as much as 14% in China.[66] Today, total green building floor space in China represents less than 0.5% of new urban construction floor area per year.[67] China Greentech Initiative research suggests that wider availability of green building materials is a prerequisite for a healthy market. Numerous supply chain problems hamper green building materials in China, but steps can be taken to accelerate the market.

65. GCiS China Strategic Research, Assessment of China's Market for Green Building Materials (Shanghai, China: GCiS Limited Publication, 2009)
66. Kats, Greg, Greening Our Built World: Costs, Benefits, and Strategies (US: Island Press, 2009); 中国建筑科学研究院上海分院,"国内绿色建筑的造价成本调查和分析," [Shanghai Branch of the China Academy of Building Research, "Investigation and Analysis on Construction Cost of Green Building in China"] (Shanghai, China: China Academy of Building Research, April 18, 2008)
67. China Greentech Initiative analysis

Industry definitions and standards for green building materials are lacking

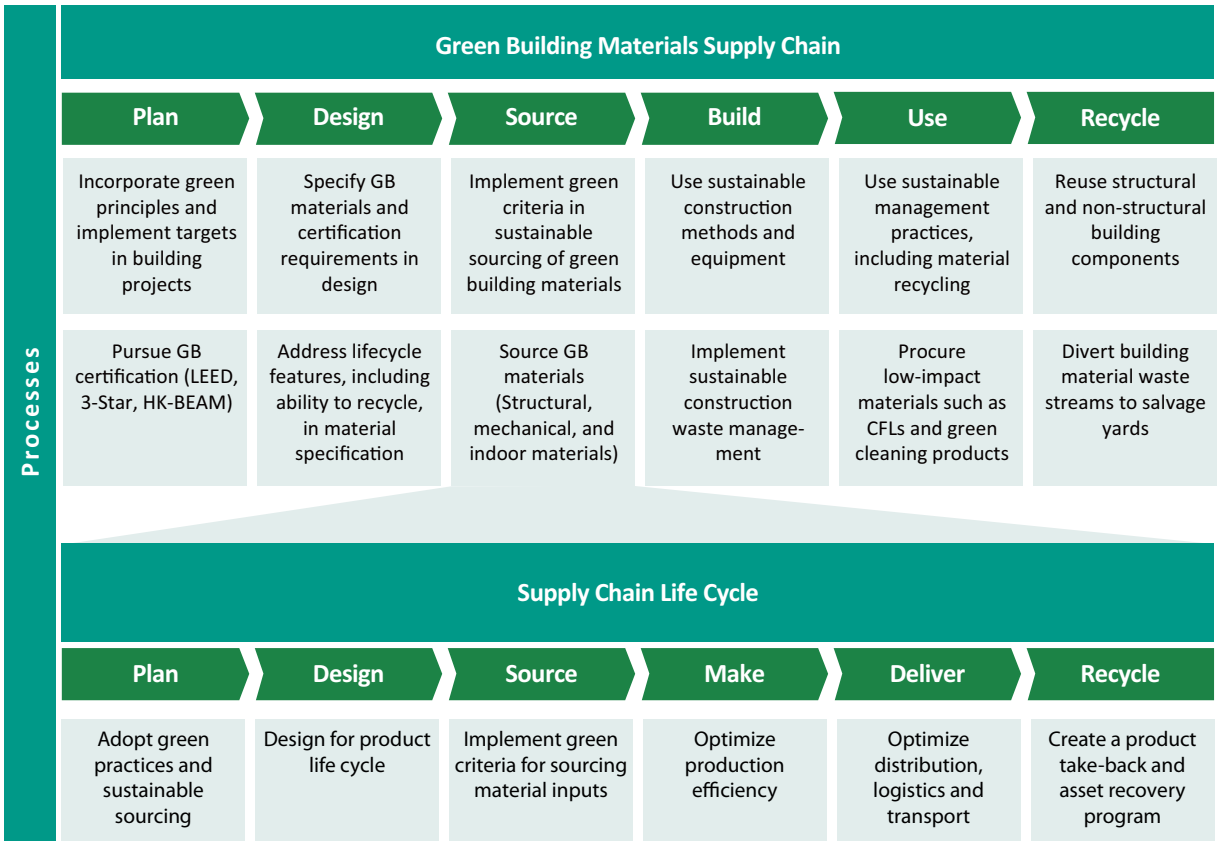
Existing standards in China fall short of addressing life cycle aspects of building materials and do not sufficiently clarify the definition of green building materials. Mandatory building codes and standards only address the environmental performance of building materials indirectly, while dominant green building certification schemes provide little further direction. A range of central, provincial and municipal government agencies issue policies that impact building materials at different points across the supply chain.[68] This reflects the central importance of building materials, which impact the safety, health, energy and environmental performance of buildings.[69] Regulations address green building materials in different ways:[70]

- MOHURD issues energy performance standards for buildings that have the most direct link to green building materials, but energy measurements are made for the whole building and do not differentiate between individual building components.
- MOHURD is also responsible for mandatory building codes that determine design standards for architects, specifying physical and chemical properties for building materials to prevent fire hazards and protect occupant health.
- NDRC and the Ministry of Environmental Protection (MEP) determine industrial energy efficiency standards that influence raw material extraction and manufacturing processes for building components such as steel and cement, affecting their emissions profile.
- The General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) and similar authorities determine industry-specific standards that assign testing methods for building materials manufacturing.

Aside from a lack of clarity in government standards, ambiguities also arise from green building certification schemes. The dominant green building certification schemes in China are the U.S. LEED and Chinese 3-Star systems, which have different interpretations on the attributes of green building materials.[71] Similar material requirements may be covered under different categories in each rating scheme, while some requirements may be absent altogether. For example, rapidly renewable materials and certified wood have quantitative targets in LEED but are ignored in 3-Star.[72] In general, China's domestic green building certification system is less strict than international counterparts when it comes to building materials. However, China Greentech Initiative partners noted in the 2010 working sessions that all current certification systems lack methods to rate green building materials by their life cycle environmental impact or their effect upon building energy efficiency.

The lack of industry standards and metrics on how to measure and communicate the financial, environmental and social benefits of competing green building materials contributes to overall market fragmentation. Without methods to quantify the relative environmental performance of suppliers, developers have little means to identify green building material suppliers or verify the integrity of their products. As a result, stakeholders throughout the green building value chain are not working together to bring down costs, and corporations seeking green building certification must often turn to more expensive foreign suppliers.[73]

68. Lawrence Berkeley National Laboratory, 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)
69. Lal, Abhishek and Qian Yingchu, "Green Building Trends in China," BusinessForum China, Apr. 2007, www.bdchina.de
70. Lawrence Berkeley National Laboratory, 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); Hao Bin, "Building Energy Efficiency Evaluation and Labeling," (presentation given at the informal session of the European Council for an Energy Efficient Economy 2009 summer study proceedings, Colle Sur Loop, France, June 5, 2009); China Greentech Initiative analysis
71. China Greentech Initiative analysis
72. U.S. Green Building Council, LEED 2009 for New Construction and Major Renovations Rating System (Chicago, IL: U.S. Green Building Council Inc., 2009); 中华人民共和国住房和城乡建设部建筑节能与科技司,"全国绿色建筑创新奖获奖项目名单,"[Bureau of Building Energy Efficiency and Technology, MOHURD, "List of Awardees of National Green Building Innovation Projects"] 2009-2010
73. China Greentech Initiative interviews



Source:China Greentech Initiative analysis

Low enforcement of existing standards creates little incentive

While standards may exist, lapses in enforcement and compliance undermine the market. At the final stage of construction before occupancy, some developers report auditors rarely perform mandatory material sampling. Large developers have been known to specify building material suppliers for contractors to use even though contractors are legally responsible for meeting building material standards. Small upstream suppliers may submit samples of their product to the local environmental protection bureau or other authorities for laboratory testing, but the actual material inputs and processes used in factories may contradict test results. These practices throw the legitimacy of green building materials into doubt, as green building materials may not have been manufactured in accordance with environmental standards. Indeed, lack of enforcement gives developers little incentive to source environmentally-friendly building materials, which often have a higher initial cost, and instills little confidence in the environmental quality of green building materials, giving buyers little reason to purchase green buildings. As a result, availability and domestic production capacity of legitimate green building materials remains low in China.[74]

Developers and building materials suppliers pay little attention to environmental standards

Chinese developers are driven to build the greatest amount of floor space in the shortest period of time. As urbanization accelerates, the overwhelming demand for new floor space incentivizes quantity and speed over quality. In such an aggressive environment, developers select suppliers for the price of their materials and their ability to deliver on time. Using environmental principles in supplier selection is a new concept for most Chinese developers, who will readily switch suppliers to meet construction targets. [75]

74. China Greentech Initiative interviews
75. Ibid.

Upstream building material suppliers tend to be SMEs and family-owned businesses with narrow operating margins. Their decisions are driven by margins, and environmental compliance is generally seen as an extra cost. While environmental certification is an important means for these suppliers to broaden their market reach, certification doesn't always translate into compliance. For this reason, Chinese companies readily seek ISO 14001 certification to do business with multinational corporations, but foreign companies often question the validity of this certificate in China.

The Sustainable Indoor Environment market needs better enforcement and integrated solutions to develop further.

For the majority of Chinese developers and suppliers, supply chain management is a relatively new concept, and incorporating environmental criteria into sourcing practices is virtually nonexistent, whether in selection of suppliers or material inputs. Typically, developers and suppliers do not measure or track environmental metrics such as energy and fuel consumption, water use or emissions. This prevents them from recognizing how to reduce costs by improving environmental performance. These stakeholders are also fairly adverse to upfront investment, even if gains in operational efficiency can reduce overall costs.[76]

Environmental criteria in sourcing and value chain partnerships can move the market forward

Despite these challenges, opportunities exist for companies willing to lead the market. Developers and building material suppliers can incorporate environmental principles into sourcing strategies, while developers can implement environmental criteria in supplier selection and create a sustainable code of conduct. Supplier questionnaires, scorecards and periodic site audits are some of the methods developers can use to standardize supplier screening. These measures can express clear demand for suppliers of legitimate green building materials. Suppliers can measure predefined environmental metrics such as energy and fuel use, water consumption, and direct and embedded emissions to reveal operational inefficiencies, and then use the data to identify cost-effective ways to reduce environmental impact and communicate environmental performance to buyers, thus driving brand recognition.

Developers and other buyers throughout the supply chain can offer incentives such as purchasing agreements or long-term contracts, or enter into cost-sharing programs with suppliers to accelerate market growth. Suppliers can collaborate and form supplier networks to share best practices and offer integrated green building solutions. For example, insulation, window, roofing and HVAC suppliers can collaborate to offer integrated building envelope and HVAC solutions, and communicate the environmental and financial benefits to developers. These value chain partnerships can help drive down overall costs in the green building materials market.

Rapidly Improving Market for Sustainable Indoor Environment Solutions

Opportunity Assessment

Indoor air quality (IAQ), thermal efficiency and energy efficiency are aspects of the sustainable indoor environment (SIE) that have green building solutions with considerable market potential in China, yet uneven standards and weak enforcement prevent the market from reaching its full potential.

SIE, which affects human health and productivity as well as the environment, is influenced by a number of factors, including IAQ, thermal efficiency and energy efficiency. Solutions addressing these factors, such as air purification, floor heating and energy efficient lighting technologies, have markets that are relatively well-developed or are improving quickly. As with green building materials, a major challenge for SIE is weak enforcement of existing standards. Other issues preventing the SIE market from maturing include lack of motivation, design process difficulties, lack of reliable products and services, and low market awareness. Better enforcement and integrated solutions are needed for the SIE market to develop further.

76. China Greentech Initiative interviews

Indoor air quality, thermal efficiency and energy efficiency are attractive SIE markets

Indoor environments are influenced by a number of factors, such as IAQ, thermal comfort and illumination. These all affect health, productivity and the natural environment.[77] Various building materials and remediation equipment can improve environmental performance in these areas, each with unique market characteristics in China. China Greentech Initiative partners identified IAQ, thermal efficiency and energy efficiency as factors with relatively attractive green building solutions. The IAQ and floor heating markets are relatively mature, while lighting is improving rapidly.

Technologies that regulate IAQ are increasingly popular in China. The market for air purifying solutions grew to RMB 8 billion in 2009, up 14.6% from 2008, according to the China Interior Decoration Association.[78] Air pollutant removal technologies include static electricity, activated carbon and photo catalyst systems. They may be standalone products or used in conjunction with air filtration components of air conditioning and ventilation systems. Air purification technologies have less than 1% market penetration in China and mainly cover public buildings. By contrast, residential penetration rates in Japan, the U.S. and Europe are 17%, 27% and 42% respectively, suggesting the large potential size of the market.[79] Indeed, China's urban residents face much greater ambient air quality problems, giving them more motivation to implement these solutions compared with residents in developed countries. Integrated air purifying technologies which eliminate pollutants and replenish oxygen represent another promising market.

Cooling and heating technologies through wall, floor or ceiling radiation are also gaining traction in the marketplace due to increased comfort and energy efficiency. Floor heating has replaced radiators as the primary choice for heating, while radiant air conditioning, or cooling delivered through capillary tubes in drywall and ceiling panels, remains underdeveloped. More than 80% of new residential buildings in northeast China now use floor heating instead of radiators. The total heating floor market grew to RMB 18 billion (US$ 2.8 million) in 2009, up 20% from 2008, with rapid growth concentrated in eastern China; however, the market penetration of capillary air conditioning systems remains small due to high cost and limited applicability in the retrofit market.[80]

Low consumer awareness restricts market development.

Smart lighting (automated lighting systems that use wireless networks and intelligent remote systems to regulate indoor lighting) is an attractive emerging technology in energy efficient illumination, with primary benefits including better use of natural light, automatic dimming and user programmability. Although the market has been growing steadily from RMB 4.9 billion (US$ 754 million) in 2005 to RMB 13.7 billion (US$ 2.1 billion) in 2009, smart lighting is still at an early stage of development in China.[81] Market development is restricted by factors such as high installation costs, low consumer awareness, and undeveloped distribution channels.

China's market for SIE solutions shows signs of overall growth

While specific figures on the size of China's SIE market are difficult to estimate, other indicators point to enormous market potential and overall growth. The interior fit-out market in China is a useful barometer for the market potential of SIE solutions. The total China interior fit-out market reached RMB 1.85 trillion (US$ 285 billion) in 2009, consisting of 180,000 companies with a total of 14 million employees, according to the China Building Decoration Association.[82] Turnover for fit-out contractors

77. "Effects of Green Buildings on Employee Health and Productivity," American Journal of Public Health, Jul. 15, 2010, ajph.aphapublications.org
78. Song Guangsheng, "Issues Relating to Sustainable Indoor Environment," Indoor Air Quality Monitoring Association (presentation given on First International Indoor Environment Safety and Health Forum during World Expo, Shanghai, China, Oct. 22, 2010)
79. Broad Group, "Indoor Air Quality Management" (Changsha, China: Broad Group, 2010)
80. Yuan Li, Market Report for China Heating and Air Conditioning (Berkshire, U.K.: BSRIA-Proplan, 2010)
81. Research in China, China Smart Lighting Market Report (Beijing, China: Research in China, 2009)
82. Zhang Zhonglin, "Development of Chinese Building Decoration Market," China Building Decoration Association (presentation on press release of carpenter exhibition, Beijing, China, 2008)

has been rising dramatically due to climbing wages and material prices, increasing threefold from 2005 to 2009. Underlying market drivers include abundant new floor area, which grew more than 15% annually from 2007 to 2009, more spending on interior design as disposable incomes increase, and the rising price of indoor decoration materials. Higher raw material costs contributed to price hikes in 2010. For example, in the third quarter of 2010, it was reported that wallpaper prices grew by 10% and furniture prices increased by 10-20%.

Another noteworthy development is the Kangju Initiative, introduced by MOHURD in 1999 to promote integrated solutions in the residential market through certified demonstration projects. This program aims to strengthen research on residential building technologies, develop new building solutions and improve management systems. Roughly 200 residential projects were Kangju-certified in 2010, with 70-80% located in second-tier cities.[83] SIE solutions naturally complement Kangju projects due to their integrated approach; 35 out of 116 recommended integrated solutions are already closely related to the indoor environment. Jiangsu, Shandong, Zhejiang and Shanghai are the top four administrative areas where Kangju projects are located, accounting for nearly 50% of the nationwide total.[84]

Uneven standards and weak enforcement prevent the SIE market from reaching full potential

The diversity and complexity of regulations relevant to the indoor environment, some of which are mandatory while others merely voluntary, creates significant challenges for China's SIE market. There are many mandatory and voluntary standards on building performance and materials related to sustainable indoor environments. Government authorities regularly issue banned material mandates, while AQSIQ defines national compulsory material standards relating to harmful substances. MOHURD issues compulsory building codes and standards addressing design aspects for thermal engineering, energy efficiency and lighting. Voluntary directives and standards on indoor environmental performance, integrated design and advanced technologies are more relevant to SIE, but are elective criteria. Within standards, there are various confusing procedures, metrics and benchmarks.[85] At least nine distinct standards with unique metrics and evaluation systems apply to the indoor acoustic, thermal and illumination environment.[86] Indoor noise and natural lighting guidelines vary with building and room type, climate conditions and time of day. [87]

Standards are useless if enforcement is weak. Across all existing standards, lagging enforcement in monitoring and inspection depresses market uptake. Although fire and safety inspections are consistently done before occupancy, mandatory testing on indoor environmental quality varies in practice. Environmental testing and certification have garnered little credibility among end-users and the reliability of testing agencies has been put into question. As a result, developers have little motivation to adopt SIE concepts.

In addition to regulatory challenges, other issues constraining SIE include design difficulties, lack of reliable products and services, and low market awareness. Sustainable indoor environment solutions are often not integrated in the building design, undermining their potential value. A fragmented market in SIE suppliers prevents developers from procuring solutions and establishing distribution channels, while contractors are unfamiliar with SIE concepts and practices. Lack of end-user awareness and education can lead to improper installation, maintenance and operation of SIE technology.

83. "Kangju Initiative," Center for Housing Industrialization, www.chinahouse.gov.cn, accessed on Dec. 2, 2010
84. 中华人民共和国住房与城乡建设部，"国家康居住宅示范工程成套技术量化评价指标，" *[MOHURD, "Technical Indicator of Quantifying Integrated Solutions for National Kangju Initiative Projects"] 2010*
85. China Greentech Initiative interviews
86. 洪学斌，"最新建筑设计标准大全，" *[Hong Xuebin, "The Latest Compilation of Building Design"] 2007*
87. 中华人民共和国住房与城乡建设部，"建筑隔声评价标准，" *[MOHURD, "Code for Design of Sound Insulation of Civil Buildings"] 2005;* 中华人民共和国住房与城乡建设部，"建筑采光设计标准," *[MOHURD, "Design Standard for Building Illumination"] 2001*

Some SIE markets are already promising but integrated solutions can accelerate the market further

SIE solutions that address IAQ, thermal efficiency and energy efficiency have the most potential in China, as seen in the air purification, floor heating and lighting markets. But the sheer quantity of standards influencing indoor environments is confusing, and spotty enforcement of existing standards weakens the market. To overcome these and other barriers the government needs to issue regulations that are simple to understand and ramp up enforcement; otherwise, the industry must determine and enforce its own standards. By working together, developers and SIE solution providers could develop integrated solutions to accelerate the market.

Green Building Opportunities for 2011

This chapter provides an update of China's Green Building sector and three Opportunity Assessments prioritized by the China Greentech Initiative's partners and advisors in 2010. As the sector evolves, participants in the China Greentech Initiative Partner Program will continue to collaborate on additional opportunity areas. The first topic in 2011 covers optimal green building design in China. Other topics may include green building cost analysis, building waste management, prefabricated building materials, water efficiency, building integrated renewable energy, and combined heat and power. The China Greentech Initiative will also continue to track the overall evolution of China's Green Building sector.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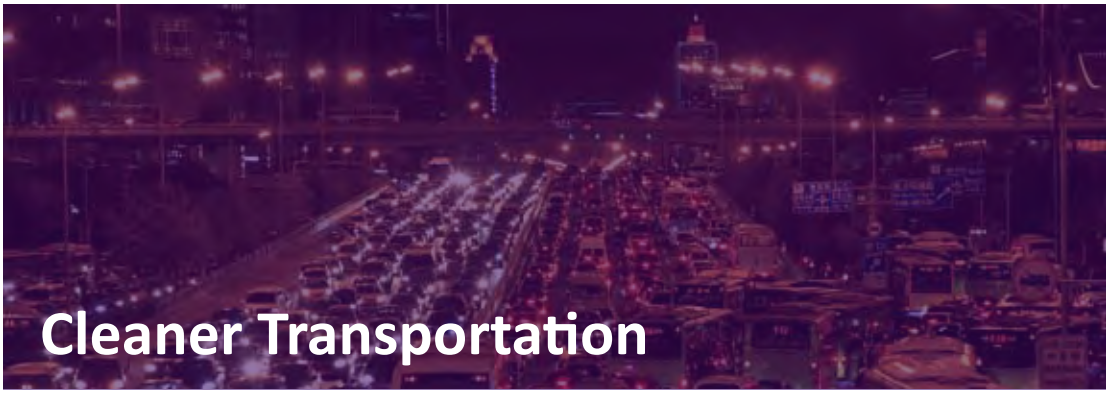


Cleaner Transportation

To address growing problems with traffic congestion, energy efficiency, emissions and energy security, China is pursuing diverse cleaner transportation solutions ranging from alternative fuels to electric vehicles.

Rapid growth of China's transportation sector has led to major issues, including vehicle emissions, oil use and road congestion. As with other greentech sectors, the government has adopted ambitious programs and targets to address these issues and pave the way for industry leadership in areas considered strategic for China's future development. Although China has already far exceeded the high-speed rail accomplishments of many developed countries, the central government has ambitious plans to expand the industry further. Government, industry and private investors are making sizable investments in the early-stage development for electric vehicles, batteries and alternative fuels; however, the government's aggressive targets may prove unrealistic.

This chapter begins by providing an overview of Cleaner Transportation sector developments since the publication of *The China Greentech Report 2009*. It then summarizes four Opportunity Assessments developed by the China Greentech Initiative in collaboration with partners and advisors during 2010:

- China's Emerging Electric Vehicle Ecosystem
- Electric Vehicle Battery Market Evolution
- Alternative Fuels for Road Transportation
- Rapid Growth in Cleaner Rail

The China Greentech Initiative's partners and advisors prioritized each of these Opportunity Assessments as critical to the growth of China's Cleaner Transportation sector over 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 the organizations participating in the China Greentech Initiative Partner Program. The chapter concludes with an outlook on additional opportunities and issues in the Cleaner Transportation sector that the China Greentech Initiative plans to explore during 2011.

The writing of this chapter was led by Joel Rosen and Giuseppe Parente, based upon strategic research deliverables completed by Lixuan Zhou (周丽璇) and Joel Rosen of the China Greentech Initiative's Cleaner Transportation sector research team.

Cleaner Transportation Sector Definition

The China Greentech Initiative 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 waterway. In 2010, the China Greentech Initiative focused on road transport, which includes efficient powertrains, cleaner fuels, electric vehicles and road networks, and rail transport, which includes electrification of railways and low-emissions locomotives, as well as high-speed rail. For a more in-depth definition and explanation of existing and emerging Cleaner Transportation solutions, refer to the Cleaner Transportation chapter of *The China Greentech Report 2009*.

Market Update

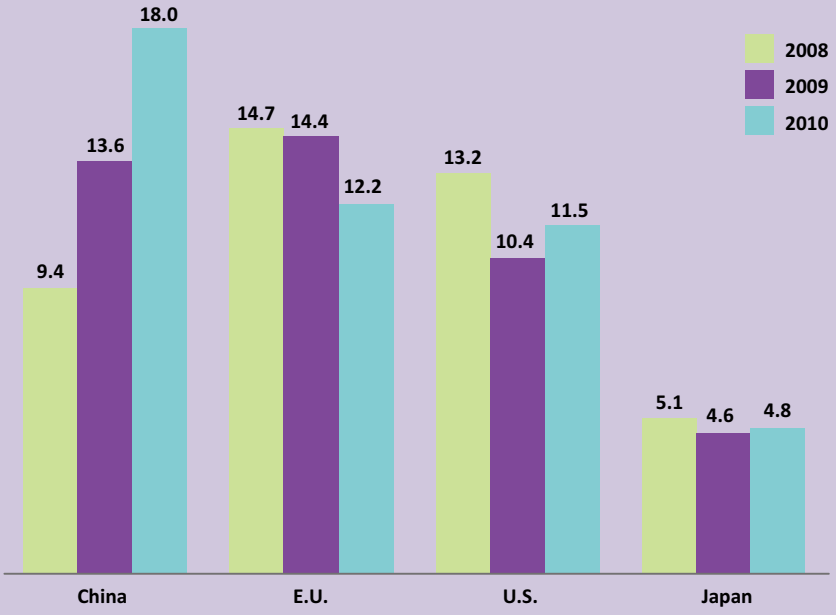
Cleaner Transportation solutions face various challenges throughout various stages of development

The rapid growth of China's transportation sector has led to dependence on foreign oil, rising emissions, choking traffic jams, and an endless appetite for new infrastructure. To solve these problems, policy-makers are turning to Cleaner Transportation solutions, especially electric vehicles and the advanced batteries to power them, alternative fuels and cleaner rail networks. Each is at a different stage of development and faces specific challenges that need to be addressed to help realize China's vision of cleaner, technologically advanced vehicles and transportation networks.

Rapid growth in auto ownership

China has the largest and fastest growing auto market in the world. Whereas auto markets in the U.S., Europe and Japan saw declining sales between 2008 and 2010, China's vehicle sales volume grew 38% annually, nearly doubling in just three years. China's sale of 18 million vehicles in 2010 makes it the largest automotive market in the world by volume.[1] This growth is reflected on China's roads and highways: China had approximately 74 million vehicles on the road by the end of 2010, and the fleet is expected to exceed 200 million by 2020.[2] Given that in 2008 China's overall vehicle ownership level was just 38 vehicles per 1,000 people, compared to 815 vehicles per 1,000 in the U.S., auto ownership seems certain to continue its rapid expansion.[3]

Vehicle Sales in Four Major Markets, millions of units, 2008-2010



Source: National Bureau of Statistics of China, China Statistical Yearbook, 2008 (Beijing, China: National Bureau of Statistics of China, 2009); China Greentech Initiative analysis

1. Patti, Waldmeir, "China car sales stay in the fast lane," Financial Times, Jan. 4, 2011, www.ft.com; China Greentech Initiative analysis. Note: Figures discussed here include on-road passenger vehicles such as cars, minivans and SUVs, and commercial vehicles such as buses and trucks.

2. "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, Feb. 21, 2011, http://news.chinacars.com

3. Yu, Yimin, et al., Energy Challenges the Automobile Industry Faces in China (U.S.: International Association for Energy Economics, 2010)

Mounting challenges propel new policies for Cleaner Transportation

While growing car use reflects China's rising living standards, it comes at a cost, particularly in terms of ever-increasing oil demand. Assuming continued reliance on fossil fuel-powered vehicles, China's oil demand could reach an estimated 15 million barrels per day by 2030, compared to 8.3 million barrels in 2009.[4] Vehicles already use roughly a third of all oil consumed, a proportion which will expand as the number of vehicles on China's roads increase.[5] China now imports more than half its oil supplies, making energy security a major impetus for improved transportation efficiency and use of alternative fuels.[6]

Auto emissions account for an estimated 79% of carbon monoxide (CO) and other hydrocarbon pollutants in urban areas.

Burgeoning car use has had a huge impact on quality of life in China, particularly with respect to the environment and traffic congestion. According to the Ministry of Environmental Protection (MEP), auto emissions as far back as 2005 accounted for an estimated 79% of carbon monoxide (CO) and other hydrocarbon pollutants in urban areas.[7] With nearly three times more vehicles expected on the roads by 2020, the situation is certain to worsen without aggressive steps by government and industry. Traffic congestion is also on the rise, with average rush-hour speeds on major roads in Beijing and Shanghai dropping to as low as 10 kilometers per hour.[8] Motor vehicle accidents have become one of the leading causes of fatalities for people aged 15 to 44.[9]

In response to worsening pollution and traffic, the government implemented nationwide fuel economy and emission standards, set limits on new vehicle registrations, and restricted vehicle usage in major cities such as Beijing and Shanghai. China's existing fuel economy standards of eight liters per 100 kilometers (29.4 mpg) for light-duty vehicles, currently ranked third in the world behind Japan and the E.U., will be tightened to 6.9 liters (34.1 mpg) by 2015.[10] Nationwide vehicle emission standards are already equivalent to the Euro III level, and will be ratcheted up to Euro IV in 2011. Building on its existing restrictions that only allow car owners to drive on certain days of the week, Beijing adopted strict license plates quotas for 2011, limiting new registrations to 240,000 motor vehicles annually.[11] The government is also considering a vehicle emissions tax, likely to be implemented in 2013.[12] There is speculation that other cities may follow Beijing's lead to cope with mounting traffic congestion and pollution problems.

Ambitious plans for high-speed rail

China intends to use high-speed rail to improve the country's strained rail network and provide attractive alternatives to road and air travel for the hundreds of millions of commuters and long-distance travelers across the country. China has the second largest railway system in the world after the U.S.; however, with rapid economic growth, pressure is mounting on the existing infrastructure. China's rail passenger network is losing market share to highways for short-to-medium distance travel and to air transportation for long-distance travel.[13] In contrast, railway utilization rates for freight are the highest in the world—not surprising considering that 85% of China's wood and oil, 80% of steel, and 60% of coal are transported

4. "International Energy Outlook 2010," U.S. Energy Information Administration, Jul. 27, 2010, www.eia.doe.gov; U.S. Energy Information Administration, "International Energy Statistics," http://www.eia.doe.gov/
5. He, K., et al., Oil consumption and CO emissions in China's road transport: current status, future trends, and policy implications (Energy Policy, Vol. 33, no. 12, 2005)
6. "China Energy Data, Statistics, and Analysis," U.S. Energy Information Administration, www.eia.doe.gov, accessed on Nov. 15, 2010
7. The World Bank, China: Building Institutions for Sustainable Urban Transport (China: Transport Sector Unit, Infrastructure Department, 2006, 3)
8. Ibid.
9. "China's injuries from road traffic injuries and other causes," WHO China, http://www.wpro.who.int, accessed on Sep. 15, 2010
10. "Global Passenger Car: Fuel Economy and Greenhouse Gas Emission Standards" International Council on Clean Transportation, www.theicct.org, accessed on Jan. 15, 2011
11. "Beijing To Limit Number Of New Car License Plates To Ease Traffic Congestion," Xinhua, Dec. 23, 2010, news.xinhuanet.com
12. "环境税拟2013年起征 湖南等省市或成为试点," [Environmental Tax to be Levied in 2013, Hunan May Become Pilot City], National Business Daily, Jul. 22, 2010, www.nbd.com.cn
13. Li, Jacqueline, China Railway Construction Corporation—a key beneficiary of soaring Chinese railway spending (China: Merrill Lynch, Oct. 2, 2008)

via rail.[14] As a result, policymakers have set their sights on increasing overall rail capacity, especially for high-speed rail. China has opened dozens of new high-speed lines and plans to link more of the nation's major cities with high-speed rail over the next decade. With over 8,000 kilometers of lines already in operation, China's high-speed rail network is the largest in the world.[15] However, Chinese authorities have begun to express concern over unsustainable debt levels caused by the nation's domestic rail program, with spending expected only to grow over the next five years.[16] Continuing losses from new high-speed rail lines, which are running far below capacity, frustrate efforts to stem rail-related debt.[17] Meanwhile, China has found success abroad, having signed agreements for cooperation on railways in more than 30 countries since 2003, including high-speed rail projects in Thailand and Laos, which are expected to start this year.[18]

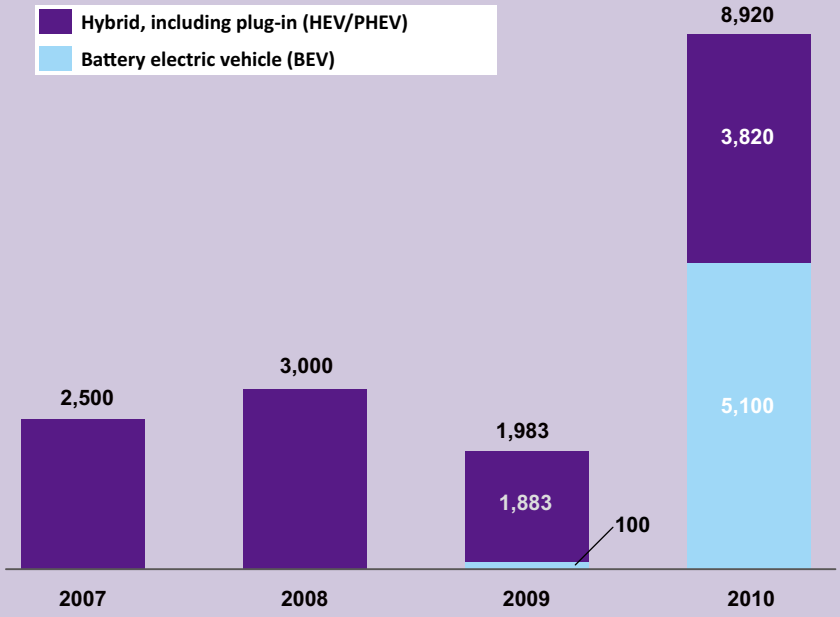
Electric vehicles show modest progress, thanks to government support

Growth estimates vary significantly for China's electric vehicle (EV) market. With electric vehicle sales limited mainly to municipal government-led pilot programs, the current market is tiny. From 2006 to 2009, fewer than 3,000 private hybrid electric vehicles (HEVs) were sold each year, but as pilot projects and subsidy programs took hold in 2009, the market for EVs began to show signs of life: sales of electric passenger vehicles rose to roughly 9,000 in 2010, including over 5,000 battery electric vehicle (BEV) units and nearly 4,000 hybrids, according to an estimate by J.D. Power.[19]

Undiscouraged by this slow start, the central government has prioritized electric vehicles nationally. With support from the central government, local governments introduced private purchase subsidies for electric vehicles in six cities in 2010. They also expanded programs to increase public sector EV usage to 25 cities (up from 13 cities in 2009) and released at least nine separate EV-related standards, many concerning charging infrastructure.[20] Meanwhile, state-owned enterprises (SOEs) have begun actively promoting the development of the electric vehicle industry. In August 2010, 16 SOEs formed the EV Industry Alliance of Centrally Administered Enterprises to promote development of the industry, including electric vehicle drivetrains, batteries, and charging infrastructure. The release of key standards and strengthened leadership of SOEs are expected to help overcome fundamental barriers such as insufficient charging infrastructure.[21] For example, even Shenzhen, one of the earliest EV pilot cities, still only had three charging stations and about 100 charging posts by mid-2010.[22]

14. Manmohan, Parkash, Promoting environmentally Sustainable Transport (Manila, Philippines: Asian Development Bank, 2009, 9)
15. "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, Mar. 4, 2011, www.chinanews.com
16. "铁路投资十二五将超3万亿 铁道部不再占大头,"[Rail Investment in the 12th FYP to Exceed 3 Trillion, MOR to Step Aside] Economic Observer News, Nov. 6, 2010, www.eeo.com.cn
17. "On the wrong track?" The Economist, Feb. 3, 2011, www.economist.com
18. Zhang, Qi. "CSR Aims for No.1 in High Speed Railways." China Daily, Jan. 4, 2011, www.chinadaily.com
19. "浅析中国新能源汽车市场," [Analysis of Chinese New Energy Vehicle Market] Shanghai CATARC, http://www.shcatarc.com.cn, accessed on Mar. 11, 2011; China Greentech Initiative interviews and analysis; Humphrey, J., et al., Drive Green 2020: More Hope than Reality? (Westlake Village: J.D. Power & Associates, 2010, 57-8)
20. "2010年批准发布的行业标准" [Industry Standards Approved and Issued in 2010] CAAM, Dec. 30, 2010, www.caam.com.cn
21. Xing, Wayne. "Despite Challenges, EV Alliance Shows Central Resolve." Sep. 8, 2010, http://www.chinaautoreview.com
22. China Greentech Initiative interviews

Electric Passenger Vehicles Sold in China, actual units, 2007-2010



Source: Humphrey, J. et. al., Drive Green 2020: More Hope than Reality? (Westlake Village, US: J.D. Power & Associates, 2010); "浅析中国新能源汽车市场," [Analysis of Chinese New Energy Vehicle Market] Shanghai CATARC, www.shcatarc.com.cn, accessed on Aug. 27, 2010; China Greentech Initiative interviews and analysis

Battery technology and cost remain major roadblocks for EVs

China needs to improve technology and production methods before vehicle-grade battery cells and packs become inexpensive and reliable enough for broader commercial use in EVs. Despite being home to some of the world's largest lithium battery cell producers, China's relatively weak R&D capabilities (reflected by its lack of international battery technology patents) compared to other leading contenders in the EV battery technology race hinder Chinese battery producers.[23] Other problems include manufacturing challenges, which lead to scrap rates as high as 50%, and limited cooperation between battery producers and EV manufacturers, which impedes battery-vehicle integration.[24] Nevertheless, supported by government initiatives such as the Ministry of Science and Technology's (MOST) 863 Plan, and a new ten-year EV industry development plan led by the Ministry of Industry and Information Technology (MIIT), Chinese EV battery makers continue to make progress. By 2015, MIIT aims for battery system energy density to reach 120 watt hours per kilogram, lifespan to reach 2,000 cycles, and costs to fall to RMB 2,000 (US$ 308) per kilowatt hour.[25] Whether these targets can be met remains an open question; however, it is clear the government intends to support the development of the battery industry—whether in the form of subsidies, standards, R&D funding or other policy incentives.

Government plans an alternative fuels push

Alternative fuels are a major part of the Chinese government's efforts to manage the country's reliance on petroleum. Of the various alternative fuels being considered in China, ethanol, methanol and natural gas are the prime contenders.[26] While the lack of

23. Lowe, M., et al, Lithium-ion Batteries for Electric Vehicles: The U.S. Value Chain (U.S.: Duke University, Center on Globalization, Governance & Competitiveness, 2010)
24. China Greentech Initiative interviews
25. "'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, Sep. 21, 2010, http://auto.163.com
26. For ethanol, see "2008-2009年中国乙醇汽油发展现状分析," [Ethanol: 2008-2009 China ethanol gasoline development analysis," CMRN, Jul. 29, 2009, www.cmrn.com.cn; for methanol see "甲醇汽油" 遍地开花" 市场供需失衡需警惕," [Methanol fuel supply is seen everywhere, be careful about the oversupply of methanol gasoline] IC98, Aug. 16, 2010, www.ic98.com; and for natural gas see "2010年天然气汽车市场趋势观察研究预测报告," [2010 natural gas vehicle market trend research forecast report] a8m, Apr. 29, 2010, www.a8m.cn

significant government support for other alternative fuels has limited their development, even with government backing the leading fuels face technology and supply-related issues. Ethanol, for instance, faces feedstock shortages that even next-generation production technologies struggle to address.[27] Neither the central government nor vehicle manufacturers have wholeheartedly embraced methanol, which if managed improperly harms vehicles, people and the environment. Broader natural gas uptake will require construction of additional pipeline infrastructure and refueling stations, which will require concerted government efforts and substantial investment.[28]

Continued government support and technology breakthroughs are needed

To overcome China's many challenges for Cleaner Transportation, continued government support and technological breakthroughs will be needed. Whether for high-speed rail, electric vehicles, EV batteries or alternative fuels, industry players will need to rely on government support over the next several years for infrastructure investment, technology funding and the creation of early-stage market opportunities.

EVs could achieve 68% emission savings if charged with electricity produced by cleaner energy sources such as natural gas.

The government's involvement in Cleaner Transportation is extensive. At the central level, the Ministry of Railways (MOR) sets the overall direction of China's ambitious high-speed rail program and plays multiple roles as the planner, investor and adopter of high-speed rail solutions. Similarly, MOST and MIIT are architecting China's electric vehicle future. At the local level, provincial governments support projects linked to local resources, such as Shanxi Province's methanol development programs that capitalize on the province's coal resources. Municipal governments rely on central government EV pilot programs to support the growth of local industry players, while sometimes missing chances to cooperate with and learn from pilot programs in other cities.[29] Meanwhile, SOEs are often ambivalent about carrying out government directives if they believe doing so could hurt profits.

Large scale adoption of electric vehicles and batteries will require breakthroughs in technology and business models. Barriers to large scale adoption include immature technologies for EV battery packs, unclear commercialization prospects for electric vehicles, lack of charging infrastructure, and little coordination between EV battery makers and vehicle manufacturers. To overcome these and other challenges, government and industry will need to work together to foster the innovation needed to translate China's bold electric vision into reality.[30] China's focus on new energy vehicles as one of seven Strategic Emerging Industries in the 12th Five-Year Plan may provide the impetus for breakthrough innovations, but technology availability in the short-term is more likely through collaboration with international companies who are receptive to transfer technology and know-how in exchange for market access.

Debate continues over environmental impact of greentech in transportation

In 2009, the China Greentech Initiative identified electric vehicles, alternative fuels and cleaner rail as some of the Cleaner Transportation solutions with the highest commercialization and environmental impact potential. However, industry experts and policy analysts continue to debate how green these technologies really are, especially when considering environmental impacts on a life cycle basis. Core components used in electric vehicles, for example, such as electric motors and certain types of batteries, require rare earth elements that are obtained through intensive and environmentally destructive mining. Once on the road, electric vehicles' ability to reduce emissions depends highly on the source of electricity used to charge them: 68% emission savings are possible if electricity is produced from cleaner energy sources such as natural gas, but with a heavily coal-based energy mix such as China's, savings could be as minimal as 13%.[31]

27. "吉林甜高粱秆制乙醇示范项目启动" [Jilin Sweet Sorghum Ethanol Fuel Demonstration Project Launched] Agrione, Apr. 3, 2010, http://agrione.cn; China Greentech Initiative interviews
28. China Greentech Initiative interviews
29. Ibid.
30. China Greentech Initiative analysis
31. Liu, Yin, et al., Towards Market Transformation: Electric Vehicles (Beijing, China: The Climate Group and Bain & Company, 2010, 6)

The same concerns apply for electrified and high-speed rail. In addition to the question of emissions from electricity production, rail's energy efficiency compared with road transport is also a subject of debate. While some would argue that rail uses less energy per passenger-kilometer than road, others urge the industry to consider that given the full life cycle impact of the construction of railways and trains, high-speed rail barely reduces pollution compared to air transport; these experts point instead to the long-distance bus as the most efficient mode of transport.[32] The China Greentech Initiative believes that, in the long run, electrified and high-speed rail is more efficient than other alternatives, and thus includes them as greentech solutions.

Likewise, alternative fuels used in road transportation such as ethanol and bio-diesel, which offer lower greenhouse gas emissions than conventional fuels, spur additional environmental and agricultural concerns over land use for feedstock. By some life cycle calculations, coal-based alternative fuels such as methanol emit significantly more greenhouse gas than gasoline.[33] Therefore, in order to achieve China's environmental goals over the next five years, policymakers and industry participants must evaluate the environmental impact potential of Cleaner Transportation solutions and their energy sources. When managed properly, the commercial and environmental implications for these solutions represent tremendous greentech opportunities.

China's Cleaner Transportation sector grows more attractive each year

Growing government commitment to Cleaner Transportation technologies makes the sector increasingly attractive in both the road and rail subsectors. For the cleaner road subsector, the government has set high goals and allocated significant funds for electric vehicle development, and plans to impose increasingly stringent fuel economy emission standards that will push uptake of cleaner technologies in all modes of road transport. Five-year market growth potential is extremely high if electric vehicles develop according to government goals, but current technology challenges keep solution attractiveness and profitability limited for the time being. Increased government funding and accelerated construction goals also contribute to the attractiveness of cleaner rail, and will ensure that Cleaner Transportation solutions such as high-speed rail become industry standards, despite substantial costs.

By life cycle calculations, methanol and other coal-based alternative fuels emit significantly more greenhouse gas than gasoline.

The China Greentech Initiative developed a Market Attractiveness Assessment (MAA) to evaluate the cleaner road and rail market subsectors on six criteria: government support, addressable market size, solution attractiveness, five-year market growth potential, market accessibility, and profit opportunity. Information on the Market Attractiveness assessment methodology is found in the Research Methodology chapter.

Cleaner Road

In terms of government support, addressable market size, and market growth potential, China's cleaner road subsector is highly attractive, but current solution attractiveness and profitability issues mainly attributed to immature technology levels limit the sector's short-term attractiveness.

Government support for cleaner road is rated as *highest priority*, as new energy vehicles are a major focus in the 12th Five-Year Plan period. The government selected new energy vehicles as one of seven Strategic Emerging Industries, and set ambitious deployment plans supported by strong funding and subsidies. Meanwhile, authorities will continue to impose increasingly stringent fuel economy and emission standards for conventional vehicles.

With the world's largest vehicle market by volume, the addressable market for cleaner road solutions is *very large,* and is expected to continue growing.

Cleaner road solution attractiveness is *disadvantaged* in the short term given

32. China Greentech Initiative interviews

33. Partner and Strategic Advisor discussion during CGTI Cleaner Transportation Working Session, December 2010

that electric vehicles can cost up to 200% more than conventional vehicles, the technology is still immature, and there is a lack of supporting infrastructure. While many alternative fuels are available at prices lower than fossil fuel equivalents, limited feedstock supply and distribution infrastructure remain major barriers to broader adoption.

Five-year market growth potential is *very rapid*. MOST's 12th Five-Year Plan targets a fleet of one million EVs on the road by 2015, a tremendous leap from the 10,000 EVs estimated to be on China's roads by the end of 2010.

The cleaner road market is generally open in areas of vehicle production, but deployment and operation of charging infrastructure for electric vehicles is restricted to SOEs. Authorities are also considering imposing restrictions on the degree of foreign ownership in key EV technologies such as batteries. Moreover, government subsidies are only applicable to EVs produced domestically. The market therefore is seen as *partially limited*.

Cleaner road profitability in China is currently *limited*, due to highly price-sensitive consumers, intense competition among vehicle manufacturers, and limited market size. Without technology breakthroughs and a major increase in production volumes, manufacturers face challenges in bringing cost down enough to be profitable, even with strong government subsidies. Considering business models where batteries are sold or leased separately from the car itself, automakers that do not own battery technology may not expect to see tremendous profits by selling empty electric cars, which risk becoming commoditized in the future.

Cleaner Transportation Market Attractiveness Assessment—Road

Assessment Criteria	Attractiveness	Explanation
Government Support	●	■ Electric vehicles made one of seven Strategic Emerging Industries ■ Central government to spend RMB 100 billion on EV development over next ten years ■ Increasingly stringent fuel economy and emission standards
Addressable Market Size	●	■ China's vehicle sales are the highest in the world, presenting a huge addressable market for greentech alternatives
Solution Attractiveness	◔	■ BEVs cost up to 200% more than conventional vehicles; HEVs cost 15-50% more ■ For private sector, lack of infrastructure, technology immaturity, and high cost even with purchase subsidy in select cities make EVs unattractive ■ Many alternative fuels such as natural gas are priced competitively compared to conventional fuels, but supply limits adoption
Five-Year Market Growth Potential	●	■ MOST's 12th FYP for EVs targets 1 million on the road by 2015, which would represent tremendous annual growth compared with current sales rates
Market Accessibility	◑	■ EV charging infrastructure currently restricted to SOEs ■ Vehicle market is generally open, but regulators are considering restrictions on foreign ownership of key EV technology JVs ■ Incentives only applicable to domestically-produced EVs
Profit Opportunity	◔	■ Highly price-sensitive consumers prefer conventional vehicles ■ High competition makes cost and performance top concern for vehicle manufacturers ■ Government subsidies help but are not yet sufficient for profit ■ EV market still too small to benefit from economies of scale, and key battery technologies still depend on imports

Market Attractiveness Assessment Legend

Government Support	Addressable Market Size	Solution Attractiveness
● Highest priority	● Very large	● Advantaged
◕ High priority	◕ Large	◕ Attractive
◑ Medium priority	◑ Medium	◑ Emerging
◔ Low priority	◔ Limited	◔ Disadvantaged
○ No priority	○ Niche	○ Unavailable
Five-Year Market Growth Potential	**Market Accessibility**	**Profit Opportunity**
● Very rapid	● Fully open	● Superior
◕ Rapid	◕ Open with restrictions	◕ Above average
◑ Medium	◑ Partially limited	◑ Average
◔ Slow	◔ Limited	◔ Limited
○ Very slow	○ Restricted	○ Challenging

Source: China Greentech Initiative analysis

Cleaner Rail

Government planning and investment drives China's cleaner rail subsector in the face of high costs for new infrastructure and trains. On the other hand, government dominance restricts market accessibility and profit opportunity.

Government support for cleaner rail is rated as *highest priority*, as government planning and investment directly determine growth of rail in China, and the 12th Five-Year Plan notes high-speed rail as a development focus. Government investment in rail is expected to increase to RMB 3.5 trillion (US$ 538 billion), up from RMB 2.2 trillion in the past five years.

With government expenditures in rail exceeding RMB 650 billion (US$ 100 billion) each year on infrastructure alone, the addressable market size for cleaner rail solutions is *very large*.

Cleaner rail solutions are rated as *attractive*, because despite the high costs of electrified and high-speed rail construction, these cleaner technologies are on their way to becoming standards for the rail industry, primarily pushed through by the government's emphasis of cleaner rail development.

Five-year market growth potential for cleaner rail in China is rated as *medium*. The expected boost in government investment over the next five years will mean accelerated market growth, but the sector is unlikely to grow much faster compared to current growth rates, which are already high.

While China has encouraged foreign technology providers to participate in its high-speed rail market, it receives a *partially limited* rating due to imposition of technology transfer requirements, as well as the dominance of SOEs in management and operation of the rail industry.

Profit opportunity for cleaner rail in China is rated as *average*. While SOEs possess the buying power, relatively low competition levels and a lack of substitutes creates profit opportunity for providers of key components, notably those with little to no domestic production such as wheels and axles.

Cleaner Transportation Market Attractiveness Assessment—Rail		
Assessment Criteria	**Attractiveness**	**Explanation**
Government Support	●	■ 12th FYP includes focus on high-speed rail development ■ Cleaner rail expansion and investment plans developed by Ministry of Railways; local government involvement to grow
Addressable Market Size	●	■ Tremendous annual expenditure in rail construction
Solution Attractiveness	◕	■ Electrified and high-speed rail are costly to build, but will become industry standard due to government mandate
Five-Year Market Growth Potential	◑	■ Increased government investment in rail over the next five years will accelerate market growth
Market Accessibility	◑	■ Rail is open to foreign investment, but foreign manufacturers are subject to technology transfer requirements ■ Ministry of Railways and SOEs dominate railway construction and operation
Profit Opportunity	◑	■ Dominance of SOEs as primary buyers limits profits for solution providers ■ Relatively low competition and lack of substitutes creates profit opportunity for providers of key components

Market Attractiveness Assessment Legend

Government Support	Addressable Market Size	Solution Attractiveness
● Highest priority	● Very large	● Advantaged
◕ High priority	◕ Large	◕ Attractive
◑ Medium priority	◑ Medium	◑ Emerging
◔ Low priority	◔ Limited	◔ Disadvantaged
○ No priority	○ Niche	○ Unavailable
Five-Year Market Growth Potential	**Market Accessibility**	**Profit Opportunity**
● Very rapid	● Fully open	● Superior
◕ Rapid	◕ Open with restrictions	◕ Above average
◑ Medium	◑ Partially limited	◑ Average
◔ Slow	◔ Limited	◔ Limited
○ Very slow	○ Restricted	○ Challenging

Source: China Greentech Initiative analysis

The path forward

China has adopted a strategy for the Cleaner Transportation sector that is every bit as ambitious as its plans for renewable energy and carbon intensity. Solving the major issues of increased car use—congestion, emissions and rising oil imports—will require more than aggressive targets and increased budgets. For alternative fuels, feedstock supply and other issues hamper large scale usage of fuels such as ethanol or biodiesel, and breakthroughs are needed before next-generation fuels can be commercialized. Similarly, the array of obstacles facing electric vehicles range from lack of charging infrastructure to high battery costs. Finally, while China's rail expansion has indeed been impressive, this sector too must resolve its own set of unique challenges, such as debt incurred by the government's massive investment to fund rail's accelerated growth.

China's Emerging Electric Vehicle Ecosystem

Opportunity Assessment

While the growth prospects for China's EV market are substantial, the nascent market faces major challenges, including inadequate charging infrastructure and high battery costs.

Though the government has set ambitious growth targets for the EV market between now and 2020, the industry faces many hurdles. Government-led pilot programs are the main near-term market driver, supported by a new EV development plan and charging standards. Technology constraints, high battery costs and the lack of charging infrastructure in pilot cities all pose major barriers to success. Unlike in more developed countries, low-speed EVs may serve as a bridge for the eventual commercialization of high-speed electric vehicles.

Electric vehicles are a major government priority

Government policy is actively developing China into an electric vehicle market leader. Whether through targeted subsidies, pilot programs or the creation of broader industrial development strategies, support from the national, provincial and local levels of the government has catalyzed China's burgeoning electric vehicle market.

China's major EV pilot programs demonstrate the level of government commitment. For instance, the three-year Tens of Cities, Thousands of Vehicles Program announced in 2008 selected 13 pilot cities to promote EVs in the public sector. Each participating city set goals for the number of EVs (mainly buses and taxis) to be on the road by 2012, which ranged from 1,000 in Kunming to as many as 9,000 EVs in Shenzhen.[34] Through this program, the central government pledged subsidies of up to RMB 420,000 (US$ 64,615) per hybrid bus, RMB 500,000 (US$ 76,923) per pure electric bus and RMB 600,000 (US$ 92,307) per fuel cell bus. Public trials expanded to a total of 25 cities in 2010. The government also launched a new program in 2010 to subsidize private EV purchases in the six cities of Shanghai, Changchun, Shenzhen, Hangzhou, Hefei and Beijing, offering up to RMB 50,000 (US$ 7,692) for plug-in hybrid cars and RMB 60,000 (US$ 9,231) for pure electric cars.[35] Local governments have gotten in on the act as well, offering to match central government subsidies on both public and private purchases.

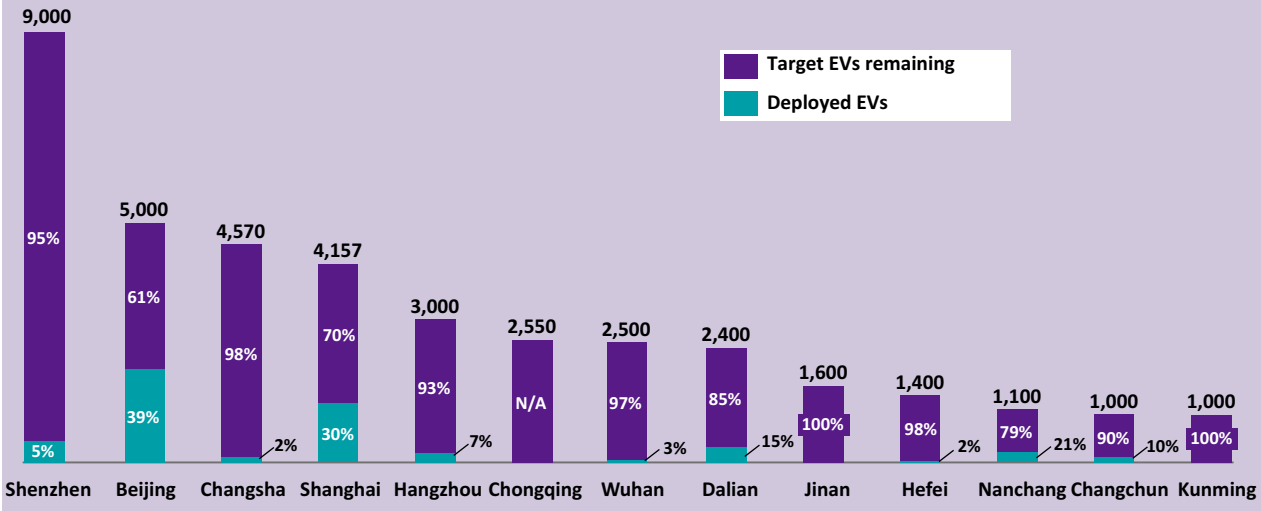
Industry development plans from the central government that commit substantial funding and set additional growth targets bolster the pilot programs. The State Council's March 2009 Plan on Adjusting and Revitalizing the Auto Industry set aside RMB 10 billion (US$ 1.5 billion) to develop key EV technology and targeted a production capacity of 500,000 EVs by the end of 2011. MIIT is set to implement an even more ambitious ten-year development plan. According to a draft released in August 2010, the Energy Saving and New Energy Vehicle Industry Development Plan (2011 - 2020) calls for government investment of RMB 100 billion (US$ 15.4 billion) to help China achieve build a fleet of 5 million new energy vehicles by 2020.[36] Further underscoring that China's commitment to the industry will not wane, the State Council recently selected electric vehicles as one of its seven Strategic Emerging Industries.

34. Zheng, Jie, et al., Strategic Policies and the Ongoing Demonstration Program of Electric Vehicle Deployment in China (Beijing, China: World Bank, 2009, 502)

35. "国内新能源汽车试点城市地图," [Map of China's New Energy Vehicle Pilot Cities] China Energy News, Sep. 17, 2010, http://paper.people.com.cn; "Beijing Sets Subsidies for New Energy Vehicles," Caixin, Nov. 29, 2010, http://english.caing.com

36. "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, Sep. 21, 2010, http://auto.163.com

China's "Tens of Cities, Thousands of Vehicles" EV Pilot Program
Deployment Targets and Progress in First 13 Cities, actual units, mid-2010



Note: Data for Chongqing were not available.

Source: Zheng , J.et al., Strategic Policies and the Ongoing Demonstration Program of Electric Vehicle Deployment in China (Beijing, China: World Bank, 2009); China Greentech Initiative analysis

How successful will these pilot projects and development plans be in transforming China's roads? In the short term, the answer is unclear. The Tens of Cities, Thousands of Vehicles Program saw varied pace of uptake. For example, as of mid-2010, Beijing led the original 13 cities by meeting 39% of its 2012 target, while seven other cities had achieved less than 10% of their targets.[37] Shenzhen mirrors these findings: while the city set an ambitious 2012 target of 24,000 EVs, including 15,000 private and 9,000 public vehicles, there were only 700 EVs in service by June 2010, only 100 of which were in private hands.[38] Clearly, the gap between current market realities and ambitious government targets still needs bridging.

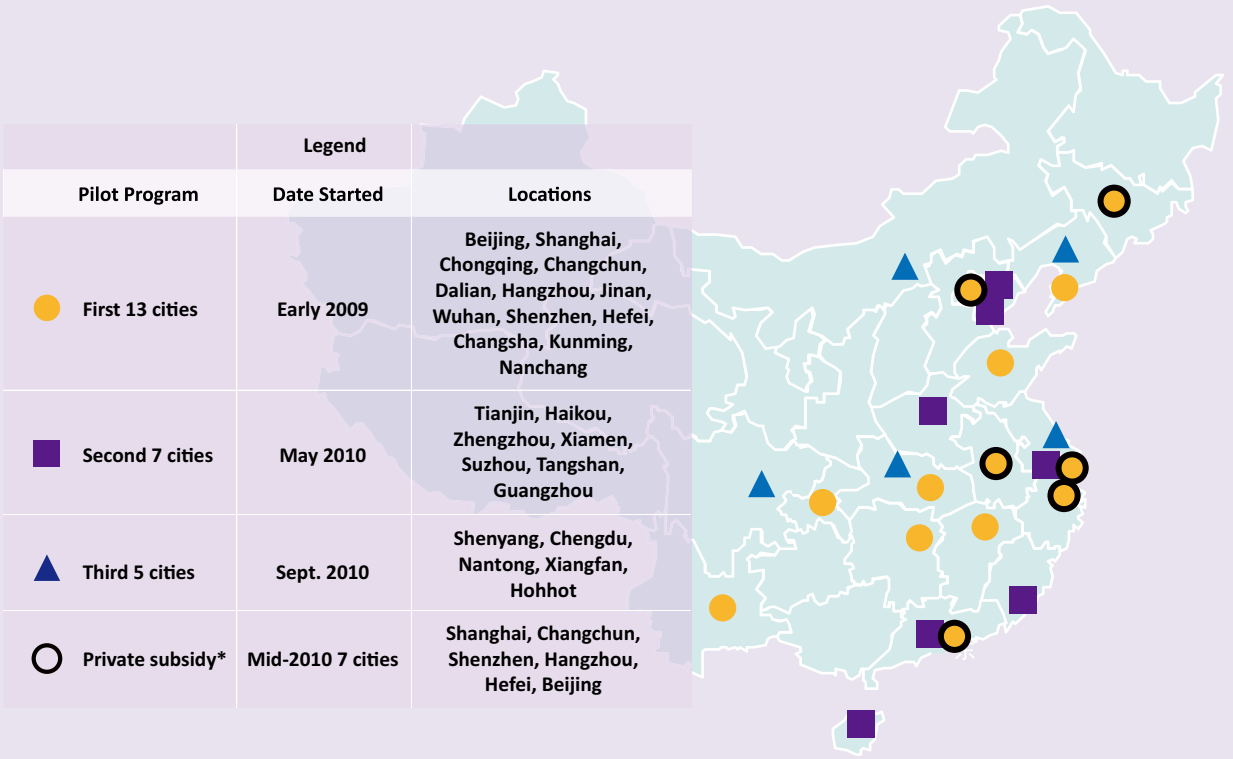
Electric vehicle market challenges

Immediate challenges confronting China's EV market include the lack of vehicles, infrastructure and industry standards. Technical challenges and high costs, especially with vehicle batteries, limit the number of high-speed electric cars on the market. As of 2010, only three models were reportedly available for private purchase, while other announced models were limited to concept or testing stages, despite press releases that suggested otherwise.[39] BYD, for example, released its first plug-in hybrid electric vehicle (PHEV), the F3DM, for purchase in Shenzhen in March 2010, but consumers have had trouble actually purchasing a model. The BYD E6, meanwhile, has been restricted to use in Shenzhen's taxi program, despite plans to release it to the public in September 2010.[40] However, the situation should improve as more car makers bring PHEVs and BEVs to market in 2011. Until then, growth should come mainly from the public sector, where coordinated rollouts of vehicles and charging infrastructure are easier to plan and implement.

Sluggish infrastructure construction also restrains progress for public buses and taxis in the pilot cities. In 2010, a lack of industry standards kept enthusiasm for infrastructure investment lukewarm: given uncertain standards, SOEs did not want to invest in charging stations that would not fit the cars. Likewise, the high investment

37. Zheng, Jie, et al., Strategic Policies and the Ongoing Demonstration Program of Electric Vehicle Deployment in China (Beijing, China: World Bank, 2009)
38. China Greentech Initiative interviews
39. Robert, Earley, et al., Electric Vehicles in the Context of Sustainable Development in China (Beijing, China: iCET, Mar. 5, 2011)
40. Media reports; China Greentech Initiative interviews

China's 25 EV Pilot Cities, 2010



* Cities that offer subsidy on private EV purchases in addition to public-sector pilot programs

Source: "国内新能源汽车试点城市地图" [Map of China's New Energy Vehicle Pilot Cities] China Energy News, Sep 17, 2010, http://ev.cctv.com; "Beijing Sets Subsidies for New Energy Vehicles," Caixin, Nov 29, 2010, http://english.caing.com; China Greentech Initiative analysis

costs for infrastructure—a battery swapping and charging station capable of servicing 50 buses costs RMB 30 to 40 million (US$ 4.6 to 6.2 million), batteries not included—and unproven rates of return further dampen expansion.[41] However, the release of at least nine charging-related national standards in 2010 (several of which will take effect in 2011) takes a big step toward solving the infrastructure problem and will encourage faster rollout in 2011.[42]

Low-speed electric vehicles

While the brunt of China's efforts is on high-speed EVs, some stakeholders believe that low-speed electric vehicles (LSEVs) are an attractive short-term choice for manufacturers. LSEVs travel at under 50 kilometers per hour and use much simpler technology than their high-speed counterparts; as a result, they are best suited for short, intra-city trips or short trips in rural areas. With domestic sales limited mainly to Shandong Province and certain rural areas, LSEVs have yet to capture the imagination of Chinese consumers. In fact, China's market for LSEVs is mainly for export, with 100,000 vehicles sold overseas in 2009.[43]

China's LSEV industry also faces major challenges. Approximately 50 companies, mainly in Shandong province, dominate production.[44] These producers are mostly smaller-scale auto parts and agricultural equipment makers as opposed to car-makers for the mass consumer market. For now at least, China's major automakers have not entered the field. In terms of technology, LSEVs may be suited for limited travel within urban areas, but finding a broader consumer base will require technical upgrades that address negative perceptions about quality and safety. Given poor performance,

41. China Greentech Initiative interviews
42. "2010年批准发布的行业标准."[Industry Standards Approved and Issued in 2010] CAAM, Dec. 30, 2010, www.caam.com.cn
43. "新能源车规划征求意见低速电动车或被放行,"[New Energy Vehicle Plan Seeks Public Opinion, LSEVs may be Given Go-Ahead] Sohu Auto, Jun. 30, 2010, http://auto.sohu.com
44. "山东时风：低速电动车市场化探索,"[Shandong Shifeng: An Exploration into Commercializing Low-Speed EVs] CCTV, Aug. 23, 2010, http://ev.cctv.com

cost is a related constraint: at RMB 30,000 to 40,000 (US$ 4,615 to 6,154) per vehicle, consumers have to wonder how value compares to similarly-priced small gas cars.[45] Possibly the most important obstacle is that LSEVs are not yet legal for road use in most cities, with Shandong Province being the major exception. While buyers in rural cities may not have to worry as much about legality of the vehicles, city-dwellers risk having their vehicles confiscated by the police.

Yet China's LSEV market does have potential. Driven by increased export demand and government deliberations to legalize the domestic market, LSEV production may soon expand dramatically. Policymakers are currently debating whether to legalize production and registration of LSEVs. Enhanced market regulations could mean consolidation of production and the shuttering of low-quality small-scale producers.[46] This could spur major automakers to experiment with LSEV production, which some expect will serve as a bridge to commercialization of high-speed vehicles.

Forecasts vary widely

In a pilot stage of development, there is no consensus on how rapidly the EV market will grow. Annual EV sales projections for 2020 run the gamut, from six million units to less than 400,000.[47] Which scenario proves most realistic will depend on how successfully the central government promotes the sector with subsidies and standards, technology developments, and how manufacturers respond to market opportunities. As more electric vehicle models hit the market in the coming few years, growth forecasts for the sector will become more concrete, and policies to support the transition to electric vehicles are expected to become more focused.

Low-speed electric vehicles may serve as a bridge for automakers to commercialize high-speed EVs.

Electric Vehicle Battery Market Evolution

Opportunity Assessment

China's many battery makers have set their sights on EVs, and while technical challenges abound, government support and optimism remain strong.

Even as lithium-ion battery manufacturers vie for a share of China's EV battery market, the market is still in the early stages, with few orders from automakers and numerous technical challenges awaiting the victors. Major obstacles include weak R&D capability, lack of automated production methods, insufficient key technologies and components, and difficulties in vehicle integration. Government and investor funds continue to flow into the sector, suggesting optimism that these barriers can be overcome.

Nascent market with many battery-making contenders

Lithium-ion batteries are generally agreed to be the most attractive technology for powering electric vehicles due to their high energy, power density and sizable potential for costs to drop. As one of the top manufacturing countries of lithium-ion battery cells for consumer electronics, China is well-positioned to leverage its existing production capacity to become a leader in lithium-ion batteries for EVs. In recent years, many of China's battery makers have entered the EV market with investments in R&D and new facilities. Of more than 400 battery manufacturers, at least 60 now produce lithium-ion cells designed for use in vehicles.[48] In this respect, China far exceeds the U.S., which lacks a significant presence in cell manufacturing.[49] However, fewer than 20 of these Chinese companies are considered serious contenders, with many industry insiders believing that only two or three will emerge as top players.

45. Liu, Yin, et al., Towards Market Transformation: Electric Vehicles (Beijing, China: The Climate Group and Bain & Company, 2010, 25)
46. Partner and Strategic Advisor discussion during CGTI Cleaner Transportation Working Session, September 2010
47. Boston Consulting Group, The Comeback of the Electric Car? (U.S.: The Boston Consulting Group, 2009, 7-8)
48. China Greentech Initiative interviews and analysis
49. Lowe, M., et al., Lithium-ion Batteries for Electric Vehicles: The U.S. Value Chain (U.S.: Duke University, Center on Globalization, Governance & Competitiveness, 2010, 20)

Some of the older and most recognized Chinese manufacturers to enter the EV battery arena include Advanced Battery Technologies, ATL, BAK, BYD, China Aviation Lithium Battery (CALB), CITIC Guoan Mengguli (MGL), Coslight, Lishen, Phylion, Unipower, and Wanxiang. Other younger startups, such as GBS Energy and HIFE Green Power, have also won recognition for their EV battery technology. Just like electric vehicles, EV batteries are still in a pre-commercial pilot stage of development in China, making it difficult to forecast which companies will emerge as winners.

Despite the excitement and speculation on who will win the EV battery race, very few batteries actually have been sold to date. Most EV battery sales have been limited to small orders for demo fleets, at or under 100 battery systems per order.[50] While estimates suggest China's EV battery market could swell to nearly US$ 20 billion by 2020, at this stage the market is just starting up.[51]

China appears to favor LFP chemistry, though which technology is best remains unclear

Much of the uncertainty about the future of China's EV battery market revolves around unresolved battery technology questions. While most EV battery makers have placed bets on lithium, the numerous choices for lithium-ion cathode chemistries and the ongoing debate over battery cell shape means there is no clear answer on how to make the best EV battery.

The approaches taken by battery manufacturers often vary by country. Thus far, Chinese manufacturers tend to favor lithium-iron-phosphate (LFP), with over 80% of producers choosing LFP chemistry. Meanwhile, Japan and Korea focus on three-element chemistries[52] and lithium-manganese oxide (LMO), whereas fewer than 10 Chinese companies were producing LMO batteries as of late 2010. Low material costs and comparative ease of production are two of the main reasons for favoring LFP. The raw materials needed for LFP batteries are relatively cheap and available domestically. Moreover, LFP cathode production uses the same methods as the lithium-cobalt oxide (LCO) cathodes used in laptops, which means manufacturers can switch between LCO consumer electronics applications and LFP production with comparative ease.[53]

China's EV battery market could swell to nearly US$ 20 billion by 2020.

Current LFP technology is safer than other battery chemistries given phosphate's fire-proofing properties; however, LFP provides lower energy and power density relative to other promising chemistries. Some Japanese manufacturers, for example, report testing LMO batteries with a 3,000-cycle lifespan at half the cost of LFP, while other companies are making headway with lithium-nickel-manganese-cobalt (NMC) chemistries by using additives to improve lifespan and overcome stability issues.[54]

Technical challenges abound

Regardless of technology choice, poor performance, short lifespan and high costs are common challenges for EV battery makers both in China and abroad.[55] Battery makers struggle to increase energy and power density to meet volume and weight requirements, while still ensuring that batteries perform well in abusive environments and at extreme temperatures. Current EV batteries do not last long enough before performance and capacity begin to degrade, and costs are still too high to support broader acceptance.

50. China Greentech Initiative interviews and analysis
51. China Greentech Initiative calculation based on Boston Consulting Group, The Comeback of the Electric Car? (U.S.: The Boston Consulting Group, 2009)
52. Note: Three-element chemistries include lithium-nickel-cobalt-aluminum (NCA) and lithium-nickel-manganese-cobalt (NMC)
53. China Greentech Initiative interviews
54. Partner and Strategic Advisor discussion during CGTI Cleaner Transportation Working Session, December 2010
55. China Greentech Initiative analysis

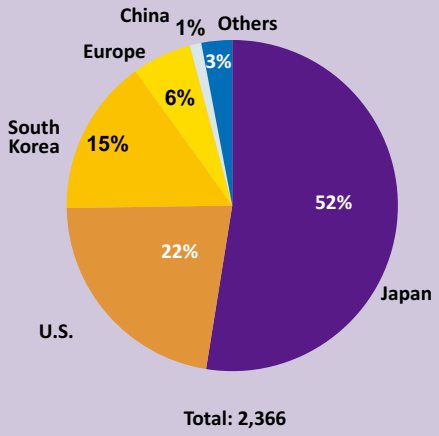
Despite common obstacles for EV battery makers worldwide, many industry experts agree that Chinese battery makers are falling behind in overcoming these technical challenges.[56] The weak R&D capability of many Chinese battery manufacturers restricts improvement in cathode materials, cell design and battery management system (BMS) technology.[57] Compounded by a lack of advanced production methods and equipment, many Chinese EV battery makers, such as China BAK Battery, choose to use automated machinery only at stages where absolutely necessary, preferring inexpensive manual labor where possible.[58] Unfortunately these savings come at the expense of cell consistency, which hurts battery performance and lifespan. For example, inconsistent Chinese battery cells with individual 2,000-cycle life spans may drop to as low as 600 cycles when combined into a pack. Sophisticated battery management systems can help handle problems created by cell inconsistency, but as mentioned, China has made few advances in BMS technology to date. Meanwhile, Chinese battery makers are often forced to scrap inconsistent cells, with scrap rates reaching as high as 50%. China also currently lacks production capabilities for key battery components (such as separator membrane and electrolyte), which leads to reliance on expensive imports from the U.S. and Japan.[59]

International Lithium-ion Battery-Related Patents, 2009

China lags behind its international peers in battery R&D breakthroughs, as reflected by its production of related patents: in 2009, China held only 1% of 2,366 international lithium-ion battery-related patents in effect at the time. Comparatively, with 52% of the total, Japan has taken the clear lead in the sector. The U.S. (22%) and South Korea (15%) are other important source nations for lithium-ion advances.

China's lack of international patents and reliance on LFP technology are complicated by long-running tangled disputes over LFP patent ownership involving multiple nations and companies.[1] For the moment, Chinese battery producers can manufacture and sell LFP batteries unhindered in the domestic market, and may export to Europe; however, they face risks in exporting to the U.S., which continues to uphold LFP patent claims.

1. "磷酸铁锂专利战升级 谨防中国电动车受制于人," *[LFP Patent War Escalates; China's EV Industry on Guard] CNAutoNews, Jan. 28, 2010, http://auto.sohu.com*



Source: Lowe, M., et al., Lithium-ion Batteries for Electric Vehicles: The U.S. Value Chain (North Carolina, US: Duke University, 2010)

Cheaper cells come at a price

In spite of reliance on imports, many Chinese EV battery makers quote cell costs of less than RMB 3,000 (US$ 461) per kilowatt hour, or between 25-50% lower than their foreign equivalents, due to lower raw material, land and labor costs. However, after taking into account the cost of high scrap rates and shorter life spans, some industry participants estimate Chinese-made battery packs can cost almost 50% more than foreign-made batteries on an adjusted per-cycle basis.[60]

56. Liu, Yin, et al., Towards Market Transformation: Electric Vehicles (Beijing, China: The Climate Group and Bain & Company, 2010, 23); China Greentech Initiative interviews
57. China Greentech Initiative interviews
58. "China BAK Battery's 2009 U.S. SEC Form 10-K Filing," Nasdaq, http://secfillings.nasdaq.com, accessed on Feb. 15, 2011
59. China Greentech Initiative interviews; Partner and Strategic Advisor discussion during CGTI Cleaner Transportation Working Session, December 2010
60. China Greentech Initiative interviews and analysis

Estimates vary on how fast battery costs will drop in China and abroad, as experts disagree how much further costs will need to fall to support commercialization of EVs; however, most agree that several factors could drive costs down. Improvements in production technology and material performance will raise quality while reducing scrap rates and thus the amount of materials needed. Increased production due to the growing EV market is also expected to help cut costs dramatically, as approximately 70% of battery costs are production volume-dependent.[61]

Vehicle integration

Aside from the challenging technical aspects of battery production, integration in vehicles remains unresolved. How should battery cells be integrated into a complete pack for a car, and who designs the battery management system to make this possible? As an integral element of EV power trains, battery systems must be carefully designed to meet the performance requirements of each individual vehicle design, making it unlikely that battery makers can simply sell ready-to-go systems without close consultation with automakers.[62] Similarly, automakers cannot easily order cells and integrate them into vehicles without guidance from battery makers.

While foreign and domestic automakers have been exploring partnerships with Chinese EV battery makers, many have yet to solidify substantial relationships that would facilitate technical cooperation and exchange. Most Chinese automakers have experimented with small orders from various battery makers, trying out different companies' products without conclusively settling on any one application. Inexperience is another barrier. Both Chinese vehicle manufacturers and battery producers are relatively young, lacking deep knowledge and experience with their own technologies, which makes mutual knowledge exchange difficult.[63]

With strong government support, optimism prevails

Approximately 70% of battery costs are production volume-dependent.

Despite technical challenges, strong governmental support keeps investors and experts optimistic. In addition to the overall government commitment to make China a leader in EVs through purchase subsidies and pilot projects, government funding for R&D efforts buoys the battery industry's growth. According to one estimate, the Chinese government spent approximately RMB 1 billion (US$ 153.8 million) on EV battery R&D over the last decade, only slightly less than the U.S. and Japanese governments.[64] MOST is expected to announce another RMB two billion (US$ 307.7 million) for battery R&D during the 12th Five-Year Plan period (2011-2015); much of the RMB 100 billion (US$ 15.4 billion) that China announced for EV applications over the next 10 years is expected to go to battery manufacturers.[65]

Many investors are confident that continued government funding over the next five years will support the industry long enough for technology and costs reach commercial levels, as was demonstrated by an added wave of investments in China's EV battery sector in 2010. In the meantime, Chinese battery makers will need to be persistent and strengthen cooperation with automakers before the industry can take off.

61. Liu, Yin, et al., Towards Market Transformation: Electric Vehicles (Beijing, China: The Climate Group and Bain & Company, 2010, 27)
62. China Greentech Initiative interviews
63. Ibid.
64. China Greentech Initiative interviews; Lowe, M., et al, Lithium-ion Batteries for Electric Vehicles: The U.S. Value Chain (U.S.: Duke University, Center on Globalization, Governance & Competitiveness, 2010, 23)
65. China Greentech Initiative interviews

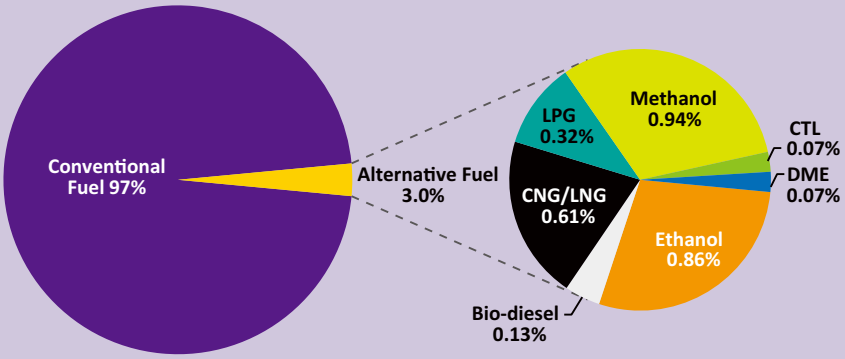
Alternative Fuels for Road Transportation

Opportunity Assessment

Ethanol, natural gas and methanol are the three most widely adopted transportation fuels in China today; however, further progress requires breakthroughs in feedstock supply, technology development, infrastructure rollout and user acceptance.

The central government continues to promote a full spectrum of alternative fuels; however, these fuels account for only 3% of the market to date. Ethanol, natural gas and methanol have developed rapidly over the past five years, but still face major development challenges. Other alternative fuels appear less promising, at least in the near term.

China's Road Transportation Fuel Consumption Mix
percent, 2009 (calculated on an energy-adjusted basis)



Source: "2008-2009年中国乙醇汽油发展现状分析" [2008-09 China Ethanol Fuel Market Development Analysis] CMRN , Jul. 29, 2009, www.cmrn.com.cn; "二代生物燃料: "酿酒" 不用粮食" [Second Generation Bio-fuel] Mittrchinese.com, Oct. 10, 2010, www.mittrchinese.com; "2010年天然气汽车市场趋势观察研究预测报告," [2010 China Natural Gas Vehicle Development Trends] a8m.cn, Apr. 4, 2010, www.a8m.cn; "中国液化石油气生产与进出口现状及展望" [China LPG Production, Import and Export Current Development and Prospectcs] LNGonLine.cn, Nov. 7, 2010, www.lngonline.cn; China Greentech Initiative analysis

Ethanol production has grown with government support

Ethanol is currently China's largest alternative fuel by volume, thanks to government support in the form of subsidies, pilot programs and ethanol fuel standards. Domestic ethanol production tripled between 2003 and 2009 to reach 1.9 billion liters, making China the world's fourth largest producer—albeit far short of the 40.7 billion liters produced annually in the U.S. or 24.9 billion liters annually in Brazil.[66] Given China's ethanol production target of 11.3 billion liters annually by 2020, the government aims to expand production six-fold, in part by using non-maize feedstock such as cassava, sweet sorghum and cellulose.[67]

The central government has supported five major ethanol fuel projects to help meet these targets. Four of these began in 2004, accounting for 83% of domestic ethanol production.[68] Provincial governments have also adopted policies to support alternative fuels, with six provinces implementing policies which mandate the use of E10 gasoline, which is 90% gasoline and 10% anhydrous ethanol. Twenty-seven cities

66. "燃料乙醇发展现状与趋势," [Ethanol Fuel Development and Trends] Chinavalue, http://www.chinavalue.net, accessed on Nov. 22, 2010
67. Zhang, Yue et al., "Alternative fuel implementation policy in China and its assessment" (Institute of Energy Economics, Japan, May 2007)
68. "燃料乙醇发展现状与趋势," [Ethanol Fuel Development and Trends] Chinavalue, http://www.chinavalue.net, accessed on Nov. 22, 2010

in four other provinces have also adopted E10 standards.[69] E10 coverage in the pilot provinces has reached 90% saturation, while nationally E10 fuel accounts for 30% of transportation gasoline consumption by volume, albeit less on an energy-adjusted basis.[70]

Local governments advocate methanol from coal, despite questionable environmental impact

Coal-based methanol also shows growth potential over the next five years due to expanded domestic production and wider availability. While government efforts to promote methanol are less impressive than those for ethanol, the central government issued standards for M85 (85% methanol and 15% unleaded gasoline) in 2009.[71] Several provincial governments have launched methanol demonstration programs, issuing standards for M15 and offering subsidies for methanol-fuel vehicle retrofits. For example, coal-heavy Shanxi Province adopted pro-methanol policies as far back as 2002. Local governments in Zhejiang started promoting the fuel in 2010, providing it at many private fuel stations. In Shaanxi Province, government officials are considering mandating methanol blends province-wide. In adopting these measures, provinces cite the fuel's low cost, but abundant local coal supplies are also a motivating factor.[72]

Though LNG use is still very limited, the fuel shows particular promise for use in medium- and heavy-duty vehicles.

Despite regional advocacy for coal-based methanol to cut China's reliance on oil, the China Greentech Initiative's partners and advisors have suggested China ultimately should not support methanol because of its toxicity, potential to damage vehicles, and questionable environmental impact. Methanol is toxic and readily absorbed through skin, and while methanol advocates argue that low-concentration blends (such as M15) can be used directly without need for retrofits, automakers maintain that methanol causes damage by releasing impurities and rust in fuel lines and tanks, causing over-wear, leakages, and other performance problems. With life cycle greenhouse gas emissions estimated to be more than twice that of gasoline, it is questionable whether methanol can be considered a green alternative fuel at all.[73]

Natural gas vehicles have grown through government demonstration programs in 20 cities

Natural gas for transportation fuel is either in the form of compressed natural gas (CNG) or liquefied natural gas (LNG). The volume of natural gas used in China's road transportation grew by 30% every year from 2004 to 2009. By January 2010 approximately 500,000 natural gas-enabled vehicles (NGVs)—99% of which run on CNG—were in service in 80 cities.[74] Though LNG use is still very limited, the fuel shows particular promise for use in medium- and heavy-duty vehicles. The government has provided strong support to promote natural gas by issuing at least 29 standards related to natural gas vehicles, as well as organizing Clean Vehicle demonstration programs that have now expanded to 20 cities.[75] Here too, provincial governments have taken a lead. Provinces have invested in fueling stations, subsidized natural gas vehicle purchases, as well as issued standards and safety regulations.

69. "2008-2009中国乙醇汽油发展现状分析,"[2008-2009 China Ethanol Gasoline Development Analysis] CMRN, www.cmrn.com.cn, Jul. 29, 2009; "燃料乙醇将步入快速发展阶段,"[Ethanol fuel is about to enter a fast development stage] 51value, Jun. 14, 2006, www.51value.com

70. "2008-2009中国乙醇汽油发展现状分析,"[2008-2009 China Ethanol Gasoline Development Analysis] CMRN, www.cmrn.com.cn, Jul. 29, 2009

71. Xie, Xina, et al., "Methanol as Motor Fuel in China," Energy Tribune, Oct. 9, 2007, www.energytribune.com

72. "China's methanol gasoline promotion develops tardily," C1 Energy, May 24, 2010, www.c1energy.com

73. Partner and Strategic Advisor discussion during CGTI Cleaner Transportation Working Session, December 2010

74. "2010年中国天然气汽车市场趋势观察研究预测报告," [2010China CNGV Market Analysis] a8m, http://www.a8m.cn, accessed on Nov. 22, 2010; Li, Jun, et al., Development of NGV in China (Madrid: Span, Asian NGV Communications, Volume V Number 39 May 2010, 18)

75. Ibid.

Other alternative fuels have less near-term promise

China's policymakers have opted to support all alternative fuels, but currently emphasize mainly ethanol, methanol and natural gas.[76] Other less-promising fuels include liquefied petroleum gas (LPG), dimethyl ether (DME), coal-to-liquid (CTL) and bio-diesel, which together account for only 20% of the country's alternative transportation fuels consumption.[77] The LPG market is in decline with no significant growth potential for the near future, partly a result of LPG prices rising in accordance with world oil prices.[78] Bio-diesel's development is limited by lack of feedstock (oil plants) and underdeveloped oil collection systems.[79] However, bio-diesel is continuing on a small scale, with the 2006 Medium to Long-term Renewable Energy Development Plan targeting 2 million tons of bio-diesel production for 2020.[80] For CTL, due to the high investment cost and significant water use in production, as well as concerns over emissions, the central government has banned new small-scale projects.[81] In the meantime, DME applications have lingered in the pilot project stage.[82] With no significant government support on the horizon, this is unlikely to change.

Given feedstock, technology, infrastructure and user acceptance issues, alternative fuels face uncertain growth prospects

Alternative fuels consumption forecasts for 2020 vary widely. Ethanol forecasts range from a low of 3.7 billion liters to a high of 69.1 billion liters.[83] Projected methanol consumption ranges from 7.5 billion liters to 83.4 billion liters—a range so wide as to be nearly meaningless.[84] All of the other alternative fuels share similar gaps. The question of how alternative fuels will develop in China depends on how successful fuel producers are in overcoming feedstock supply, technical, infrastructure and user acceptance hurdles.

For ethanol, lack of feedstock is the most important obstacle. Maize (corn) is the main source of ethanol, so policymakers need to balance the need for fuel with the need for domestic food supply. In China, the need for domestic food supply has generally won out. With ongoing maize supply issues—China became a net maize importer in 2010—the government has banned all maize-based ethanol projects except for those originally established in 2004.[85]

The development of alternative fuels will depend upon overcoming technical, infrastructure, user acceptance and feedstock supply hurdles.

As maize ceases to be a viable source material for ethanol production, producers are experimenting with other plant-based materials. Ethanol that uses less critical food sources such as cassava and sweet sorghum as feedstock, sometimes called generation 1.5 ethanol, has reached a collective capacity of over 378 million liters per year, but feedstock shortages remain problematic.[86] Next on the horizon are second generation (2.0) ethanol projects that utilize non-food feedstock sources such as cellulose from plants, grass and trees, but due to immature technology, high costs and an underdeveloped feedstock supply chain, 2.0 ethanol has yet to be commercialized in China.

76. China Greentech Initiative interviews and analysis; for ethanol, see cmrm.com.cn, "2008-2009中国乙醇汽油发展现状分析,"[2008-2009 China Ethanol Gasoline Development Analysis] CMRN, www.cmrn.com.cn, Jul. 29, 2009; for methanol see "甲醇汽油'遍地开花'市场供需失衡需警惕,"[Methanol fuel supply is seen everywhere, be careful about the oversupply of methanol gasoline] IC98, www.ic98.com, Aug. 16, 2010; for natural gas see "2010年天然气汽车市场趋势观察研究预测报告,"[2010 natural gas vehicle market trend research forecast report] a8m, April 29, 2010, www.a8m.com

77. China Greentech Initiative interviews and analysis

78. "中国液化石油气生产与进出口现状与展望," [China LPG production, import and export current development and prospects] LNGOnline, Nov. 7, 2010, http://www.lngonline.cn

79. China Greentech Initiative interviews and analysis, and "2008年中国生物柴油行业投资价值研究报告," [2008 China Bio-diesel industry investment report], Xinhua, Sep. 26, 2008

80. Zhang, Yue, et al., "Alternative fuel implementation policy in China and its assessment," Institute of Energy Economics, Japan, May 2007, www.eneken.ieej.or.jp

81. Ibid.

82. China Greentech Initiative interviews and analysis, and "二甲醚的清洁能源之路," [DME's path as a clean energy source] NEV Focus, Oct. 12, 2010, http://nevfocus.com

83. China Greentech Initiative interviews and "车的能源的变革之风,"[Reformation of Alternative Fuels] Cpechina, http://www.cpechina.com , accessed on Nov. 11, 2010

84. China Greentech Initiative interviews, and Zhang, Yue, et al., "Alternative fuel implementation policy in China and its assessment," Institute of Energy Economics, Japan, May 2007, www.eneken.ieej.or.jp

85. "美林银行表示中国仍是玉米净进口国," [Merrill Lynch says China will continue to be a corn net import country] Hljjcsd, http://www.hljjcsd.com, Jul. 15, 2010

86. "燃料乙醇发展现状与趋势," [Ethanol Fuel Development and Trends] Chinavalue, http://www.chinavalue.net, accessed on Nov.22, 2010

Concerns from consumers and vehicle manufacturers toward methanol's harmful properties have slowed market uptake. While methanol's toxicity could be handled by well-managed supervision of the fuel's production and refueling processes, such an endeavor would be challenging considering the current lax supervision of China's fuel market.[87] The costs associated with methanol retrofits have also cooled demand for the fuel. Consequently, Chinese automakers have only dabbled in small-scale production, with the exception of Geely, which plans to build a methanol car plant with an annual capacity of 200,000 vehicles.[88]

Rail expenditures may reach RMB 3.5 trillion (US$ 538.5 billion) during the 12th Five-Year Plan period.

Lack of infrastructure, limited natural gas supplies and rising prices all affect the attractiveness of natural gas as a road transport fuel. China currently has more than 1,500 operating natural gas refueling stations, of which 1,400 are for CNG.[89] New stations require investments driven by high real estate costs in urban areas with restrictive zoning practices. Natural gas supply and pricing are also issues. China has experienced natural gas shortages in the past few years, which are predicted to increase despite growing supplies: the shortage was 4 billion cubic meters in 2009, when several cities were forced to curtail supplies to those with natural gas vehicles.[90] In Wuhan, to prevent residential customers from losing gas supplies, the city rationed gas by cutting off supplies to natural gas fueling stations and paid subsidies to drivers of natural gas taxis.[91] In Chongqing, which relies on natural gas buses for public transportation, bus services were curtailed.[92] The government raised prices by 24.9% in June 2010 to help demand match more restricted supplies.[93] Like other alternative fuels, natural gas faces its share of challenges.

Rapid Growth in Cleaner Rail

Opportunity Assessment

Rapid economic development and urbanization intensify China's need for greater rail capacity at both national and local levels, and the government is responding to the challenge.

In response to the mounting need for more long-distance freight and passenger capabilities, China has embarked on a major expansion of its already extensive rail network. Metropolitan systems are also undergoing a makeover as subway and light rail coverage expands dramatically. As rail transportation is generally perceived as more energy efficient than road or air alternatives, the China Greentech Initiative considers these to be greentech solutions.

By the end of 2010, China's rail network extended 91,000 km, making it the second longest in the world. The nation's Mid- and Long-Term Rail Network Plan will see the system grow to 120,000 km by 2020.[94] Unsurprisingly, railway expansions of this scale do not come cheap—rail expenditures under the 11th Five-Year Plan (2006-2010) amounted to RMB 2.2 trillion (US$ 338.5 billion), and may reach a total of RMB 3.5 trillion (US$ 538.5 billion) during the 12th Five-Year Plan period (2011-2015).[95]

87. China Greentech Initiative interviews
88. "China's methanol gasoline promotion develops tardily," C1 Energy, May 24, 2010, www.c1energy.com
89. Wei, Hong, "The Role of the Mini LNG in the Natural Gas Supply of China," Presentation to the U.S. China Oil and Gas Forum, Ft. Worth, Texas, Sep. 2010, http://www.uschinaogf.org
90. "China's 2010 Natural Gas Shortage To Exceed 10 Bln Cubic Meters," Asia Pulse, Jun. 6, 2010, http://chinamining.org
91. "China's natural gas shortage relieved, top economic planner," Xinhua, Nov. 23, 2009, www.xinhuanet.com
92. "Chinese cities grappling with natural gas shortage," China Daily, Nov. 23, 2009, www.chinadaily.com
93. "车用天然气价格不得低于最高油价的75%," [The Price of Natural Gas Used in Transportation Should Be No Less Than 75% of the Highest Fossil Fuel Price] Netease Auto, http://auto.163.com, accessed on Nov. 11, 2010
94. "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, Mar. 4, 2011, www.news.163.com; 铁道部, "中长期铁路网规划 (2008年调整),"[Ministry of Railways, "Mid- and Long-Term Rail Network Plan (2008 Revision)"] Oct. 31, 2008
95. "铁路投资十二五将超3万亿 铁道部不再占大头,"[Rail Investment in the 12th FYP to Exceed 3 Trillion, MOR to Step Aside] Economic Observer News, Nov. 6, 2010, www.eeo.com.cn

China's Mid- and Long-Term Rail Development Plan, 2020

Source: 铁道部, "中长期铁路网规划图(2008年调整)", *[Ministry of Railways, "Mid- and Long-Term Rail Network Plan Map (2008 Revision)"] Oct. 31, 2008*

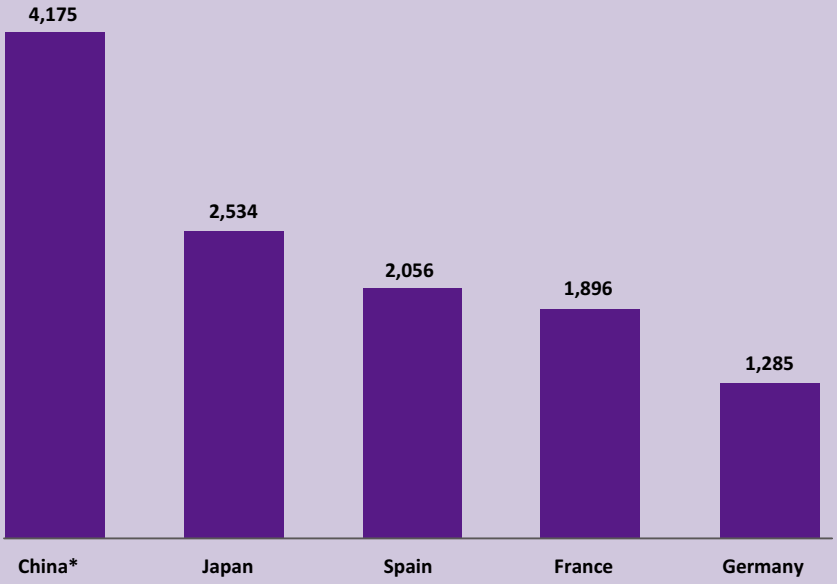
Expansion of China's electrified network and high-speed rail system has been dramatic

Electrification of China's rail system and development of a high-speed rail network have become interrelated priorities. During the 11th Five-Year Plan period, China built an additional 21,000 km of electrified rail, reaching a total 46% electrification rate for the entire network.[96] Meanwhile, the Ministry of Railways has accelerated its already aggressive target set out in the Mid- and Long-Term Rail Network Plan of a 60% electrification rate in 2020, now aiming for completion by 2015.[97]

High-speed applications are another focus of rail expansion. China's first high-speed rail line, a 200 kilometer per hour link between Guangzhou and Shenzhen, was inaugurated in 1998. Expansion since then has been dramatic: by the end of 2010, 8,358 km of high-speed rail were in operation, making China the world leader in operating distance.[98] If current development plans are realized, the network will have 16,000 km of high-speed rail by the end of 2015.[99] In terms of other superlatives, China now has the world's fastest rail link, connecting the cities of Guangzhou and Wuhan at an average speed of 350 km per hour.[100] When it begins operating in 2012, the 1,318 km Beijing-Shanghai track will be the world's longest and fastest line, carrying a forecasted 80 million passengers per year.[101]

96. "'十一五'我国铁路营业里程达9.1万公里," [China's Rail Reaches 91,000 km in Operation During 11th FYP] People's Daily, Jan. 4, 2011, http://finance.people.com.cn
97. Zhi Zhang, "高铁目标提前五年 资金紧张未来成常态," [High-Speed Rail Target Pushed Ahead 5 Years, Tight Funds to Become the Norm] China Times, Jan. 15, 2011, www.ce.cn
98. Note: This figure includes rail lines with operating speeds over 200 km/h. "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, Mar. 4, 2011, www.news.163.com
99. Ibid.
100. "China unveils the world's fastest train link; Electrified network surpasses 30,000 km, earning #2 spot in the world," Transport Gooru, www.transportgooru.com, accessed on Mar. 14, 2011
101. "京沪高铁全线铺轨 2012年前通车 京沪4小时直达," [Track Laid for Beijing-Shanghai High Speed Line, Operation

High-Speed Rail in Operation in Leading Countries, kilometers January 2011 (lines with operating speeds over 250 km/h)



*Note: China's Ministry of Railways includes lines with operating speeds over 200 km/h in its data, accounting for figures higher than shown here. China's high-speed rail is the world's longest by either count.

Source: "High speed lines in the world," International Union of Railways, Jan. 11, 2011, www.uic.org

Urban rail transport is a development priority

China's metropolitan railway network (subways and light rail) is also undergoing rapid expansion, buoyed in part by the commitment from municipal governments to deal with rising traffic congestion. Six cities (Beijing, Shanghai, Guangzhou, Tianjin, Changchun and Dalian) collectively had 363 km of railway in 2003.[102] By the end of 2010 urban rail line coverage had grown to over 1,000 km.[103] If current estimates hold, metropolitan railways will reach 3,200 km by 2015 and 5,000 km by 2020.[104] As proof of this commitment to expansion, in late 2009 almost two dozen cities received authorization to build 89 metro lines by 2016 at a total cost of RMB 880 billion (US$ 135 billion).[105] Beijing's subway system alone is slated to have 19 lines with 561 km of track in operation by 2015.[106]

Reconciling rapid growth with cleaner rail

While economic priorities drive China's railway expansion efforts, environmental considerations also play a role. The country's rail electrification plans, in which diesel fuel consumption by locomotives will be superseded gradually by an electrified network, can be viewed as an attempt to foster a more environmentally-friendly rail system. Among their advantages, electrified rail networks emit less air and noise pollution than systems that utilize diesel locomotives, and electrified locomotives are generally more efficient than their diesel counterparts. While electrified rail relies on predominantly coal-based electricity for the time being, in the future the system could use renewable power like solar and wind. High-speed rail consumes less fuel and emits fewer pollutants per passenger kilometer compared to automobiles and aircraft transport, and total costs of ownership are generally lower than competing highway and air transport alternatives.[107]

in 2012, 4 Hours from Beijing to Shanghai] The Central People's Government, Jul. 20, 2010, www.gov.cn

102. Li, Jacqueline, China Railway Construction Corporation – a key beneficiary of soaring Chinese railway spending (U.S.: Merrill Lynch, Oct. 2, 2008)

103. 中国高速铁路运营里程已达7055公里 世界第一," [China's High-Speed Rail Reaches 7,055 km in Operation, No. 1 Worldwide] China News, Oct. 26, 2010, http://news.sohu.com

104. Li, Jacqueline, China Railway Construction Corporation – a key beneficiary of soaring Chinese railway spending (U.S.: Merrill Lynch, Oct. 2, 2008)

105. "China rail firms look abroad for expansion," Channelnewsasia, Feb. 27, 2011, www.channelnewsasia.com

106. "Subway," Beijing Traffic Management Bureau, http://www.bjjtgl.gov.cn, accessed on Mar. 24, 2011

107. China Greentech Initiative analysis

China is also experimenting with greener rail technologies at the rolling stock level. Hybrid locomotives that use rechargeable energy storage systems, for example, have become a commonly adopted technology. The Chinese Mainline Evolution train, a powerful diesel-electric engine, emits up to 80% fewer emissions.[108] Energy efficient multiple unit trains (MUs), in which the train's power and traction components are spread throughout all of the cars that make up a train rather than being concentrated in one or more locomotives, are also making inroads. The number of operating MUs in China grew from only 140 in 2007 to an estimated 1,000 by 2010.[109]

High-speed rail development has its share of challenges

Rail development on this scale comes with its share of problems. Take the case of high-speed rail: the current system is disjointed, with segments that fail to form a coherent link between many of the country's major cities. Fortunately, this will be addressed as the government unveils new links designed to create a true high-speed network; however, for the time being the system remains disconnected.[110]

There is speculation that the poor quality of building materials could halve the lifespan of high-speed rail supports.

The network's rapid expansion has also called into question the quality of its construction. Emerging reports indicate that the concrete bases supporting the system's tracks were made cheaply and lack adequate chemical hardening agents. These vital support structures are also dependent upon high-quality fly ash, a powder-like byproduct of coal combustion that is mixed with gravel and cement. There is speculation that the poor quality building materials could at best halve the lifespan of these supports (from 100 to 50 years), and at worst pose safety problems to the system in as little as five years.[111]

Costs have emerged as another potential problem that may hinder China's rail expansion efforts. The Chinese Academy of Sciences has publicly expressed concern over what it considers unsustainable debt levels related to China's rail program. The Chinese government reportedly has ordered a review of priorities, perhaps driven in part by the fact that many new lines are operating significantly under capacity. [112] The Beijing-Tianjin high-speed line, for instance, is reportedly losing RMB 663 million (US$ 102 million) per year.[113] The February 2011 removal of Liu Zhijun, head of China's Ministry of Railways, on corruption charges may also be part of a broader review of China's rail expansion plans. Under Liu's watch, the Ministry of Railways accumulated significant debt levels. As recently as 2009, the Ministry was carrying RMB 854.8 billion (US$ 131.5 billion) in short-term debt and RMB 448.6 billion (US$ 69 billion) in long-term debt, a debt level that has reportedly reached RMB two trillion (US$ 307.7 billion) by early 2011.[114]

Cost is also an issue at the consumer level. The high-speed network is unpopular with working- and middle-class Chinese due to high ticket prices. Migrant laborers in particular are unable to afford the premium that high-speed travel commands .[115] For example, a high-speed ticket between Guangzhou and Wuhan costs RMB 469 (US$ 72), which is comparable to an airline ticket booked one week in advance.[116]

A long-term investment

The expansion of China's rail network has been nothing short of dramatic, with high-speed rail the most visible manifestation of this growth; however, immediate challenges remain, including concerns over quality, financing, capacity utilization

108. Pasternack, Alex, "China's Powerful New Emission-Killing Trains," Treehugger, Aug. 8, 2008, www.treehugger.com
109. China Greentech Initiative analysis
110. David, Michael, "The Year of the Metal Rabbit: China's High-Speed Rail Network," BusinessWeek: Asia, Feb. 9, 2011, www.businessweek.com
111. Chen, Stephen, "'Judgment day' fears for high-speed rail tracks," South China Morning Post, Jan. 10, 2011, www.scmp.com
112. "On the wrong track?" The Economist, Feb. 3, 2011, www.economist.com
113. "A look at China's high-speed rail investments," Climate Progress, Feb. 21, 2011, http://climateprogress.org
114. "Will Massive Debt Derail China's High Speed Train Plans?" The Wall Street Journal – China Realtime Report, Feb. 18, 2011, http://blogs.wsj.com
115. "On the wrong track?" The Economist, Feb. 3, 2011, www.economist.com
116. "Will Massive Debt Derail China's High Speed Train Plans?" The Wall Street Journal – China Realtime Report, Feb. 18, 2011, http://blogs.wsj.com

and consumer acceptance. Nevertheless, from a longer term perspective, the investment in subways and high-speed rail may very well pay off, as China puts in place infrastructure for the coming decades that can move hundreds of millions of people efficiently, cost-effectively and in a more environmentally-friendly way than many alternative forms of transportation.

Cleaner Transportation Opportunities for 2011

This chapter provides an update of China's Cleaner Transportation sector and four Opportunity Assessments prioritized by the China Greentech Initiative's partners and advisors in 2010. As the sector evolves, participants in the China Greentech Initiative Partner Program will continue to collaborate on additional opportunity areas. The first topic in 2011 covers energy-efficient and emission-reducing technologies for conventional internal combustion engine-based vehicles. Other topics may include cleaner fleets, light electric vehicles, electric vehicle charging infrastructure and vehicle-to-grid (V2G), natural gas vehicles, domestic innovation and foreign participation in high-speed rail, and further developments in EV battery technology. The China Greentech Initiative will also continue to track the overall evolution of China's Cleaner Transportation sector.

Steve Bale

Clean Water

Given the critical importance of water to China's future, the government has made Clean Water a major priority, including investing in wastewater treatment, improving water efficiency, and ensuring adequate water supply; however, much more remains to be done.

Water pollution and scarcity due to drought, overuse and weak enforcement are some of the biggest problems facing China today. The government is responding to these problems with new policies and major investment projects: China has tripled the number of municipal wastewater plants, initiated the immense South-to-North diversion project, and planned desalination projects near urban areas. Better enforcement of existing water laws and new regulations to increase efficiency are also government priorities, but the scale of the problem is sufficiently large that even these laudable policies will not be enough.

This chapter begins by providing an overview of Clean Water sector developments since the publication of *The China Greentech Report 2009*. It then summarizes the three Opportunity Assessments developed by the China Greentech Initiative in collaboration with partners and advisors throughout 2010:

- Private Sector Opportunities for the Municipal Wastewater and Sludge Treatment Market
- Private Sector Participation in Water Utilities
- Improving the Profitability of Municipal Wastewater Treatment Plants

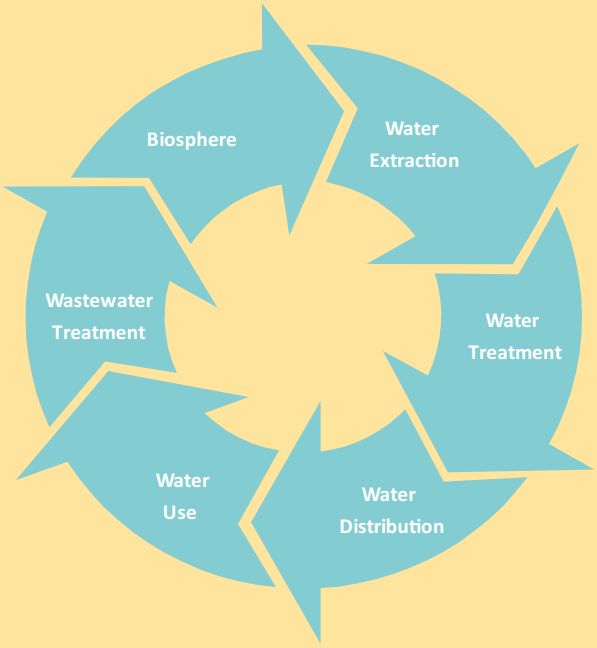
The China Greentech Initiative's partners and advisors prioritized each of these Opportunity Assessments as critical to the growth of China's Clean Water sector within the next two to three years. These summaries represent high-level findings of the detailed proprietary research and analysis developed in collaboration with and for organizations participating in the China Greentech Initiative Partner Program. The chapter concludes with an outlook on additional opportunities and issues in the Clean Water sector that the China Greentech Initiative intends to explore in 2011.

The writing of this chapter was led by Ana Lin T. Chiong, based upon strategic research deliverables completed by Angela Fan (范羽) and Julien Bedin (朱立安) of the China Greentech Initiative's Clean Water sector research team.

Clean Water Sector Definition

The China Greentech Initiative defines the Clean Water sector as all activities within the economic water cycle: water extraction, water treatment, water distribution, water use and wastewater treatment. Clean Water technologies include those related to water treatment, water quality measurement or monitoring, and efficient point-of-use equipment.

China's Clean Water Sector



Water Extraction: Provision or extraction of water resources from the biosphere to original water rights holders

Water Treatment: Processes by which raw water is made ready for use

Water Distribution: Transportation of treated water to end users

Water Use: Consumption of water by agricultural, industrial or domestic users

Wastewater Treatment: Collection and cleansing of water discharged after consumption for secondary consumption or release back to nature

Source: China Greentech Initiative Analysis

Market Update

China has made substantial progress on clean water, but issues remain

China's Clean Water sector has developed quickly in recent years. The country has established new national water quality criteria and increased the percentage of the population that consumes drinking water from improved water sources, from 69% in 1990 to 89% in 2010.[1] The government has promoted public-private partnerships (PPPs) in water projects to allow technology and financial transfers from private to state-owned treatment plants. The wastewater treatment market also has grown rapidly, increasing the national average treatment rate.

However, serious problems of water pollution and continued drought still loom over the sector. These water supply problems have the potential to lead to further economic, agricultural and public health issues; therefore, the government has made water a major priority. New policies include water desalination targets, water diversion projects and new wastewater treatment plants. The 12th Five-Year Plan includes a range of targets and policies to improve water supply, usage and treatment.

1. Wu, F. et al., China Embarking on Development of its Own National Water Quality Criteria System (Beijing, China: Environmental Science & Technology Viewpoint, Vol. 44, No. 21, 2010, 2); current national aquatic environmental quality standards in China were derived from and/or based on environmental quality standards or criteria of developed countries and have no specific protection objectives, which may not fit the regional environmental and current needs of environmental management in China; Progress on Sanitation and Drinking Water: 2010 Update (Geneva, Switzerland: World Health Organization and UNICEF, 2010, 10); improved drinking water sources are defined in terms of the types of technology and levels of services that are most likely to provide safe water than unimproved technologies. Improved water sources include household connections, public standpipes, boreholes, protected dug wells, protected springs and rainwater collections.

Water pollution remains a major issue

Water pollution is a major issue in China despite the progress made over the past few years. Lakes and rivers are severely polluted, with the Yellow River, Yangtze River and Lake Tai among the most polluted in the world.[2] In 2007, China discharged a total of 55.7 billion cubic meters of wastewater, a large portion of which flowed directly into surface water bodies without treatment.[3] For municipal wastewater, the government in 2008 estimated the treatment rate at 59%.[4]

In February 2010, China released the results of its first national census on pollution, revealing that water pollution levels were worse than initially thought.[5] The census found that pollution discharged into the water in 2007 was 30.3 million metric tons, more than twice the government's prior estimate of 13.8 million metric tons.[6] Vice Environment Protection Minister Zhang Lijun explained that the survey's expanded scope, inclusion of agricultural sources of water, and different calculation methods all contributed to the different result.[7] The government has more to do to manage the quality of wastewater being discharged into the environment.

Clean water is a government priority

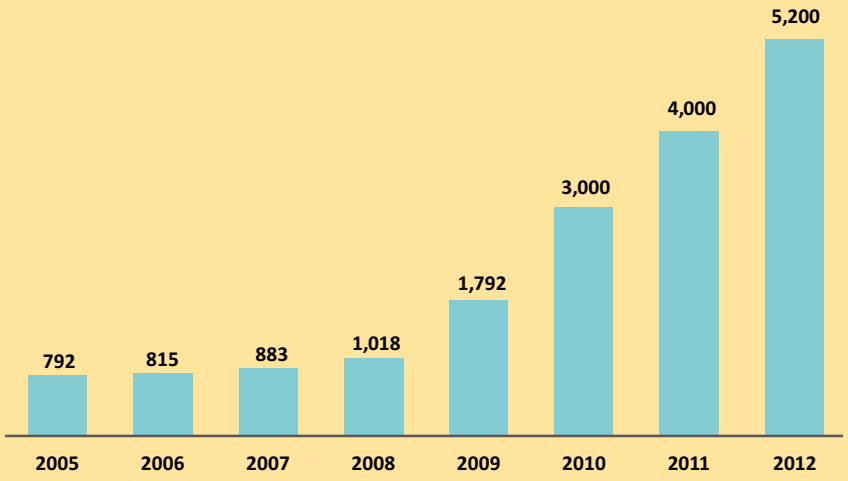
China's central government announced in December 2009 that it will invest RMB 90 billion (US$ 13.8 billion) from 2010 to 2012 to build wastewater disposal systems to ensure drinking water safety.[8] Though the country has made improvements in the wastewater treatment industry in the past three decades, the quality of major water sources is still unsatisfactory. One estimate indicates that in 2009, 270 million people in rural China had no access to safe drinking water.[9]

From 2005 to 2009, the number of municipal wastewater treatment plants grew from 792 to 1,792, an 18% compound annual growth rate.[10] China estimates annual growth will rise to 31% between 2009 and 2012, resulting in around 5,200 treatment plants by 2012, an astonishing six times the number in 2005.[11] The size and location of the plants will also shift. In 2008, 57% of wastewater treatment plants in China were classified as medium-sized, defined as able to treat 10,000 to 100,000 cubic meters of water daily—roughly equal to three to 32 Olympic-sized pools of water per plant.[12] Many medium-sized treatment plants are in second-tier cities or the outskirts of large cities as the trend is towards building smaller plants as lower-tier cities invest in their own wastewater treatment facilities.[13]

While mid- and small-sized cities work at improving their water quality and supply, Tier One cities are also facing issues of their own. Tap water in Beijing and Shanghai has been found to contain over 89 chemicals, elements and compounds.[14] Laboratory reports from Tsinghua University and Beijing Institute of Technology confirmed that Beijing tap water contains dangerous levels of mercury and other heavy metals. Shanghai and Chongqing tap water are said to be even worse.[15] A survey conducted by the Ministry of Environment Protection (MEP) revealed more than half the water in China is so polluted as to be undrinkable, and nearly a quarter is so toxic that it is unsafe even for industrial use.[16]

2. Kristin, Underwood, "World's Dirtiest Rivers and Lakes," Tree Hugger, June 10, 2009, www.treehugger.com
3. Innovation Center Denmark, Wastewater Treatment in China (Shanghai, China: Innovation Center Denmark, 2009, 4)
4. Ibid.
5. The comprehensive national census started in 2007 and was finished two years later. Results were released in early 2010.
6. "China's First Pollution Census Shows Worsening Environment," Asia Briefing, Feb. 10, 2010, www.2point6billion.com; "China says water pollution double official figure," China Daily, Oct. 2, 2010, www.chinadaily.com.cn
7. Ibid.
8. "China To Invest CNY90 Billion For Waste Water Treatment," China CSR, Dec. 4, 2009, www.chinacsr.com
9. Ibid.
10. "China wastewater discharge and treatment," National Bureau of Statistics of China, www.stats.gov.cn, accessed on Feb. 25, 2011
11. Ibid.
12. Small plants are defined as having a capacity of 10,000 cubic meters per day or less, medium as 10,000-100,000 cubic meters per day, and large as over 100,000 cubic meters per day.
13. Tier I cities include: Shanghai, Beijing, Guangzhou and Chengdu; Tier II cities include secondary provincial capitals; Tier III includes: prefecture or county level city capitals
14. ChinaScamBuster, "China's Tap Water – Anything But Safe!" Zimbio, Jan. 17, 2011, www.zimbio.com
15. Ibid.
16. David, Gutierrez, "Over half of China's water polluted beyond drinkability," NaturalNews, Dec. 6, 2010, www.naturalnews.com,

China's Municipal Wastewater Treatment Plants
number of plants, 2005-2012



Source: National Bureau of Statistics of China, "China Statistical Yearbook, 2005-2010"; China Greentech Initiative Analysis

MOHURD Measures Aim to Improve Wastewater Treatment Plant Performance

The Ministry of Housing and Urban-Rural Development (MOHURD) issued "Interim Measures in Assessment of Municipal Wastewater Treatment" in September 2010 to improve the performance assessment of wastewater treatment plant construction and operation.

"Interim Measures in Assessment of Municipal Wastewater Treatment" calls for wastewater treatment plants to be assessed on wastewater treatment coverage, treatment, equipment usage, pollutant reduction efficiency and other management indicators. Annual internal plant performance assessments, which include wastewater treatment plans, implementation, supervision, wastewater treatment fees, water quality control and reports of major accidents, should be completed each March and submitted to MOHURD.

Source: 中国水网，"住房城乡建设部制定‘城镇污水处理工作考核办法’，" *2010年09月07日 (China Water website, "MOHURD regulates "Municipal Wastewater Treatment Assessment Method"), http://news.h2o-china.com*

Because of this, Chinese residents are increasingly turning to bottled or barrelled water. From 2003 to 2008, China was the only country with double-digit annual growth in total bottled water consumption, and is now a leading bottled water consumer in absolute volume.[17] China's per capita bottled water consumption is still far below that of the developed world, so there is further room for growth even in the absence of water problems.[18]

The bottled water market in China is fragmented and composed of domestic and foreign suppliers, with foreign players dominating the premium market. Analysts believe that China's bottled water industry faces challenges preserving water quality and protecting consumers from unscrupulous operators.[19] Proper regulation and strict enforcement will be needed as the industry continues to expand. In the long run, however, it is better for the government to strive to make clean tap water accessible, as this would minimize the need for bottled water packaging and transportation that contributes to land and air pollution.

Severe drought prompts major water infrastructure investments

Drought has caused severe damage to China's agricultural and industrial sectors in the past two years. In 2009 more than 4.5 million people were short of water in northern China due to the severe drought, while crops and livestock were threatened

17. Rodwan, Jr., John, Confronting Challenges: U.S. and International Bottled Water Developments and Statistics for 2008 (New York, USA: Beverage Marketing Corporation, Apr./May 2009, 5-6)
18. Ibid.
19. Shaun, Weston, "The Chinese bottled water market," FoodBev, Aug. 12, 2009, www.foodbev.com

in the South.[20] Drought also affected industry: for example, in early 2010 half the smelting capacity in Gejiu City in Yunnan Province closed temporarily due to water shortages.[21] The crisis forced the government to earmark RMB 6 billion (US$ 923 million) in emergency water aid to give temporary relief to those affected by what many consider the most severe drought in recent history.[22]

In the long-term, the government is working on investments in water desalination and diversion projects. The National Development and Reform Commission (NDRC), State Oceanic Administration (SOA) and Ministry of Finance (MOF) issued the Special Plan for Seawater Utilization in 2005, which announced desalination and seawater use targets. For 2010, desalination capacity was 0.8 to 1 million cubic meters per day, equivalent to one day's water consumption for 270 million people, and direct seawater utilization capacity was 55 billion cubic meters per year. In 2020, desalination capacity is expected to reach 2.5 to 3.0 million cubic meters per day, equivalent to one day's water consumption for 810 million people; direct seawater utilization is forecasted at 100 billion cubic meters per year.

Financing is a significant issue preventing private participation in desalination opportunities in China.[23] Desalination plants need a tremendous amount of investment to support the technologies, engineering and construction involved. Desalinated water is approximately three times more expensive than tap water.[24] The government does not have any direct incentives or funds for desalination projects.[25] Despite the high costs and lack of incentives, there are still various desalination projects expected in Beijing, Hebei, Tianjin and Shandong.

Northern China has 47% of the country's population, produces 45% of China's GDP and has 65% of the country's cultivated land, yet it has only 19% of the country's water resources. To alleviate this water resource imbalance, the government is moving ahead with the controversial South-to-North Diversion project, originally proposed by Mao Zedong in the 1960s. After decades of planning and discussion, construction began in December 2002—with completion not expected for decades.[26] The RMB 500 billion ($77 billion) project will divert 44.8 billion cubic meters of water per year, equivalent roughly to half the amount of water consumed in California annually, from the Yangtze River in southern China, to the Yellow, Huaihe and Haihe Rivers in northern China.[27]

The South-to-North Diversion project is made up of three routes: eastern, central and western. The 1,156 km eastern route will run from Jiangsu to Shandong, while the 1,267 km central route stretches from Hubei to Beijing and Tianjin.[28] The western route, proposed to run through the Qinghai-Tibet Plateau, is still being assessed because the route is immensely expensive and difficult to construct.[29] It was expected that the central route would be finished in time for the 2008 Beijing Olympics, but construction has been beset by delays pushing completion to 2014. Delays have also prolonged the construction of the eastern route, causing completion of the first phase to be pushed back to 2013.[30] The delays are primarily due to inflating costs and financing challenges.[31]

20. "Millions at risk in China drought," BBC, Aug. 23, 2009, www.news.bbc.co.uk
21. Polly, Yam, "China's main lead centre may cut 10% of production capacity in 2010," Mineweb, Jun. 3, 2010, www.mineweb.com
22. Jonathan, Watts, "China bids to ease drought with $1bn emergency water aid," Guardian, Feb. 11, 2011, www.guardian.co.uk
23. "Market Report: Developing Desalination in China," Water World, www.waterworld.com, accessed on Mar. 14, 2011
24. According to Guo Youzhi, Vice-chairman of the Membrane Industry Association, not including fixed investments, estimated desalination cost is about RMB5-7/m^3
25. "Market Report: Developing Desalination in China," Water World, www.waterworld.com, accessed on Mar. 14, 2011
26. "South-to-North Water Diversion Project, China," Water-Technology, www.water-technology.net, accessed on Mar. 14, 2011
27. "South-North Water Transfer Project," International Rivers, www.internationalrivers.org, accessed on Mar. 14, 2011; Jamil, Anderlini, "China: A blast from the past," Financial Times, Dec. 14, 2009, www.ft.com
28. "South-to-North Water Diversion Project, China," Water-Technology, www.water-technology.net, accessed on Mar. 29, 2011; Xu Weiyi, "Experts: Water Diversion Project is Only a Supplementary Solution to North China's Water Shortage," CRI English, Mar. 17, 2010, http://english.cri.cn
29. Ibid.
30. "FACTBOX: Facts on China's South-to-North Water Transfer Project," Reuters, Feb. 26, 2009, www.reuters.com
31. Tian Lei, "Why is the south-north water project being postponed?" PROBE International, Oct. 1, 2009, www.probeinternational.org

Proponents of the massive project stress that 250 million people from the provinces of Hebei, Henan, Shandong, Beijing, Tianjin and other adjacent areas will benefit from the project upon completion.[32] However, critics point out that the project can only partly solve north China's water shortage dilemma. Instead, they recommend that China improve attitudes toward water use and prioritize water conservation and use of treated wastewater.[33] Cost is also a problem—water provided by the project will cost five times the current national average price and 25% more than desalination.[34]

The diversion scheme also raised concerns over the displacement of affected people whose homes will be submerged after the project is completed. In February 2011, it was announced that 190,000 local residents in central China will be resettled in addition to the 149,000 already relocated.[35] Environmental degradation is also a potential consequence of the project, which will require significant incremental energy and could further pollution challenges. For example, pollution from factories along the eastern route and plans for further industrialization in the other routes may render the water unfit to drink.[36]

Beyond mega-projects, the government strives to address efficiency and pollution

According to Wang Yahua, Deputy Director of the Center for China Study at Tsinghua University, "Water shortage is the most important challenge to China right now, the biggest problem for the future growth. It's a puzzle that the country has to solve."[37] The government must take immediate steps to ensure adequate water resources to support growth. Water is a major priority of the 12th Five-Year Plan, with marine ecological restoration included for the first time in any Five-Year Plan.[38] The 12th Five-Year Plan will also double China's investments in water, with the bulk of investments allocated to projects to treat drinking water and wastewater.[39] The plan also targets to reduce water consumption per unit of industrial output by 30% by 2015.[40]

Penalties for Exceeding National Water Pollution Limits

2010 pollution reduction targets were strictly implemented by the central government as China's water cleanup progress did not meet targets in 2009. Fines were levied upon municipalities that went beyond water pollution limits.

In January 2010, Shaanxi Provincial Environmental Protection Bureau implemented a regulation that would penalize city governments RMB 100,000 for each milligram per liter of chemical oxygen demand (COD), a gauge for water pollution, above acceptable levels found in rivers and lakes. Xian and Xianyang were the first cities fined under the new law, with Xian fined a total of RMB 400,000 for pollution that exceeded the COD limit by 4 milligrams per liter.

Source: Honey Garcia, "China reaches for green goals with an iron hand," EcoSeed, Jun. 1, 2010, www.ecoseed.org; "City governments fined for Yellow River pollution," China Daily, Mar. 11, 2010, www.chinadaily.com.cn

32. Xu Weiyi, "Experts: Water Diversion Project is Only a Supplementary Solution to North China's Water Shortage," CRI English, Mar. 17, 2010, http://english.cri.cn
33. Ibid.
34. According to Guo Youzhi, Vice-chairman of the Membrane Industry Association, not including fixed investments, estimated desalination cost is about RMB5-7/m^3 and SNWD costs about RMB10/m^3
35. "China to relocate 190,000 people for south-north water diversion project this year," Xinhua, Feb. 25, 2011, www.newsxinhuanet.com
36. "South-to-North Water Diversion Project, China," Water-Technology, www.water-technology.net, accessed on Mar. 14, 2011
37. "Choke Point: China – Confronting Water Scarcity and Energy Demand in the World's Largest Country," Circle of Blue, Feb. 15, 2011, www.circleofblue.org
38. "12th Five-Year Plan targets polluted water," China Daily, Nov. 6, 2010, www.chinadaily.com.cn
39. "Research and Markets: China Water and Wastewater Treatment Market," Business Wire, Dec. 23, 2010, www.businesswire.com
40. China Greentech Initiative analysis

Local governments are also doing their share to curb water pollution and inefficient consumption. Jiangsu Province piloted a water pollution emission trading scheme among factories around Lake Tai in 2009. Lake Tai is notorious for recent severe pollution problems: in 2007 an algae bloom caused the closure of a thousand factories operating around the lake, not to mention undrinkable water. The provincial cap-and-trade scheme will sell discharge permits to businesses operating near the lake, which they can then buy or sell if their discharge is above or below their set quota.[41] The pilot trading scheme may pave the way for a national water pollution cap-and-trade program once the system has been perfected.

Government support will push rapid growth of China's wastewater treatment market

Two of the three Clean Water sector Opportunity Assessments developed in 2010 were directly related to the burgeoning wastewater treatment market. Wastewater treatment is an integral part of the country's strategy to provide its citizens with adequate and safe water as it struggles with water scarcity and pollution problems. While the wastewater treatment market experiences rapid growth, it is important to note that many of the municipal wastewater treatment plants in operation are struggling to break even, with private companies receiving mixed signals from the government regarding their participation.

The China Greentech Initiative developed a Market Attractiveness Assessment (MAA) to evaluate the wastewater treatment market on six criteria: government support, addressable market size, solution attractiveness, five-year market growth potential, market accessibility and profit opportunity. Information on the Market Attractiveness Assessment methodology is found in the Research Methodology chapter.

Municipal wastewater treatment

The attractiveness of China's municipal wastewater treatment market is driven mostly by strong government support as announced by increased investment under the 12th Five-Year Plan. Solution attractiveness, five-year growth potential and market accessibility are all rated as above average; however, estimated addressable market size and profitability challenges presently limit profit opportunities for plant operators.

Government support for the municipal wastewater treatment is rated as highest priority because of its designated importance in the 12th Five-Year Plan: a bulk of the investment allocated to the water sector is set aside for wastewater treatment projects. Quantity is not only the focus of the government. In 2010, it issued wastewater treatment plant performance assessment measures to monitor the performance quality of each facility. Additionally, provincial governments fined municipalities that went beyond water pollution limits to encourage them to adopt wastewater treatment facilities in their respective municipalities.

The addressable market size is considered *medium* based on the China Greentech Initiative's estimates of potential market size for solutions related to the wastewater treatment market. Solutions considered are primary, secondary and tertiary treatment technologies, and sludge treatment and disposal technologies.

Solution attractiveness is evaluated as *attractive.* Primary treatment solutions are considered industry standard since all wastewater treatment facilities are expected to have this technology, while secondary and tertiary treatment processes will be increasingly adopted by municipal wastewater treatment facilities as they aim to improve quality of service.[42] In November 2010, MEP issued a notice urging municipal wastewater treatment plants to incorporate sludge treatment solutions, recognizing that as sludge treatment lags behind sewage treatment, it results in improper disposal of sludge into the environment.[43]

41. "China's Permit-Based Emissions Trading to Cut Down on Major Pollutants," EcoWorld, Mar. 6, 2008, www.ecoworld.com; "China to test water-pollution permit in Jiangsu," China.org.cn, Dec. 27, 2007, www.china.org.cn

42. He, P.J., Sewage Sludge in China: Challenges Toward a Sustainable Future (Shanghai, China and Taipei, Taiwan: Tongji University and National Taiwan University, 2007)

43. "Sewage Treatment Plant Sludge Disposal," Yixing HY Environment Technology Co., Ltd., Jan. 2, 2011, www.hyenvironment.com

Five-year market growth potential will be *rapid* based on investment estimates. Investment in wastewater treatment market is expected to double in the 12th Five-Year Plan, while sludge treatment market investment is expected to increase from RMB 32.3 billion in the 11th Five-Year Plan to RMB 100 billion by the end of the 12th Five-Year Plan.[44]

Accessibility to the wastewater treatment market is *open with restrictions.* Private sector participation in the market is allowed but usually done in cooperation with government entities. Participation is mostly through build-operate-transfer/transfer-operate-transfer (BOT-TOT) and operation and maintenance (O&M) arrangements.

Profit opportunity in China's wastewater treatment market is considered *average.* Plant operators are permitted by the government to implement wastewater treatment fee hikes provided that they adhere to certain legal procedures and consider the welfare of the public.[45] Competition in China's wastewater treatment market is mostly between SOEs and large private domestic and foreign companies, making it difficult for relatively small companies and new entrants to compete in the market. Threat of substitute to wastewater treatment facilities is low since water that comes from the tap should be safe for human, agricultural and industrial use.

Clean Water Market Attractiveness Assessment—Municipal Wastewater Treatment

Assessment Criteria	Attractiveness	Explanation
Government Support	●	■ The 12th Five-Year Plan will double investments in water, with much of that allocated to projects to treat drinking water and wastewater ■ Issued "Interim Measures in Assessment of Municipal Wastewater Treatment" in September 2010 to improve performance assessment of wastewater treatment plants ■ Implemented penalties upon municipalities that went beyond water pollution limits
Addressable Market Size	◑	■ Solutions related to municipal wastewater treatment have an average estimated addressable market size
Solution Attractiveness	◕	■ Primary treatment solutions are considered industry standard ■ Wastewater treatment plants will increasingly adopt secondary or tertiary treatment processes ■ Sludge treatment solutions are being pushed by the government to be incorporated in municipal wastewater treatment plants
Five-Year Market Growth Potential	◕	■ Investment in wastewater treatment market is expected to double in the 12th Five-Year Plan ■ Investment in sludge treatment in the 12th Five-Year Plan is around RMB 100 billion (US$ 15 billion) up from RMB 32.3 billion (US$ 5 billion) in the 11th Five-Year Plan
Market Accessibility	◕	■ Allowed private sector participation in wastewater treatment market since the late 1990s ■ Private participation in the wastewater treatment market is mostly through build-operate-transfer/transfer-operate-transfer (BOT-TOT) and operation and maintenance (O&M) arrangements
Profit Opportunity	◑	■ Plant operators are permitted by the government to increase wastewater treatment fee to reflect true cost of operations ■ Market is characterized by intense competition between SOEs and large private companies (both domestic and foreign) ■ Low threat of substitute to wastewater treatment facilities ■ The government supports private domestic and foreign participation in the wastewater treatment sector through the various wastewater treatment laws and policy statements issued however, implementation in provincial levels is a challenge ■ High-end technology solutions are favored by foreign companies while domestic companies lean towards more affordable technology

44. "Research and Markets: China Water and Wastewater Treatment Market," Business Wire, Dec. 23, 2010, www.businesswire.com; Innovation Center Denmark, Wastewater Treatment in China (Shanghai, China: Innovation Center Denmark, 2009); "China Industrial Waste Management's Sewage Sludge Treatment Facility Voted 'Best Sewage Sludge Process Application of China'," PRNewswire, www.prnewswire.com, Sep. 21, 2010

45. Dr. Guo Peiyuan, "Increasing water tariffs: Are Chinese companies ready?" The Asia Water Project, accessed on Mar. 22, 2011

Market Attractiveness Assessment Legend

Government Support	Addressable Market Size	Solution Attractiveness
● Highest priority	● Very large	● Advantaged
◕ High priority	◕ Large	◕ Attractive
◑ Medium priority	◑ Medium	◑ Emerging
◔ Low priority	◔ Limited	◔ Disadvantaged
○ No priority	○ Niche	○ Unavailable
Five-Year Market Growth Potential	**Market Accessibility**	**Profit Opportunity**
● Very rapid	● Fully open	● Superior
◕ Rapid	◕ Open with restrictions	◕ Above average
◑ Medium	◑ Partially limited	◑ Average
◔ Slow	◔ Limited	◔ Limited
○ Very slow	○ Restricted	○ Challenging

Source: China Greentech Initiative analysis

The path ahead

China faces a continued water crisis despite the many major steps the Chinese government has taken in the past years to address water problems. It is clear from the scale of pollution and rapidly increasing water shortage in the North that more needs to be done. Fortunately, water is a major government priority. Government support of water price hikes to improve profitability of utility companies and execution of various infrastructure projects such as desalination, the North-South diversion project, and new treatment plants are only a part of the solution. Much more attention to efficiency and enforcement of pollution regulations is also needed.

Private Sector Opportunities for the Municipal Wastewater Treatment Market

Opportunity Assessment

As China shifts investment in wastewater treatment to low-tier cities in the South and Southwest, there are opportunities for private participation in build-operate-transfer (BOT) and operation and maintenance (O&M) models, though low cost solutions and inefficient operation remain the norm.

China has rapidly boosted municipal wastewater treatment rates since 2007, with investment now shifting towards lower-tier cities, as well as the South and Southwest. Pricing is still set locally, with no obvious national trends. Private participation can bring needed expertise to the sector (plagued by inefficient public operation), but most regions still focus on low-cost solutions. BOT-TOT and O&M models are the most promising areas for private sector involvement.

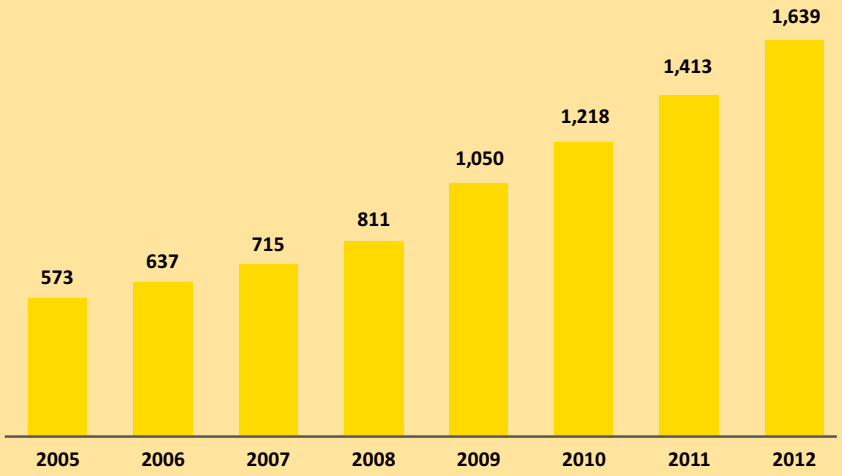
Wastewater treatment rate is rising rapidly

China's urban wastewater treatment ratio steadily grew from 34% in 2000 to 57% in 2006, reaching the 70% target in 2010 established under the 11th Five-Year Plan.[46] However, the same cannot be said about the rural wastewater treatment rate, which is significantly lower than urban treatment rates: at the outset of 2010, less than 15% of towns and villages even had wastewater treatment facilities.[47]

This dire situation is expected to improve slowly with the construction of new wastewater treatment plants. Magnifying growth from 2005 to 2009, during which time the number of plants increased by 18% annually (from 792 to 1,792), this figure is expected to more than double again to over 5,000 by 2012.[48] The China Greentech Initiative's interviews with industry experts suggest over a thousand wastewater treatment plants will be built in 2011 alone. Daily treatment capacity will reach 1.6 billion cubic meters per day by 2012, roughly equivalent to the total storage capacity of Gezhou Dam on the Yangtze River.

46. China market overview: Waste water treatment (Beijing, China: Yatsen Associates Co., Ltd., 2009, 3)
47. Dr. Hui Zhao, Decentralized Approaches to Rural Wastewater Treatment in China (China: Ministry of Housing and Urban-Rural Development, January 27, 2010)
48. "China wastewater discharge and treatment," National Bureau of Statistics of China, www.stats.gov.cn, accessed on Feb. 25, 2011

China's Municipal Wastewater Treatment Daily Capacity, million cubic meters, 2005-2012



Source: National Bureau of Statistics of China, "China Statistical Yearbook, 2005-2010"; China Greentech Initiative Analysis

Cities in eastern China generally have more funds for water treatment than other areas, since they have the highest concentration of the urban industrialized areas which are the largest generators of wastewater.[49] In 2008, 37% of China's municipal wastewater treatment plants were located in eastern China, with most plants concentrated in the provinces of Hebei, Shandong, Henan, Jiangsu and Zhejiang. To correct this geographic imbalance, construction of new wastewater treatment plants has slowly migrated from eastern to southern China. Over 30% of new wastewater treatment plants by the end of 2010 were estimated to have been built in southern China, compared to just 15% in 2008. Moreover, new treatment plants are increasingly being built in second- and third-tier cities as the focus shifts towards building medium and small plants.

The 11th Five-Year Plan (2005-2010) allocated RMB 330 billion (US$ 50.8 billion) for the wastewater sector, 67% of which went to pipe network improvement. The inadequate pipe network is said to be a major reason why some wastewater treatment plants were operating below capacity, since wastewater was inefficiently directed to the plants. MOHURD plans to continue investing in the upgrade and maintenance of pipes as proposed in the 12th Five-Year Plan, and to construct extensive separate rainwater and sewage systems integrated with roads, residential buildings and industries.[50] However, as always, cost is an issue. Though wastewater pipes in China are available in three sizes to accommodate precipitation rates, most cities choose the smallest size to save costs, which results in pipes being overwhelmed during heavy rainfall.[51]

Progress in sludge treatment lags behind wastewater treatment

Even though wastewater treatment has improved in the past few years, the same cannot be said about the treatment of sludge (the waste product after sewage treatment). Less than 25% of wastewater treatment plants in China have stable operating sludge treatment facilities, while less than 10% have facilities that work relatively well.[52]

Sludge is a major pollution offender: 76% of sludge produced currently ends up in landfills, while 14% is improperly discharged into the environment causing secondary pollution.[53] Less popular methods of sludge disposal are incineration and fertilizer or gardening use. Recent estimates show that around 175,000 tons of sludge is generated per day in China.[54]

49. "New Deals in China's Wastewater Treatment Market," The JLJ Group, Apr. 20, 2010, www.rightsite.asia
50. "Flooding exposes Chinese infrastructure woes," Global Water Intelligence, Aug. 2010, www.globalwaterintel.com; Innovation Center Denmark, Wastewater Treatment in China (Shanghai, China: Innovation Center Denmark, 2009, 24)
51. "Flooding exposed Chinese infrastructure woes," Global Water Intelligence, Aug. 2010, www.globalwaterintel.com
52. Innovation Center Denmark, Wastewater Treatment in China (Shanghai, China: Innovation Center Denmark, 2009, 14)
53. "Sewage Treatment Plant Sludge Disposal," Yixing HY Environment Technology Co., Ltd., Jan. 2, 2011, www.hyenvironment.com
54. Isabel Ding, "Dirty Business," China International Business, Oct. 15, 2009, www.cibmagazine.com.cn

Prices are rising overall, but increases are uneven

Analysis of wastewater treatment prices indicates that 10 out of 31 capital cities increased their municipal wastewater prices between 2009 and 2010, most of which already had prices above the national average.[55] Industry experts believe wastewater treatment prices will continue to rise, especially in medium and large cities, but the variation and uncertain timing make future prices unpredictable. Jiangsu, Shandong, Guangdong, Henan and Zhejiang will likely take the lead in price increases to promote the development of wastewater treatment infrastructure. [56]

The typical operating expense breakeven point of a wastewater treatment plant ranges from approximately RMB 0.45 to 1.1 per cubic meter; at the moment, however, only large and experienced companies operate within the breakeven ranges. Additionally, even though many plant operators have been allowed rate increases, the government could cap price hikes in the future. However, increases in energy efficiency combined with the amount of treated water may help plant operators become more profitable over time.[57]

Municipal Wastewater Treatment Price Increases in Chinese Provincial Capital Cities, RMB per cubic meters, 2009-2010

Provincial Capital City	2009	2010	Percentage Increase
Yinchuan (Ningxia)	0.40	0.70	75%
Chongqing	0.70	1.00	43%
Guangzhou (Guangdong)	0.63	0.90	43%
Kunming (Yunnan)	0.75	1.00	33%
Nanjing (Jiangsu)	1.00	1.30	30%
Jinan (Shandong)	0.70	0.90	29%
Shanghai	0.90	1.08	20%
Shenyang (Liaoning)	0.50	0.60	20%
Beijing	0.90	1.04	16%
Tianjin	0.80	0.82	3%

Source: 中国水网, "全国水价," [China Water Website, "National Water Prices"] price.h2o-china.com, accessed on Jun. 14, 2010; China Greentech Initiative Analysis

The China Greentech Initiative identified several factors to assess the market potential of wastewater treatment in provinces: discharge volume, treatment rate, prices, treatment regulatory standards, investment, government support and pipe network infrastructure. Based on this criteria Jiangsu, Sichuan, Guangdong, Hubei, Liaoning and Yunnan provinces appear to have strong market potential. Sichuan and Guangdong have many second-tier and third-tier cities that do not have wastewater treatment plants yet, while Hubei and Liaoning are industrialized provinces that do not have enough wastewater treatment capacity.

Private participation in wastewater treatment brings needed expertise

China's water reform began in 2002 with the issuance of the Water Resource Law, in tandem with related regulations and policies.[58] At that time, the water sector was a purely public service utility industry characterized by mismanaged water resources and inefficient services. Since then, the industry has evolved into a more competitive and progressive marketplace open to both local and foreign companies.

55. As of 2009, the average wastewater price was RMB 0.75 per cubic meter.
56. China Greentech Initiative interviews
57. Ibid.
58. International Trade Administration, Water Supply and Wastewater Treatment Market in China (Washington, D.C., USA: U.S. Department of Commerce, International Trade Administration, 2005, vii)

The current water industry in China is fragmented with over 10,000 participants, but dominated by state-owned and large private domestic companies competing with a few leading foreign operators.[59] Leading foreign companies were early market entrants that secured contracts in first-tier cities, such as Beijing, Shanghai and Shenzhen, at a time when local governments and municipal utilities lacked plant design, management and financing capabilities.

2010 saw many changes in China's water sector: Marubeni Corporation of Japan purchased 30% of Anhui Guozhen Environmental Protection for RMB 110 billion (US$ 16.9 million), China Guodian Corporation, the state-owned power generation company, purchased 70% of Shenyang Zhenxing Environmental Protection, and Beijing Enterprises Water Group stated its plans to continue its expansion, seeking partnerships to explore areas such as desalination and sludge treatment.[60] Many foreign and domestic companies are seeking to establish positions in China's active water industry.

The increase in activities in the water sector does not imply the operations of foreign and domestic entrants have gone smoothly. The China Greentech Initiative's partners and advisors identified many unique challenges faced by both international and local companies operating in the Chinese water sector. Foreign companies expressed their concern about several problems: inadequate knowledge of rapidly changing markets, restricted access to local finance channels, limited integration into local value chains, insufficient sales and distribution channels to tap opportunities outside top-tier cities, and products unsuited to local requirements. Meanwhile, domestic companies face their own challenges, including limited profitability due to stiff competition among domestic enterprises, low level of standardization, and technology gaps compared to foreign products.

Multiple funding sources are available for wastewater projects. Municipal governments, the China Development Bank, commercial banks, international financial institutions and the private sector all provide financing to water and wastewater projects. Private participation in the wastewater treatment market is mostly through build-operate-transfer, transfer-operate-transfer, and operation and maintenance arrangements, retaining public ownership of assets. Joint ventures are increasingly common for equipment manufacturing and partnerships between municipal utilities and private companies.

Private sector participation in sludge treatment is poised to pick up

Realizing the importance of sludge treatment in China's water strategy, MEP issued a notice on November 26, 2010 highlighting wastewater treatment plant sludge pollution prevention.[61] The notice stated that sludge treatment facilities should be incorporated into wastewater treatment plants that are under construction, renovation or expansion, and should be simultaneously put into operation with the wastewater treatment plant. Existing wastewater treatment plants that do not have sludge treatment capacity are required to have sludge treatment facilities within two years after the issuance of the notice.[62]

The notice effectively increased demand for sludge treatment solutions. Some private companies believe that they can fill in the knowledge and capital gaps, expecting that cooperation between publicly-operated and private companies will be encouraged by the government to fast track the development of the sludge treatment market through technology transfer and capital investments.[63]

59. The top companies are involved in multiple segments of the water sector: engineering and construction, treatment, operations and monitoring.
60. "Chinese water companies show their stripes," Global Water Intelligence, Mar. 2010, www.globalwaterintel.com
61. "Sewage Treatment Plant Sludge Disposal," Yixing HY Environment Technology Co., Ltd., Jan. 2, 2011, www.hyenvironment.com
62. Ibid.
63. Isabel Ding, "Dirty Business," China International Business, Oct. 15, 2009, www.cibmagazine.com.cn

Private Sector Participation in Water Utilities

Opportunity Assessment

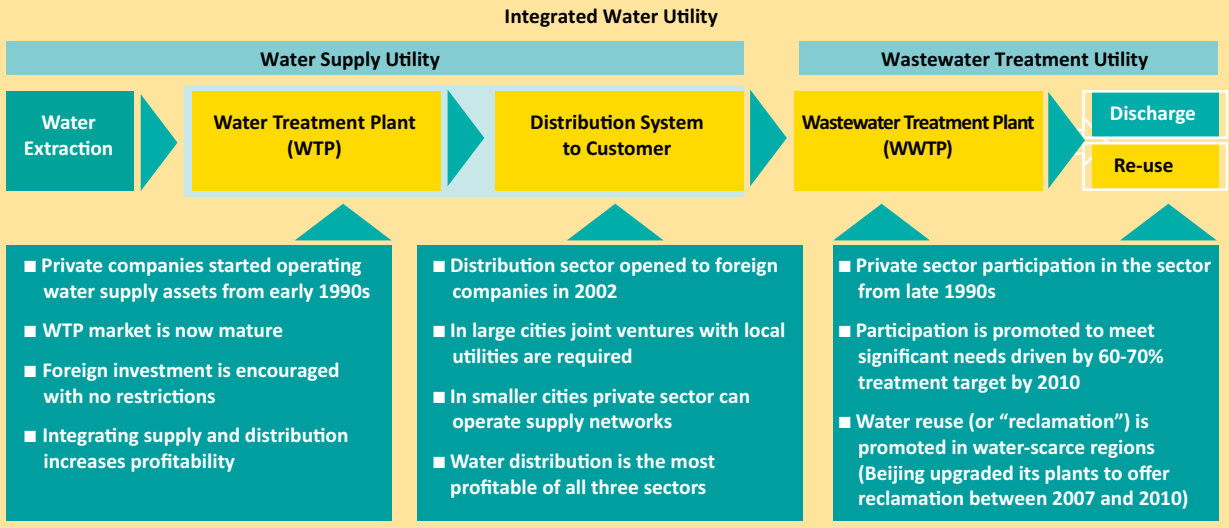
Despite market reforms and willingness of private domestic and foreign companies to participate in China's water sector, implementation proves to be a challenge. Private sector has only contributed 10-20% of recent water infrastructure financing.

Though many private companies have formed partnerships with local water utilities, just 10% of sector investment in 2008 came from the private sector. Only a few regions support such investment, while others strongly oppose private involvement. Wastewater treatment is the main area of participation, as opposed to water supply. Public-private-partnerships (PPPs) have had mixed results, with private investors facing multiple problems, including limited market knowledge, scarce financing, competition and demanding municipal customers.

Private participation has had mixed reception thus far

Private participation in China is permitted across almost the entire water value chain, from water treatment through distribution, down to wastewater treatment and reclamation. Most recent growth in private involvement came from wastewater treatment contracts, which the government actively promoted since development in wastewater treatment lagged behind water supply and distribution networks.

Private Sector Participation in China's Water Utilities



Source: China Greentech Initiative analysis

Though private participation is allowed across most of the water value chain, levels of participation vary. Direct participation is only permitted in water or wastewater treatment. Private participants may only be involved in distribution via joint ventures with the municipal water utilities, while participation in wastewater drainage operations is off-limits to private enterprises.

For state-owned treatment plants, private involvement has potential advantages and disadvantages. Public enterprises believe that partnership with private companies could bring needed expertise and technology, fresh capital, and shared responsibilities. However, many SOEs are concerned they could lose asset control, be compelled to hike water prices, and be forced to share profits disproportionately with private partners. One China Greentech Initiative partner commented that local municipalities may be reluctant towards public-private partnerships because their lack of knowledge implies they cannot be an equal partner with private players. In recent years, the government has sent mixed signals regarding private sector participation.

In 2002, a policy required municipalities to renegotiate or buy back fixed-return contracts signed with foreign firms.[64] In 2007, the Foreign Investment Catalogue promoted private and foreign participation in water and wastewater sectors. In 2008, Xian backed off after negotiating a potential stake sale or JV agreement with Veolia Water for two years. The issuance of the Indigenous Innovation Program in 2010 was seen as an impediment for operators planning to source foreign equipment in the water sector.[65] Between 1991 and 2005, only 10-20% of sector investment came from the private sector. Despite this, the importance of private companies in the water sector will continue to grow in the coming years.

Much must be done to address challenges to private involvement in the water sector

Since the 2002 market reform, many private companies have entered China's municipal water markets by forming partnerships with local water utilities. Various forms of public-private partnerships have been promoted in water projects leading to major contracts for the private sector.

There are eight common models for water utility operations and financing, with joint ventures mostly adopted for water supply, and BOT favored for wastewater operations. In 2005, a sample of 152 water supply projects showed that 50% adopted JV arrangements, while a sample of 200 wastewater projects revealed that 59% opted for BOT agreements.[66]

Private Participation Models in China's Clean Water Sector

1. Engineering-Procurement-Construction (EPC)/Design-Build (DB)	
Commissioning contract excluding participation in long-run operations	
2. Lease Contract	**5. Operation and Maintenance**
Short-term contract where private partner pays a fee to the government for asset operation	Operations are outsourced to private sector; financing and asset ownership remain public
3. Build-Operate-Transfer/Transfer-Operate-Transfer (BOT/TOT) Build-Own-Operate-Transfer (BOOT)	**6. Concession**
More likely in wastewater treatment; may include guaranteed volume and tariffs	Long-term contract for private partner including operation, maintenance and investments
4. Stake Purchase	**7. Joint Venture**
In inland provinces (Gansu, Jilin, Sichuan, Xinjiang); also termed "Partial M&A"	Water treatment plants are often operated through joint ventures between utility and private partners
8. Full Sale/Divestiture	
Mainly in small water supply projects in select provinces	

Source: Lijin Zhong et al., Public-Private Partnerships in China's Urban Water Sector (Wageningen, Netherlands and Beijing, China: Wageningen University and Tsinghua University, 2008)

Private sector participation raises significant challenges across regulatory, operational and financial areas. Regulatory issues include lack of transparency, underdeveloped legal framework, and divided regulatory oversight. Operational challenges include pipe network leaks, insufficient rainwater collection, lack of influence over network extension, and skilled labor shortages. The main financial challenges are large capital investment requirements, restrictions on raising debt financing, lack of other financing sources and low water tariffs in many regions.

64. 国务院办公厅,"关于妥善处理现有保证外方投资固定回报项目有关问题的通知," *[The General Office of the State Council, "Notice on Dealings with the Existing Projects with Guaranteeing the Fixed Investment Return of Foreign Investors"] Sep. 10, 2002*

65. China Greentech Initiative interviews

66. Zhong, L. et al., Public-Private Partnerships in China's Urban Water Sector (Wageningen, Netherlands and Beijing, China: Wageningen University and Tsinghua University, 2008, 867-869)

Improving the Profitability of Municipal Wastewater Treatment Plants

Opportunity Assessment

Municipal wastewater treatment plants have grown rapidly in China, but often at the expense of operational efficiency. Build-operate-transfer (BOT) contracts lead to higher operating efficiency and better long-term performance.

BOT municipal wastewater treatment plants appear to have lower operating costs and higher net profits than alternative investment models. Investors have generally only agreed to BOT contracts where they were able to negotiate favorable revenue terms and ensure improved long-term operational performance versus state-operated plants. Electricity is the largest area with operations improvement potential: BOT plants appear to use up to 50% less electricity than other types of plants. Other revenue and cost improvement opportunities can also be pursued to improve plant performance.

In contrast to public operators, private operators focus on long-term performance

Between 2005 and 2009, the number of wastewater treatment plants in China increased from 792 to 1,792, of which 90% are state-owned and 10% are BOT arrangements with private entities. A comparison between state-operated and BOT plants revealed differences in priorities: state-operated plants are more concerned about achieving government targets and minimizing initial investments, while BOT plants are more focused on achieving high ROI and profits.

Comparison of State-Operated and Build-Operate-Transfer (BOT) Plants in China

	State-Operated Plants	Build-Operate-Transfer (BOT) Plants
Number of Plants (2010E)	■ 3,000	■ 250-300
Plant size	■ Small, medium and large	■ Primarily medium and large
Ownership	■ 100% owned by city or county governments	■ Partially or 100% owned by private sector for the duration of the BOT contract
Technology	■ Often reluctant to adopt technologies with higher initial investment requirements	■ Receptive to adopting technologies that can optimize plant operations and profitability
Focus	■ Achieve government targets and standards ■ Improve usage and quality of water ■ Minimize initial plant investment ■ Minimize operating expenses	■ Achieve acceptable return on investment ■ Optimize profitability over life of the plant ■ Optimize plant operational performance
Other	■ Nearly 25% of state-operated plants are not operational due to insufficient funding or improper management	■ BOT arrangements typically last 15-30 years, when the public sector assumes ownership

Several practices are needed to obtain favorable revenue terms and good long-term operational performance. Experts advise that investors should focus on negotiating the best terms on drivers that most impact ROI, including acquisition of land priced below market value, locating the plant away from industrial zones, reduced tax rates, and longer tax exemption periods. Savvy private operators also negotiate revenue guarantees based on negotiated price and volume baselines (in other words, compensation regardless of actual treatment volume in case the municipality does not send sufficient waste for treatment).[67]

67. China Greentech Initiative interviews

Considering future operating performance during the design and investment stages is also important. To optimize long-term operations performance, operators should select the process technology best suited for the nature of wastewater to be treated and undergo a rigorous bidding process to ensure the right equipment for long-term performance is used. Optimizing the plant layout to reduce piping is also required.

Today's Practices Affect Tomorrow's Water Treatment Operating Costs

	Current Practice	Operating Cost Impact
Design	■ Use artificially high design capacity to receive more upfront funding from the local government	■ Inaccurate design-capacity may result in a low treatment rate and lower operational facility
Construction	■ Use low-cost and unskilled labor for plant construction and equipment installation	■ Inexperienced labor may lead to increase repair costs and operational facility
Process Technology	■ Adopt process technology with lower up-front costs and simple operation	■ Process technologies selected may not be flexible for changes in quality of water treated
Equipment	■ Focus on low-cost bid price, with minimal attention to total lifecycle costs	■ Acquisition of unsuitable equipment may lead to frequent repair due to breakdown ■ May also lead to higher electricity costs due to higher treatment time required

Source: Zheng, Xingcan et al., Municipal Wastewater Treatment –Technology Selection and Case Study (Beijing, China: China Construction Press, 2007)

Energy efficiency is critical to increasing profits

Comparative analysis between state-operated and BOT plants revealed that electricity costs at the state-operated plant were twice as much that of the private plant. The discrepancy was attributed to different levels of equipment efficiency, use of biogas, energy management practices, and operational experience.[68]

The use of biogas to supplement energy requirements, combined with energy-efficient technologies and equipment, can significantly reduce electricity costs. For long-term planning, public plants can implement energy management practices ensure electricity cost reduction. Energy management encourages operators to closely monitor energy consumption, conduct periodical inspection and training, and perform regular assessment of processes and control measures. When monitoring energy consumption, operators can evaluate rate structures as well as negotiate favorable terms and conditions with local power companies. Demand-side management can also be implemented by modifying plant's process operations to avoid significant demand charges at peak hours and increase usage during off-peak hours. Inspection involves regular maintenance of major equipment to ensure that they are running efficiently; training of employees ensures competency in handling such equipment. Regular assessment of processes and control measures entail comprehensive life cycle cost appraisals, replacement of outdated equipment with efficient technologies, and implementation of continuous improvement programs. Adopting these best practices would help the water treatment process become more profitable.

68. China Greentech Initiative analysis

Clean Water Sector Opportunities for 2011

This chapter provides an update of China's Clean Water sector and three Opportunity Assessments prioritized by the China Greentech Initiative's partners and advisors in 2010. As the sector evolves, participants in the China Greentech Initiative Partner Program will continue to collaborate on additional opportunity areas. The first topic in 2011 covers the industrial wastewater treatment market in China. Other topics may include water efficiency in industrial processes and seawater desalination. The China Greentech Initiative will also continue to track the overall evolution of China's Clean Water sector.

RESEARCH METHODOLOGY

Jim Gourley

This Report is based upon consulting-style deliverables (Opportunity Assessments) developed as part of the China Greentech Initiative's 2010 Partner Program. The China Greentech Initiative leverages an open collaborative approach to develop market insights, combining the expertise and experiences of hundreds of experts from more than one hundred partner, advisor and supporting organizations, with the China Greentech Initiative's dedicated strategic research team. Through this unique combination of industry and functional expertise, we are able to deliver fact-based insights and analysis beyond what any single organization could on their own.

The China Greentech Initiative'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 explored, 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.
- **Opportunity Assessments:** Incorporate sector working session insights and perspectives into final detailed 50-100 page deliverables.

Organizations involved in the China Greentech Initiative's Partner Program are provided with in-depth Opportunity Assessments for the sectors in which they participate. This Report provides high-level summaries of these findings.

For the convenience of readers, many figures throughout the Report are provided in both Chinese RMB and U.S. dollars. All currency conversions were calculated at 6.5 RMB per U.S. dollar, which was the approximate exchange rate as of March 2011.

Market Attractiveness Assessment

Each of the six sector chapters in this report includes a Market Attractiveness Assessment (MAA) developed by the China Greentech Initiative to evaluate specific markets in each sector based on six criteria: government support, addressable market size, solution attractiveness, five-year market growth potential, market accessibility and profit opportunity. This chapter outlines the approach used to develop the market attractiveness assessments in the six sector chapters.

Market Attractiveness Assessment (MAA)

Government Support

■ Degree to which national and provincial governments prioritize development of the sector through:

- Targets and policies in place during the 12th Five-Year Plan (12th FYP)
- Standards to promote adoption
- Subsidies and incentives, such as feed-in tariffs, low-interest loans, and capital subsidies for use of solutions
- Penalties for non-compliance, for example illegal discharge of wastewater

■ Government support for manufacturing of solutions not covered by these criteria

Value and definition

4. Highest priority:
- Targets and policies in the 11th FYP continued and strengthened in the 12th FYP
- Significant national subsidies, incentives and penalties

3. High priority:
- Explicit targets and policies identified in the 12th FYP
- Strong national subsidies, incentives, and
- penalties

2. Medium priority:
- Sector mentioned in the 12th FYP but no explicit targets or policies
- Moderate national subsidies, incentives and penalties

1. Low priority:
- No mention in the 12th FYP, but policies exist within some central government ministries or provinces
- Some central government or provincial subsidies, incentives and penalties

0. No priority:
- No mention in the 12th FYP and no known provincial policy support
- No national or provincial subsidies, incentives or penalties

Addressable Market Size

■ Annual sales of the solution if purchased by 100% of potential adopters

■ Adopters are organizations and individuals that purchase solutions (either conventional or greentech solution under evaluation) to achieve certain benefits

■ Measured in RMB billion (US$ billion) per year and mathematically is a product of:

- Total number of potential adopters that year
- Price of current "standard" (conventional) substitute

Value and definition

4. Very large: Over RMB 500 billion (US$ 77 billion) per year
3. Large: Between RMB 300 and 500 billion (US$ 46 and 77 billion) per year
2. Medium: Between RMB 100 and 300 billion (US$ 15 and 46 billion) per year
1. Limited: Between RMB 50 and 100 billion (US$ 8 and 15 billion) per year
0. Niche: Under RMB 50 billion (US$ 8 billion) per year

Solution Attractiveness

■ Economic attractiveness of the solution to adopters in 2011 (i.e. ability to deliver expected benefit at competitive cost measured on life cycle basis) driven or influenced by:

- Life cycle unit cost against coal-fired power
- Policies encouraging the adoption
- Risk of not becoming industry standard in China

Value and definition

4. Advantaged:
- Lower cost than conventional alternatives
- Regarded as the industry standard

3. Attractive:
- Cost on par with conventional alternatives
- On way to become industry standard in China

2. Emerging:
- More expensive but cost declining
- Active competition from other technologies

1. Disadvantaged:
- Significantly more expensive than alternatives
- No indication of becoming major industry force

0. Unavailable:
- Still a concept or in early research phase
- High risk of pursuing the technology

Five-Year Market Growth Potential

■ Expected compound annual growth rate (CAGR) during the 12th Five-Year Plan period (2011-2015)

■ Growth potential based on target indicators for each sector as specified in the 12th Five-Year Plan and other government announcements:

- Cleaner Conventional Energy (coal): installed generating capacity and consumption targets
- Renewable Energy (wind and solar): installed generating capacity targets
- Electric Power Infrastructure (smart meters): State Grid investment targets
- Green Building (sustainable materials and energy efficiency): green building construction targets and energy efficiency targets
- Cleaner Transportation (rail and road): high-speed rail line targets and electric vehicle use targets
- Clean Water (municipal wastewater treatment plants): municipal wastewater treatment plant targets and water pollution targets

Value and definition

4. Very rapid: >20% CAGR
3. Rapid: 15-20% CAGR
2. Medium: 10-15% CAGR
1. Slow: 5-10% CAGR
0. Very slow: <5% CAGR

Market Accessibility

■ Degree of market accessibility for private domestic or foreign companies

■ Driven or influenced by:
- Degree of direct state influence over the sector
- Openness to foreign capital, ownership and participation
- Preferential treatment of SOEs or private domestic companies

■ Where accessibility for private domestic companies is different than for foreign companies, the more restricted value is used

Value and definition

4. Fully open:
- Low to no state control of the sector
- Fully open to private domestic and foreign ownership and participation

3. Open with restrictions:
Generally open, but restrictions on the degree of private domestic and foreign ownership and participation

2. Partially limited:
Some parts of the sector are open while others restrict private domestic and foreign ownership and participation

1. Limited:
Generally strong state control of the sector
In exceptions, private domestic and foreign ownership and participation allowed

0. Restricted:
Full state control of the sector
Private domestic or foreign ownership and participation is not allowed

Profit Opportunity

■ Profit Opportunity indicates the China Greentech Initiative's views on the ability of participants to generate profits in the next three years, based on a qualitative analysis of the competitive dynamics of the market, including:
- Buyer power: bargaining leverage, volume and price sensitivity
- Supplier power: supplier concentration, industry capacity and switching costs
- Differentiation: supplier differentiation and product differentiation
- Competition intensity: industry concentration and domestic industry support
- Availability of substitutes: technology, buyer inclination to substitute and switching costs
- Government policy: incentives, subsidies, pricing (tariffs), standards and penalties
- Cost structure and trends: economies of scale, cost of inputs, capital requirements and new technology

Value and definition

4. Superior profit opportunity
3. Above average profit opportunity
2. Average profit opportunity
1. Limited profit opportunity
0. Challenging profit opportunity

Approach

The China Greentech Initiative's 2010 Partner Program covered six sectors within the greentech market, each of which has multiple sub-sectors. Nine sub-sectors are evaluated using the Market Attractiveness Assessment (MAA) in this report.

The purpose of the MAA is to assess each sub-sector in a comprehensive, consistent and rigorous manner. The assessment provides a structure in which to capture relevant available qualitative and quantitative information, apply judgment in a structured way, and compare results both within and across sectors.

The MAA criteria collectively represent the overall attractiveness of the sectors in China. Each dimension may take on one of five distinct values. Visually, a Harvey Ball is used to express the rating, with an empty ball representing the lowest value and a full ball representing the highest value.

Due to the nature of the MAA, the Initiative's partners and advisors sometimes had different views on how to evaluate given sectors. Significant effort was made to validate and reconcile differing perspectives; however, ultimately the Initiative research team used its judgment to determine the value for each criterion. Given that the MAA is only a tool meant to facilitate the evaluation of greentech markets, as with any assessment, it has limitations and its results should be interpreted accordingly.

Government support

Government support or prioritization for a sector is a strong indicator for market attractiveness in China: policies and incentives drive technology adoption in all sectors. Support for a sector is evaluated on the existence and scale of targets, policies, subsidies and standards on a national and provincial level. Sector-specific targets and goals of the 12th Five-Year Plan, China's roadmap for development from 2011 to 2015, are a particularly strong proxy for government support.

Sectors are rated from *highest priority* to *no priority*. A *highest priority* rating indicates a continued and strengthened national focus on the sector in the 12th Five-Year Plan and significant subsidies. A *no priority* rating indicates no known policies or subsidies exist on a national or provincial level.

Addressable market size

Addressable market size identifies the potential scale at which a particular solution could be applied in China. It is an estimate of the total revenues a particular solution (expressed in RMB or US$) could achieve annually if it were advantaged in terms of solution attractiveness today. This is a hypothetical number meant to differentiate technologies, rather than forecast market trends.

Values were estimated by the China Greentech Initiative, relying on information gathered by the research team as well as feedback from partners and advisors.

Solution attractiveness

Solution attractiveness aims to capture the value of adopting a greentech solution compared to conventional alternatives, focusing on the ability of the solution to deliver benefits to adopters at costs equal to or lower than substitutes on a normalized cost basis (e.g. cost of energy production over the lifetime of the technology, taking into account construction, operation and maintenance costs).

Cost competitiveness generally is correlated with technological maturity. For instance, the cost of electricity generated using solar technology to produce electricity is currently much higher than that of electricity generated using thermal coal fired power plants. Due to these higher costs, the assessment does not qualify solar for a rating of *attractive*, but rather *emerging*. This rating reflects the fact that solar electricity technology is currently under rapid development and as technology matures, it will likely achieve cost parity with conventional energy sources like coal, at which time it would be rated *attractive*.

Five-year market growth potential

China's 12th Five-Year Plan offers insights into how each sector may grow in the coming five years. The Plan includes many specific targets which, given China's track record, will likely be met and possibly surpassed. For example, the original target for wind power capacity in the 11th Five-Year Plan (5 GW) was exceeded by 35 GW. Market growth potential is calculated by determining the compound annual growth rate (CAGR) between the current market size in 2011 and the 2015 target. Since China often exceeds its targets, these growth potential estimates are likely conservative. Rapid advances in technology may also alter market prospects for certain sectors or solutions.

Each sector has a different type of target. Renewable and conventional energy generation, for example, have installed capacity targets, while cleaner transportation has a targets for kilometers of high speed rail line and number of electric vehicles on the road. Nevertheless, all market growth potential is assessed in increments of 5%, beginning with compound annual growth rate of less than 5% up to more than 20%.

Market accessibility

The objective of the market accessibility criteria is to differentiate between markets to which private domestic and foreign companies have access, and those that are restricted due to regulations or other barriers. *Mostly open* markets are not specifically restricted by the Chinese government. Examples of *mostly open*

markets include home appliances, machinery equipment and components, and select technologies that China is interested in developing. *Limited access* markets are those that China controls and allows partial access to, such as construction design and conventional power generation. *Restricted* markets are those that China normally does not allow private domestic and foreign companies to participate in, such as air traffic control and the operation of electrical grid networks.

Profit opportunity

Private domestic and foreign companies could be forgiven for looking at a sector's addressable market size and thinking that a large market presents attractive business opportunities. In China this is often not the case due to direct government participation in and shaping of markets. Many greentech sectors, such as Electric Power Infrastructure, are dominated by state-owned enterprises (SOEs). SOEs like the State Grid Corporation are the primary solution adopters for many greentech sectors in China. Through their buying power they can drive prices down and purchase solutions at high volumes, resulting in lower profitability for technology providers.

The China Greentech Initiative assessed this and other criteria within each sector that will affect profitability of companies in the next three years. Other criteria include: supplier power, differentiation, competition intensity, threat of substitutes, government policy, and cost structure and trends. This is a qualitative assessment and represents our views of the profit opportunities within each sector, with ratings ranging from *challenging profit opportunities* to *superior profit opportunities*.

GLOSSARY

Term	Definition
Access solutions	Technologies that incorporate flexible AC transmission systems or HVDC converter stations, which increase access of remote electrical generation to grid transmission links
Active and reactive power control systems	Control systems that regulate energy flows through an electric network, where active power is unilateral while reactive power oscillates
Advanced meter infrastructure (AMI)	Integrated systems that measure, collect, store and analyze utility usage. Some of which include electricity, gas or water; a broader concept than AMR-IP based solutions
Alternative fuels	Also known as non-conventional or advanced fuels, alternative fuels include any materials or substances that can be used for fuel other than conventional fuels, e.g. biodiesel, bioalcohol and hydrogen
Automatic-meter-reading (AMR)	Technologies that automatically collect real-time diagnostic and consumption data from energy metering devices (water, gas, electric) and transfer data to a central database for billing, troubleshooting, and analysis
Barrel	A unit of volume for oil measuring 42 gallons or 59 liters
Battery electric vehicles (BEVs)	Vehicles that completely rely on electricity storage batteries as a power source and are driven by electric motors
Battery management system (BMS)	Any electronic software that manages a rechargeable battery (cell or battery pack) through methods such as monitoring, reporting and balancing
Bio-diesel	Non-petroleum-based diesel fuel that utilizes either vegetable oil or animal fat
Biogas digester	Equipment that can turn organic waste fumes into usable fuel
Black carbon	A climate forcing agent formed through the incomplete combustion of fossil fuels, biofuel and biomass with an atmospheric lifespan ranging from several days to weeks
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, equivalent to about 0.25 kilocalories or 1055.06 joules
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
Building energy intensity	Measure 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
Cap-and-trade	An environmental policy that constrains the aggregate emissions of regulated sources by creating a limited number of tradable emission allowances, which emitters must secure and surrender in number equal to their emissions
Capacity factor	The ratio of the actual output of a power plant and its theoretical output at full capacity over a period of time
Carbon capture and sequestration (CCS)	System that captures carbon dioxide from fossil fuel, either prior to or after combustion, and sequesters it for long-term storage underground

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
Carbon pricing	An environmental policy that places a price on carbon through 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
Central heating systems	Systems that provide warmth to the interior of a building (or portion of a building) from one source, such as a furnace room in a house or a mechanical room in a large building, to multiple rooms
Chemical oxygen demand (COD)	COD is a testing method that measures the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals such as ammonia and nitrite, commonly used to estimate the amount of organic compounds in water
Circular economy	A model for economic growth which aims at environmental protection, pollution prevention and sustainable development, where resources are used with higher efficiency and reused and recycled when possible
Cleaner transportation	Transport solutions that increase energy efficiency, reduce emissions and improve resource utilization to minimize the negative environmental impact of transportation on the environment, which include efficient engines, cleaner fuels, electric vehicles and road networks, and electrification of railways and low-emissions locomotives
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	A type of syngas produced from coal that's a mixture of carbon monoxide (CO) and hydrogen (H_2) gas
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)	Energy efficient lamps that use fluorescent lighting technology
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)	Solar energy that is created by concentrating sunlight onto a small area using mirrors and reflectors, thus creating intense light and heat, to generate power and electricity
Conversion efficiency	Ratio between input and output after an energy is converted from one form to another. The calculation of this ratio also figures in the usefulness of the output amount. Specifically for photovoltaic cells, conversion efficiency is the proportion of sunlight energy that the cell converts to electrical energy
Crystalline silicon photovoltaic modules (PV)	A packaged interconnected assembly of solar cells made from a single crystal or a polycrystalline slice of silicon that 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	Management systems that control, operate and monitor remote assets by employing open standards based systems or two way communication systems to verify and integrate Smart Grid networks and utility back office systems
Demand-side management	Implementation of policies and measures to control, influence and generally reduce end-users' energy demand while preserving the same level of service and comfort
Desalination	Process that removes salt and other minerals from saline water (such as sea water) in order to make it suitable for human consumption or irrigation
Design-build	Also known as design-construct and single-source responsibility, design-build is a method of project delivery in which one entity - the design-build team - works under a single contract with the project owner to provide design and construction services

Dimethyl ether (DME)	Considered a clean burning hydrocarbon fuel, CH_3OCH_3 is produced by the gasification of coal or natural gas. Considered to have potential as a synthetic biofuel
Direct-current line (DC line)	A form of power transmission that's preferred over AC power transmission over long distances due to lower energy loss
Dispatch	Power transmission and distribution
Distributed renewable energy (DRE)	Usually small-scale renewable energy that is generated on-site or near the energy consumer
Distribution automation	Smart grid component that can yield significant cost savings through measurable improvements to operational efficiency, reliability, service quality and energy conservation
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, often obtained from a cogeneration plant burning fossil fuels or biomass, or using geothermal or central solar heating technologies
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 that minimizes required inputs of energy, water and food, and outputs of waste, heat, air and water pollution
Electric vehicle (EV)	Electric vehicles (EVs) are propelled by an electric motor (or motors) powered by rechargeable battery packs, usually having higher energy efficiency and less pollution emissions than internal combustion engines (ICEs)
Electrolytes	Any substance containing free ions that make the substance electrically conductive typically in liquid form, although molten electrolytes and solid electrolytes are also possible
Energy intensity	A measure of the energy efficiency of a nation's economy, calculated as unit energy per unit 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 where savings are guaranteed for the owner
Energy service companies (ESCOs)	A specialized commercial business providing energy efficiency solutions to industrial or commercial clients on a risk-reward basis over a specified payback period
Engineering-procurement-construction (EPC)	Project contract that includes engineering, procurement and construction
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 that has a measurable negative impact on the environment, e.g. energy tax, transport tax, pollution tax and resources tax
Feed-in tariff	Policy mechanism designed to encourage the adoption of renewable energy and accelerate grid parity wherein renewable energy generators are paid a premium for the energy they generate and regional or national electric grid utilities are obligated to purchase this energy
Flue gas denitration (De-NOx)	System that removes nitrogen oxides from flue gas
Flue gas desulfurization (De-SOx)	System that removes sulfur oxides from flue gas
Fly-ash	Fly ash is the very fine solid, particulate residue generated during coal combustion that rises with flue gas
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 as well

Grid connection	Physical connection between the power generation utility and the grid
Grid connectivity	Qualitative connection of power generation utility to the grid
GW	One billion (10^9) watts or 1 gigawatt = 1000 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	Electric vehicles that can travel at a speed of more than 100 km/h
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
High-speed rail (HSR)	A type of passenger rail transport that operates significantly faster than the normal speed of rail traffic, referring to any commercial train service with an average speed of 200 km/h (120 mph) or higher in China
Hybrid electric vehicles (HEVs)	Powered by conventional or alternative fuels as well as electric power stored in a battery, using the internal combustion and regenerative braking to charge
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
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	Inventions, images, and designs used in commerce such as copyrights, trademarks, patents, industrial design rights and trade secrets
Intermittence	Non-continuous power production by solar and wind energy generation
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 based on electroluminescence through light-emitting-diodes (LED), including conventional semiconductor LED, organic LED (OLED) or polymer LED (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
Liquid propane gas (LPG)	Mixture of hydrocarbon gases synthesized from petroleum that is considered to be 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 transmission lines
Low-speed electric vehicles (LSEVs)	Also known as neighborhood electric vehicles (NEVs), LSEVs travel at a maximum speed of 40km/h and are best suited for short, intra-city trips or short trips in rural areas
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
Natural gas combined-cycle (NGCC)	Systems that generate electricity using gas turbines, and then capture waste heat to generate steam and additional electricity using a steam turbine
Oil sands	A type of unconventional petroleum deposit found in extremely large quantities in Canada and Venezuela that contains naturally occurring mixtures of sand, clay, water, and a dense and extremely viscous form of petroleum

Operate and manage (O&M)	A form of public-private partnership where operations are outsourced to the private sector while financing and asset ownership remain public
Operating reserves	Operational management of power generation that provides the difference between supply and demand by instantaneous regulation and of generating capacity and transmission lines
Photocatalyst systems	Systems that employ photocatalysis or the degradation of chemical compounds by absorption of UV-light for water treatment
Photovoltaic (PV) panel	A packaged interconnected assembly of solar cells made from a single crystal or a polycrystalline slice of silicon that can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications
Plug-in hybrid electric vehicle (PHEV)	Hybrid vehicle with an extension cord that can be plugged into any 120-volt outlet for recharging
Powertrain	A group of vehicle components that generate power and deliver it to the road surface, water or air, including 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
Public-private partnerships (PPPs)	Government service or private business venture which is funded and operated through a partnership between the government and one or more private companies
Renewable energy	Energy produced from sources that are naturally replenishing, such as sunlight, wind, waves, underground heat, surface water flows and biomass
Renewable energy portfolio standard	A regulation that requires the increased production of energy from renewable energy sources, such as wind, solar, biomass and geothermal, and generally places an obligation on electricity supply companies to produce a specified fraction of their electricity from renewable energy sources
Resource tax	A kind of tax levied on volume or price to help ensure long-term sustainability of resource consumption
Selective catalyst reduction (SCR)	Post combustion nitrogen oxide (NOx) control technology capable of achieving NOx reduction in excess of 95% by converting NOx into less harmful compounds such as diatomic nitrogen, N_2, and water, H_2O
Separator	A separator is a porous membrane placed between electrodes of opposite polarity, permeable to ionic flow but preventing electric contact of the electrodes.
Sludge treatment	Processes used to manage and dispose of sludges produced during sewage treatment
Smart dispatch supporting systems	Systems that provide a more holistic view of system conditions and generation patterns, e.g. by incorporating renewable forecasts (wind, sun), demand response capabilities, carbon constraints, and estimates for distributed generation and storage
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) that simultaneously collect and supply data on harmful biological or chemical agents
Smart meter	"Electricity monitoring devices with two-way communication capabilities that allow utilities and customers to analyze real-time energy use, automatic meter readers (AMR) and advanced metering infrastructure (AMI) being popular devices in China
Solar photovoltaics (PV)	Photovoltaics (solar cells) are 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 diversion project	Planned for completion in 2050, the project will link China's four main rivers (the Yangtze, Yellow River, Huaihe and Haihe) and 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

Strategic emerging industries	Seven industries that will 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
Substation solution	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, integration automation etc.
Sulfur scrubbing	Technology that removes harmful sulfur dioxide gas from flue gases of fossil fuel power plants
Supply-chain operations reference-model (SCOR)	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 environments (SIE)	Sustainable indoor environments promote daylighting, natural ventilation, and interiors that are free of toxins, resulting in an interior environment that safeguards occupant health and reduces operating costs
Tens of cities, thousands of vehicles program	A central government program where 13 pilot cities (25 as of 2010) were promoted a certain anywhere from 1,000 to 9,000 EVs in the public sector by 2012, and which includes 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
Thin film	Technology that utilizes thin layers of material for electronic semiconductor and optical applications. Thin film is used in second and third generation photovoltaic technologies and often applied for building integrated applications
Three-phase meters	Meters for three-phase power, typically used for industrial purposes
Tons of coal equivalent (TCE)	Unit representing energy generated by burning one metric ton (1000 kilograms or 2204.68 pounds) of coal, equivalent to 29.39 gigajoules (GJ), 27.78 million Btu (MMBtu), or 8.14 megawatt hours (MWh)
Transfer-operate-transfer (TOT)	A form of public-private partnership where an investor buys the property and operational rights of a facility and receives revenue through normal business operations within a concession period
Ultra-high voltage (UHV)	Voltages of 1,000 kV alternating current or more, or 800kV direct current or more, allowing delivery of large quantities of power over very long distances with little loss of power
Ultra-highvoltage (UHV) transmission	Power transmission lines with voltages of 1,000 kV alternating current or more, or 800 kV direct current or more
Waste-to-energy (WtE)	The process of creating energy in the form of electricity or heat from the incineration of waste
Wastewater treatment	Collection and cleansing of water discharged after consumption for secondary consumption or release back to nature
Water distribution	Transportation of treated water to end users
Water extraction	Provision or extraction of water resources from the biosphere to original water rights holders
Water quality criteria (WQC)	An approach for the harmonious coexistence of humans with nature in aquatic ecosystems in terms of geographic, social and economic characteristics
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 maximum power measured is the nominal power of the module in "Wp"

Term	Definition
AMI	Advanced meter infrastructure
AMR	Automatic Meter Reader
BEV	Battery electric vehicle
BIPV	Building integrated photovoltaics
BMS	Battery management system
BOT	Build-operate-transfer
BTU	British thermal unit
CBM	Coal bed methane
CCS	Carbon capture and storage
CFL	Compact fluorescent lamp
CHP	Combined heat and power
CMM	Coal mine methane
CNG	Compressed natural gas
COD	Chemical oxygen demand
CSP	Concentrated solar power
DC	Direct current
De-NO_x	Flue gas denitration
De-SO_x	Flue gas desulfurization
DME	Dimethyl ether
DRE	Distributed renewable energy
EMC	Energy management contracting
EMS	Energy management solutions
EOR	Enhanced oil recovery
EPC	Energy performance contract
ESCO	Energy service companies
EV	Electric vehicle
GW	Gigawatt
HEVs	Hybrid electric vehicles
HSR	High-speed rail
HVAC	Heating, ventilation and air conditioning
IAQ	Indoor air quality
LEED	Leadership in Energy and Environmental Design
IGCC	Integrated gasification combined cycle
LCA	Life cycle analysis
LED	Light-emitting diode lamp
LNG	Liquefied natural gas
LPG	Liquid propane gas
LSEVs	Low-speed electric vehicles
LVRT	Low-voltage ride-through
Maglev	High-speed magnetic-levitation

Term	Definition
NGCC	Natural gas combined-cycle
O&M	Operate and manage
PHEV	Plug-in hybrid electric vehicle
PPPs	Public-Private Partnerships
PV	Photovoltaics
SEIs	Strategic Emerging Industries
SCOR	Supply-Chain Operations Reference model
SCR	Selective catalyst reduction
SIE	Sustainable indoor environments
TCE	Tons of coal equivalent
TOT	Transfer-operate-transfer
UHV	Ultra-high voltage
Wp	Watt peak
WQC	Water quality criteria
WtE	Waste-to-energy
AQSIQ	General Administration of Quality Supervision, Inspection and Quarantine
CAAM	China Association of Automobile Manufacturers
EPRI	Electric Power Research Institute
ERI	China's Energy Research Institute
IPCC	Intergovernmental Panel on Climate Change
MEP	Ministry of Environmental Protection
MIIT	Ministry of Industry and Information Technology
MOF	Ministry of Finance
MOHURD	Ministry of Housing and Urban-Rural Development
MOR	Ministry of Railways
MOST	Ministry of Science and Technology
NDRC	National Development and Reform Commission
NEA	National Energy Administration
NEC	National Energy Commission
RIFS	Research Institute of Fiscal Science
SASAC	State-owned Assets Supervision and Administration Commission
SAT	State Administration of Taxation
SERC	State Electricity Regulatory Commission
SOA	State Oceanic Administration
SOEs	State-owned enterprises

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Steve Bale

ACKNOWLEDGMENTS

Hundreds of individuals from over 100 leading technology and services companies, entrepreneurs, investors, NGOs and policy advisors provided input to *The China Greentech Report 2011*. The logos of the China Greentech Initiative's partners, advisors and supporting organizations are presented on the front and inside covers, as well as listed at the end of this document. This Report is only possible because of the support and direction provided from these organizations and their people.

The China Greentech Initiative recognizes and thanks the many talented professionals who became part of its core and extended teams over the past year. Driven by their passion for greentech opportunities in China, these colleagues demonstrated their willingness to tackle huge objectives and meet unrealistic deadlines while delivering the highest quality deliverables. They have worked countless late hours, sacrificed many weekends, mastered new skills, juggled competing priorities, and flexibly addressed problems identified along the way.

While it is impossible to name the hundreds of individuals who have assisted in so many ways, a few people and organizations stand out for special recognition.

Partners, Advisors and Supporting Organizations

Frank Lin (PwC) managed PwC's involvement as the China Greentech Initiative's strategic partner. Other PwC leadership team members who contributed greatly include Annabell Chartres, Gavin Chui, Allan Zhang (张鉴钧) and Jasmine Zhang (张金莉). They provided strategic direction and feedback, ensured availability of meeting facilities, participated in sector working sessions, and much more.

Andrew Aldridge, Annabell Chartres (PwC) and Allan Zhang (张鉴钧, PwC) spent many hours to review and provide feedback on the entire Report. Other individuals provided their industry expertise to review specific chapters: Brian Caffyn (UPC Renewables), Michael J. Desmond (BP), Ruiping Dong (ITT), Robert Earley (iCET), David Harris (Vecor), Jason Lo (Honeywell Building Solutions), Jichun Mao (GE Energy), Eldon Mou (Prudent Energy), Marvin W. Sepe (CTC), Michael Voigt (Bayer), Christoph von Waldersee (Asia Water Development), Benny Zhang (GM) and Li Zhang (Coalogix).

Numerous Chinese government organizations made significant contributions to the Initiative during 2010, including the Chinese Investment Promotion Agency and other divisions of Ministry of Commerce, Development and Research Center of the State Council, Ministry of Environmental Protection, Ministry of Industry and Information Technology, and Ministry of Housing and Urban-Rural Development. Foreign government organizations included the Embassy of the Kingdom of Netherlands, U.S. Department of Energy, U.S. Department of State, U.S. Embassy and U.S. Foreign Commercial Service.

APCO Worldwide (Greg Gilligan, Reggie Lai, Ben Ou, Amy Wendholt and Lucy Xiao) made significant contributions to facilitate the China Greentech Initiative's government outreach and support research on the 12th Five-Year Plan. Experts from CEPRI, CNOOC, Guodian Longyuan, Huadian Hong Kong Limited, New Energy Research Institute of State Grid, CTL Research Institute of Shenhua Coal Group, Tsinghua-BP Clean Energy Center, and the World Bank also contributed significant expertise to research activities and working sessions.

We would also like to acknowledge the contributions to the development and maintenance of the China Greentech Initiative's website by Rose Ann S.C. Laurel, Alex C. Mendoza, Stephanie R. Quizon-Srinivasan, Karina Jana M. Nerva, Bienvenido E. Esmero, Jr., Monchester C. Macapagal and Marie D. Rodriguez, all from MangoStrategy.

Other individuals helped launch *The China Greentech Report 2011* and enable other Partner Program events, including Dr. Chan Chai (Reignwood Group), Brenda Foster (American Chamber of Commerce, Shanghai), Chen Hong (China Entrepreneurs Club), Scott Kronick (Ogilvy), Hannah Lane (Ogilvy), Bertrand Petton (Beijing Capital Club), Frank Rexach (Haworth), and Amy Zhang (China Entrepreneurs Club).

Research Team

Alan S. Beebe (毕艾伦), co-Managing Director, and Randall S. Hancock (汉瑞德), co-Managing Director as well as CEO of MangoStrategy, LLC, led the development of the Report and management of the China Greentech Initiative's research team. Anders W. Hove (侯安德) led the initial writing and editing for the overall Report. Other writers included Ana Lin T. Chiong (MangoStrategy), Claire N. Nelson (聂凯怡), Giuseppe N. Parente (MangoStrategy), Joel Rosen, Ran Tao (陶然), and Ivan H. Torres. Caitlin C. Rhodes (周嘉莲) took a break from her role as partner relations specialist team leader to provide invaluable copy editing for the entire Report. Qiyong Cao (曹奇永) cheerfully and tirelessly served as project manager and managed multiple research teams. Other analysts who provided strategic research and analysis for the Report include Julien Bedin (朱立安), Angela Fan (范羽), Stephanie Hung (洪慕德), Junda Lin (林骏达), Sebastian Tang (汤化峻), Jackie Wang (王静), Rachel Xiao (肖凝) and Lixuan Zhou (周丽璇). Hortense Halle-Yang (海棠) served as program manager, helping coordinate the Report as well as managing external events. Constantin Crachilov helped manage the research team earlier in the year.

Partner Relations Team

Ellen G. Carberry, co-Managing Director, led the partner outreach and government relations effort. Chitra Hepburn (何诗兰) and Victoria Y. Jin (金郁玉) were principals responsible for developing and managing relationships with the Initiative's partners and advisors. Sector specialists were John C. Hanrahan (韩壮), Cindy Jiang (姜新燕), Alex G. Ornik (欧健凯), Caitlin C. Rhodes (周嘉莲), Grace E. Rumford (荣馨怡) and Mark J. Wehling (吴林涛). Mark also lent his great attention to detail to fact-checking and proof-reading the Report. Kerry S. Driver (江凯丽) and Mariel Waller (玛丽) managed marketing and communications activities. Mariel Waller (玛丽), along with Qiyong Cao (曹奇永) and Hortense Halle-Yang (海棠), managed the overall design, layout and distribution of the Report.

Lily Zhao (赵莉), with assistance from Jenny Huang (黄征), provided tremendous administrative support across all facets of the China Greentech Initiative.

Report Production

In addition to those named above, several others played critical roles in the production of the Report. Marianne Kaulima was responsible for the Report's initial design and layout. K-iD studio (赤子天下传媒文化) and Tag Advertising Co., LTD. (太和中道文化传播有限公司) meticulously applied and contributed additional design principles to every detail of the Report. Many photos were courtesy of Steve Bale (www.chinesecurrents.com), Jim Gourley (www rudenoon.com) and Photo & Video White Balance (www.white-balance.net). Print production was executed by PORO Marketing and Design Solutions (北京般若企业策划有限公司).

Jim Gourley

ABOUT THE CHINA GREENTECH INITIATIVE

中国绿色科技
China Greentech Initiative
Strategic Insights, Industry Collaboration, Market Acceleration

Founded in 2008, the China Greentech Initiative (CGTI) has rapidly grown to become the only Sino-international collaboration platform of over 100 organizations, focused on identifying, developing and promoting green technology solutions in China. Strategic market research and a network of over 200 industry experts shape the foundation of the China Greentech Initiative Partner Program, allowing it to provide participating organizations with world-class market insights and partnering opportunities.

Partnering organizations of CGTI include technology buyers and sellers, service providers, investors and policy makers. Approximately one-third of Partners are from China, one-third from the United States and one-third from other Asian countries and Europe.

The China Greentech Initiative accelerates the commercial success of organizations through the following offerings: the Partner Program, Multi-Partner Initiatives and Advisory Services. Within the Partner Program, a complementary and diverse group of organizations collaborate in six distinct sector teams. The sectors include: Cleaner Conventional Energy, Renewable Energy, Electric Power Infrastructure, Cleaner Transportation, Green Building and Clean Water. The collaboration mechanisms include insight-driven Working Sessions, CEO-level cross-sector networking events, Chinese government outreach meetings, and an online Partner network.

Sector Working Sessions are a unique hallmark of the Partner Program. Unlike conferences, Sector Working Sessions are highly collaborative settings where participants share industry expertise and perspectives to create value for one another. Participants are experts from China and other countries from a diverse range of organizations in the commercial and public sectors. The Working Sessions are held simultaneously in Beijing and Shanghai, connected via videoconferencing and simultaneously translated between Chinese and English.

Organizations participating in the Partner Program pay an annual fee. Multi-Partner Initiatives and Advisory Services are project-fee based.

For further information about the China Greentech Initiative please visit www.china-greentech.com or contact CGTI@china-greentech.com.

PARTNERS, SUPPORTING ORGANIZATIONS AND ADVISORS

Jim Gourley

Strategic Partner

Profile

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Website: www.haocapital.net

APCO Worldwide

APCO Worldwide provides clients investment, public affairs and strategic communications consultancy and support. APCO has more than 100 staff working in China in Beijing, Shanghai, Guangzhou and Hong Kong. The company's services include advising on investment strategies, government advocacy, coalition building; crisis management, corporate positioning, public relations, and corporate responsibility.
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

DNV

DNV is a global provider of services for managing risk, helping customers to safely and responsibly improve their business performance. As companies today are operating in an increasingly more complex and demanding risk environment, DNV's core competence is to identify, assess and advise on how to manage risk. Its technology expertise and industry knowledge, combined with its risk management approach, have been used to manage the risks involved in numerous high-profile projects around the world. DNV currently has 900 employees working in 36 offices in Greater China.
Website: www.dnv.com

GE

GE is a diversified global infrastructure, finance and media company taking on the world's toughest challenges. From aircraft engines and power generation to financial services, medical imaging and television programming, GE operates in more than 100 countries and employs about 300,000 people worldwide.
Website: www.ge.com

HSBC

HSBC Bank (China) Company Limited started operations on 2 April 2007 as a locally incorporated foreign bank. It is wholly owned by its parent, The Hong Kong and Shanghai Banking Corporation Limited. It is the founding and a principal member of the HSBC Group, which has around 7,500 offices in 87 countries and territories, making it one of the world's largest banking and financial services organizations. HSBC is one of the largest investors among foreign banks in mainland China, having invested over US$ 5 billion in the growth of its own operations and in select Mainland financial services entities.
Website: www.hsbc.com.cn

IBM

International Business Machines Corporation (NYE:IBM) is a multinational information technology and services corporation headquarted in Armonk, New York, USA. IBM manufactures and sells computer hardware and software, as well as offers business solutions and services such as consulting, application development and management, infrastructure, hosting and outsourcing in areas ranging from mainframe system to nanotechnology. IBM holds more patents in the US than any other company in the world. It has engineers and consultants in over 170 countries, eight Research Labs and more han 50 development labs worldwide. IBM employees have earned three Nobel Prizes, four Turing Awards, six National Medals of Technology and seven National Medals of Science. As a chip maker, IBM is among the worldwide top semiconductor leaders.
Website: www.ibm.com

KPCB China

By forming partnership with TDF Capital, **Kleiner Perkins Caufield & Byers** officially launched operation in China with offices in Beijing and Shanghai in April, 2007. KPCB China has backed successful ventures such as Alibaba, Baidu, China Netcom, Focus Media, Hurray, Cgen, A8.com, Venustech, Autonavi, Kanghui and CAR. KPCB China manages approximately US$ 500 million funds 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 TMT, greentech, life science and consumer goods and services.
Website: www.kpcb.com

Ogilvy Earth

OgilvyEarth is the global sustainability practice within the Ogilvy & Mather group. We are committed to making the world's best corporations even better - by harnessing the opportunity of sustainability. Through strategic planning and communications, we work with visionary companies that are looking to make sustainability a growth driver for both their business and the communities they serve. We identify opportunities for brands within the sustainability economy, helping them identify their role, extract value and guide them on the path to facilitate real change. We believe that sustainability is the new path to prosperity, and in the power of communications to change everything.
Website: www.ogilvy.com and www.ogilvyearth.com

Reignwood Group

Reignwood Group, headquartered in Beijing, is a multinational enterprise with a unique brand representing a diversified portfolio of businesses including luxury lifestyle, property development and management, sports and culture, functional beverages, and financial services and investments.
Website: www.reignwood.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. With US$ 350 million under management, Tsing Capital works intimately with its portfolio companies in 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 "Doing Well by Doing Good ©" philosophy. 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.
Website: www.tsingcapital.com

General Partners

AES

AES Corporation is a global power company with generation and distribution businesses. Through their diverse portfolio of thermal and renewable fuel sources, AES provides affordable and sustainable energy in 30 countries.
Website: www.aes.com

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, Alstom employs 96,000 people and had orders of EUR 19.7 billion in 2009 to 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 has 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

Amperex Technology Limited (ATL)

Amperex Technology Limited (ATL) is a premier energy solution provider. ATL concentrates on designing and manufacturing Lithium-Ion battery cells. ATL supplies battery cells and packs to global top tier brands, ranked within the top 10 Li-Ion battery suppliers worldwide. ATL is expanding its capabilities and product offering into deployment of electric vehicles and green energy storage.
Website: www.atlbattery.com

Baker Botts

Baker Botts LLP is an international law firm recognized for their creative approach to the legal and business issues facing clients. With approximately 750 lawyers and a worldwide network of offices, Baker Botts works with clients with a collaborative approach to the law practice, having lawyers functioning as integrated teams to bring the most appropriate response to client needs.
Website: www.bakerbotts.com

Bayer

Science For A Better Life
科 技 创 造 美 好 生 活

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. Bayer 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 year 2009, Bayer employed 108,400 people and had sales of EUR 31.2 billion. Capital expenditures amounted to EUR 1.7 billion, R&D expenses to EUR 2.75 billion.
Website: www.bayer.com

Carrier Corporation

turn to the experts

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

Caterpillar

For more than 80 years, **Caterpillar Inc.** has been making progress possible and driving positive and sustainable change on every continent. Caterpillar is the world's leading manufacturer of construction and mining equipment, diesel and natural gas engines and industrial gas turbines. The company is also a leading services provider through Caterpillar Financial Services, Caterpillar Remanufacturing Services, Caterpillar Logistics Services and Progress Rail Services.
Website: www.cat.com

Climate Change Capital (CCC)

Climate Change Capital (CCC) is an environmental investment management and advisory group specializing in the opportunities generated by the global transition to a low carbon economy. CCC manages funds with US$ 1.5 billion of commitments and aims to provide attractive returns to investors, demonstrating the financial opportunity associated with a low carbon economy. CCC focuses funds on five asset classes: Carbon, Private Equity, Listed Equities, Property and Energy Infrastructure.
Website: www.climatechangecapital.com

Corning Incorporated

Corning Incorporated is the world leader in specialty glass and ceramics. Drawing on more than 160 years of materials science and process engineering knowledge, Corning creates and makes keystone components that enable high-technology systems for consumer electronics, mobile emissions control, telecommunications and life sciences.
Website: www.corning.com

Composite Technology Corporation (CTC)

Composite Technology Corporation (CTC) develops, produces and markets innovative energy efficient products and renewable energy projects for the electrical utility industry. CTC's products incorporate advanced composite materials and innovative design solutions that provide solutions to efficiently modernize electrical grid systems.
Website: www.compositetechcorp.com

Cummins

Cummins is a global power 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.
Website: www.cummins.com

Dorsey & Whitney

Clients have relied on **Dorsey & Whitney LLP** as a valued business partner since 1912. Dorsey's 600 lawyers, in 19 locations in the United States, Canada, Europe and the Asia-Pacific region (including Hong Kong and Shanghai), represent a number of the world's most successful companies. Our industry focus benefits our clients in key sectors including technology, health care and life sciences, financial services, agribusiness and energy. Dorsey has consistently been ranked among the best for client service in numerous independent surveys.
Website: www.dorsey.com

Dow Corning

Dow Corning provides performance-enhancing solutions to serve the diverse needs of more than 25,000 customers worldwide. A global leader in silicones, silicon-based technology and innovation, Dow Corning offers more than 7,000 products and services via the company's Dow Corning® and XIAMETER® (www.xiameter.com) brands. Dow Corning is equally owned by the Dow Chemical Company and Corning, Incorporated. More than half of Dow Corning's annual sales are outside of the United States. Dow Corning's global operations adhere to the American Chemistry Council's Responsible Care® initiative, a stringent set of standards designed to advance the safe and secure management of chemical products and processes.
Website: www.dowcorning.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 the largest utility company 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' history.
Website: www.duke-energy.com

Evergreen

Evergreen Sustainable Development (Evergreen) is a consulting and project development firm focused on creating integrated energy and environmental assets in China. Evergreen focuses on originating projects in small to medium scale energy deployments (supply and distribution), and also considers energy management in an integrated, multi-year approach.
Website: www.evergreenbuild.ca

General Motors

General Motors Company, one of the world's largest automakers, traces its roots back to 1908. With its global headquarter in Detroit, GM employs 209,000 people in every major region of the world and does business in more than 120 countries. GM and its strategic partners produce cars and trucks in 31 countries, and sell and service these vehicles through the following brands: Buick, Cadillac, Chevrolet, GMC, GM Daewoo, Holden, Isuzu, Jiefang, Opel, Vauxhall, Wuling and Baojun.
Website: www.gm.com

Haworth Inc.

Haworth Inc. is an office furniture solutions company. We have made ourselves a champion of adaptable workspace solutions. In addition to being more user-focused and economical, we also provide more sustainable, responsible choices.
Website: www.haworth-asia.com

HIFE Green Power

HIFE Green Power is a fast-growing li ion battery manufacturer specializing in large format LiFePO4 cells and related technology for automotive and non-automotive applications. HIFE's current 15Ah and 20Ah cylindrical cells are the only one in market and represent the leading technology in China. After having signed an exclusive contract with a leading German li ion battery manufacturer HIFE will be able to offer "German quality at Chinese cost".
Website: www.hife-power.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

IQwind

IQwind is the innovator of a variable gearbox technology (IQgear™) 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. IQturbine™ Multi MW design leveraging the IQgear™ 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 IQgearbox™ 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 over 150 countries. Our 137,000 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.
Website: www.johnsoncontrols.com

Jones Lang Lasalle

Jones Lang Lasalle 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. The firm is an industry leader in property and corporate facility management services, with a portfolio of approximately 1.6 billion square feet worldwide.
Website: www.joneslanglasalle.com

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 with 12 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: www.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 industrial players in transport and power related engineering, with revenue of approximately EUR 12 billion in 2009. With more than 250 years experience, MAN has leading positions in its business as a supplier of trucks, buses, diesel engines, turbo machinery and special gear systems. MAN is at the leading edge of developing green solutions for cleaner transportation, energy efficiency, cleaner coal utilization and renewable energy. As a Fortune 500 company, MAN is listed on the DAX (German Stock Index), which comprises Germany's 30 leading stock corporations and employs approximately 47,700 people worldwide.
Website: www.man.eu

Nike

Nike, Inc. based in Oregon, United States, is the world's leading designer, marketer and distributor of authentic athletic footwear, apparel, equipment and accessories for a wide variety of sports and fitness activities.
Website: www.nikebiz.com

Owens Corning

Owens Corning is a leading global producer of residential and commercial building materials, glass-fiber reinforcements and engineered materials for composite systems. A Fortune 500 Company for 56 consecutive years, Owens Corning is committed to driving sustainability by delivering solutions, transforming markets and enhancing lives. Founded in 1938, Owens Corning is a market-leading innovator of glass-fiber technology with sales of US$ 5 billion in 2010 and about 15,000 employees in 28 countries on five continents.
Website: www.owenscorning.com

Panasonic

Panasonic has delighted global consumers with innovations for the home and business for more than 50 years. Panasonic's products range from Plasma and LCD TVs and Digital Cameras to laptop computers, communications solutions, networkable office solutions, security systems, home appliances, personal care products, components and entire in-flight entertainment and information systems.
Website: www.panasonic.com

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: Pepsico.com.cn

Philips

Royal Philips Electronics of the Netherlands (Philips) 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 119,000 employees in more than 60 countries worldwide. With sales of EUR 24.5 billion in 2010, the company is a market leader in cardiac care and home healthcare, energy efficient lighting solutions and new lighting applications, as well as lifestyle products for personal well-being.
Website: www.china.philips.com

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 efficiency 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 early 2013.
Website:http://pinnacle-engines.com/

Qiming Venture Partners

Qiming Venture Partners is an early to growth stage venture capital firm with over US$ 520 million and RMB 250 million under management. The firm invests in entrepreneurs who are creating the next generation of health care, consumer, clean tech and information technology companies.
Website: www.qimingventures.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 consist 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 35,000 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

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. The Group employs 3,100 persons in 30 countries. In 2010, Uponor's net sales totaled EUR 750 million. Uponor Corporation is listed on the NASDAQ OMX Helsinki Ltd., Finland.
Website: www.uponor.com

VantagePoint

Since 1996 **VantagePoint** has been funding transformative companies. Our strategy is clear: provide cutting-edge technology with the resources—whatever it takes—to commercialize big opportunities. And since it takes time to change the world, we stick with our companies and support them from start-up through scale-up. A look at our focus and our investments shows that our strategy is working: many of our portfolio companies are already award-winning leaders in their fields. We have $4.5 billion of committed capital and have made substantial investments in CleanTech, information technology, healthcare and Asia. We were among the first large investment firms to recognize the opportunity in CleanTech and have since committed $1 billion for this burgeoning opportunity. Our CleanTech team and resources are unrivalled in the industry.
Website: www.vpvp.com

Vecor

Vecor technologies offer a comprehensive solution for reducing the solid waste liability of thermal power generators. Vecor proprietary processes and equipment convert landfill destined fly ash into high-value; non-virgin industrial minerals and resource-efficient, sintered building materials composed of more than 70% recycled content.
Website: www.vecor.com.au

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 2010, Volkswagen Group China delivered a total of 1,923,500 vehicles to customers in mainland China and Hong Kong, 37 percent more than in 2009. 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

Westport Innovations Inc.

Westport Innovations Inc. is a leading global provider of proprietary technology that allows engines to operate on clean-burning gaseous fuels such as compressed natural gas (CNG), liquefied natural gas (LNG), hydrogen and biomethane obtained from biogas such as landfill gas. Westport Innovations Inc. is publicly traded on the Toronto Stock Exchange with the trading symbol WPT and on the NASDAQ Stock Market with the trading symbol WPRT.
Website: www.westport.com

Supporting Organizations

American Chamber of Commerce - Shanghai
Beijing Capital Co.
Beijing Shougang International Engineering Technology Co.
China Beijing Environmental Exchange (CBEEX)
China Datang Technologies & Engineering Co. (CDTE)
China Energy and Environmental Technology Association (CEETA)
China Environment Chamber of Commerce (CECC)
China-UK Low Carbon Enterprise Co. (CULCEC)
Daonong Center for Enterprise (CEC)
Shanghai University
Tsinghua University
United Nations Global Compact
United Nations Industrial Development Organization (UNIDO)
U.S. Department of Energy
U.S. Foreign Commercial Service

Advisors

Asia Society
The Capital Club, Beijing
Clean Air Task Force (CATF)
Cleantech Switzerland
CoreNet
Econet China DE (German Chamber)
Embassy of the Netherlands
Embassy of Spain
Embassy of Sweden
Innovation Center on Energy and Transportation (iCET)
Israeli Chamber of Commerce
Natural Resources Defense Council (NRDC)
State Grid-National Bio-Energy (NBE)
U.S. Information Technology Office (USITO)
Universal World Trade Investment Consulting Corp. Ltd (UWTIC)