

WORLDWATCH REPORT 182

Renewable Energy and Energy Efficiency in China:



Current Status and Prospects for 2020



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LISA MASTNY, *EDITOR*



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On the cover: Workers on a roof covered by solar panels at the Theme Pavilion of the Shanghai World Expo 2010.

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Table of Contents

| | |
|--|--------------|
| Summary | 5 |
| China's Energy Challenges: The Role of Renewable Energy and Energy Efficiency | 8 |
| Energy Efficiency in China | 11 |
| Renewable Energy in China | 23 |
| Prospects for 2020 | 34 |
| The Way Forward | 40 |
| Endnotes | 42 |
| Figures, Tables, and Sidebars | |
| Figure 1. China's Energy Consumption by Sector, 2007 | 10 |
| Figure 2. China's Energy Intensity versus GDP Growth, 2005–09 | 15 |
| Figure 3. China's Small Hydropower Installed Capacity and Power Generation, 1985–2009 | 27 |
| Figure 4. China's Installed Wind Power Capacity, 1992–2008 | 29 |
| Figure 5. Chinese Solar Cell Production and Installation, 2000–08 | 30 |
| Figure 6. China's Installed Solar Hot Water Capacity, 1997–2009 | 31 |
| Table 1. China's Energy Consumption by Fuel Type, 2007 | 9 |
| Table 2. Energy Consumption Per Unit of Major Product, 2000 and Targets for 2010 and 2020 | 14 |
| Table 3. Energy Efficiency of Major Energy-Consuming Equipment, 2000 and Targets for 2010 | 15 |
| Table 4. Change in Energy Consumption per Unit GDP Index by Province, Autonomous Region, and Municipality, 2008 | 16 |
| Table 5. Energy Consumption of Major Energy-Consuming Industrial Products, 2000, 2005, and 2008 | 17 |
| Table 6. Energy Consumption per Unit Area of Buildings in China, the United States, and Japan, 2008 | 19 |
| Table 7. Residential Heating Requirements per Unit Area in Beijing | 19 |
| Table 8. Transportation Energy Consumption in China, by Mode, 2000–05 | 19 |
| Table 9. Transportation Energy Efficiency in China, by Mode, 2006 | 20 |
| Table 10. Vehicle Performance and Fuel Economy in China versus Industrial Countries .. | 20 |
| Table 11. Important Local Wind Energy Targets in China, 2010 and 2020 | 25 |
| Table 12. China's Renewable Energy Development and Use, 2008 | 26 |
| Table 13. Grid-Connected Electricity Prices in China, by Energy Source | 27 |

Table of Contents

| | |
|---|-----------|
| Table 14. Planned Large-Scale Wind Energy Bases in Six Chinese Provinces | 29 |
| Table 15. Solar PV Installation in Key Sectors and Regions, Targets for 2010 | 31 |
| Table 16. Renewable Energy Development in China: Three Scenarios for 2020 | 37 |
| Sidebar 1. Top-1000 Enterprises Energy Conservation Program | 12 |
| Sidebar 2. Yutong Bus: Building China’s Mass Transit Bus System | 21 |
| Sidebar 3. China’s Wind Power Development: Three Stages | 28 |
| Sidebar 4. The Himin Group: Pioneering Solar Hot Water in China | 32 |

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Summary

Over the past few years, China has emerged as a global leader in clean energy, topping the world in production of compact fluorescent light bulbs, solar water heaters, solar photovoltaic (PV) cells, and wind turbines. The remarkable rise of China's clean energy sector reflects a strong and growing commitment by the government to diversify its energy economy, reduce environmental problems, and stave off massive increases in energy imports. Around the world, governments and industries now find themselves struggling to keep pace with the new pacesetter in global clean energy development.

Chinese efforts to develop renewable energy technologies have accelerated in recent years as the government has recognized energy as a strategic sector. China has adopted a host of new policies and regulations aimed at encouraging energy efficiency and expanding renewable energy deployment. Taking lessons from its own experience as well as the experiences of countries around the world, China has built its clean energy sector in synergy with its unique economic system and institutions of governance. At a time when many countries still struggle with the aftermath of a devastating financial crisis, the Chinese government has used its strong financial position to direct tens of billions of dollars into clean energy—increasing the lead that Chinese companies have in many sectors.

Among other initiatives, the Chinese government has taken strong action to promote renewable energy, establish national energy conservation targets, and delegate energy-saving responsibilities to regions. Key legisla-

tive actions include the national Renewable Energy Law, which entered into force in January 2006, the national Medium and Long-Term Development Plan for Renewable Energy, launched in September 2007, and the Medium and Long-Term Energy Conservation Plan, launched in November 2004.

Although per capita energy use in China remains below the international average, it is growing very rapidly, spurred recently by the infrastructure-intensive government stimulus program launched in late 2008. Even with efficiency advances, demand for energy is expected to continue to rise in the coming decades. Chinese energy consumption is currently dominated by coal, and the major energy-consuming sector is industry. Improving the efficiency of energy use and enhancing energy conservation will be critical to ease energy supply constraints, boost energy security, reduce environmental pollution, “green” the economy, and tackle the climate challenge.

Since 2005, the Chinese government has elevated its energy conservation and energy efficiency efforts to basic state policy. The 11th Five-Year Plan (2006–10) set an energy-savings target of 20 percent, and the country has adopted administrative, legal, and economic measures to achieve this goal. During the first three years of the plan, China's energy intensity—its energy consumption per unit of GDP—fell by just over 10 percent, saving 290 million tons of coal equivalent (tce) and reducing the country's greenhouse gas emissions by 750 million tons of carbon dioxide-equivalent. This pace of energy conservation has rarely been achieved by the rest of the world.

According to China's Medium and Long-

Summary

Term Energy Conservation Plan, the energy consumption per unit of major industrial products should “reach or be close to the international advanced level of the 1990s by 2010, and reach or be close to the international up-to-date level by 2020.” Although China is working hard on this target and has recently accelerated its pace of energy savings, especially in the industry sector, a gap remains. Challenges that impede progress in energy savings include low fossil energy prices due in part to energy and fuel subsidies, an incomplete market-drivers policy, and the lack of capacity building for energy saving.

China’s success in the renewable energy arena has been more dramatic. Renewables use in China totaled some 250 million tce in 2008 (excluding traditional biomass energy). Renewables accounted for 9 percent of the country’s total primary energy use that year, up from 7.5 percent in 2005. Hydropower dominated China’s renewable energy usage, at 180 million tce, followed by solar, wind, and modern biomass, which together comprised 70 million tce of renewables consumption.

Hydropower and wind power accounted for the bulk of China’s total installed renewable energy capacity in 2009, reaching 197 gigawatts (GW) and 26 GW respectively. Cumulative wind installations more than doubled that year, and new wind installations increased more than 100 percent, allowing China to surpass the United States to become the largest market for wind power—housing nearly one-third of the world’s total installed capacity in 2009.

Total installation of solar PV reached 310 megawatts (MW) in 2009, more than double the 150 MW in place in 2008 but leaving China with still only 2 percent of the global installed capacity. China installed 42 million square meters of solar water heaters in 2009 and increased the total installed capacity by 31 percent, to 135 million square meters, with the central government providing strong incentives for rural installations. China has accounted for 70–80 percent of the global market for solar hot water systems in recent years.

China’s rapid rise to global leadership in clean energy is rooted in an unusual level of

cooperation between government and industry, with the government providing a broad range of incentives that have led to the creation of renewable energy industrial bases nationwide. China’s past two decades of investment in science and technology, focused in large part on the energy sector, has been stepped up in recent years, with the aim of making the country an innovator as well as a low-cost manufacturer of cutting-edge technologies.

These dramatic developments have implications that go well beyond China. As the country’s skills in efficient, low-cost manufacturing are brought to clean energy industries, this could widen the energy options for the world as a whole. Already, Chinese companies have become a strong presence in clean energy markets in Europe and North America.

Renewables in China will almost certainly see continued strong growth in the years ahead as new policy incentives are enforced, including a regional feed-in tariff scheme for wind power, a plan to build seven large-scale wind-bases in six provinces, and the new Golden Sun program aimed at accelerating the domestic solar market. Across China, provincial and city governments are working with industry to create industrial parks dedicated to clean energy and are providing a range of subsidies and infrastructure investments to support the creation of new companies, jobs, and revenues for local governments.

Meanwhile, China’s renewable energy products and equipment manufacturing capacity are maturing rapidly. The domestic wind turbine industry has mastered technology at the megawatt scale and beyond and now has an annual manufacturing capacity of 10 GW. China has become the world’s largest solar PV producer, and domestic manufacturers are now offering complete production lines, from raw materials to solar modules. The annual capacity to produce solar water heaters is more than 40 million square meters. Domestic industry players are paying attention to both technological advancement and quality, aiming to improve the reliability of products while also preparing for an impending expansion of the renewables market.

Summary

Many Chinese renewable energy companies rely heavily on export markets to fuel their growth. This is particularly true in the case of solar PV, where most production is exported, but both the wind and solar hot water industries are now expanding their exports rapidly. This has led to growing tensions with European and North American companies that are losing market share. Analysts attribute this trend in part to the unusually strong state support that Chinese companies receive.

Renewable energy is positioned strategically in China's energy structure and is one of the most important instruments for boosting energy security and tackling climate change. The country has set national targets for a 10 percent renewables share in the country's over-

all energy mix by 2010 and a 15 percent share by 2020. Forecasts suggest that this share might reach 28–32 percent by 2030 and 30–45 percent by 2050, moving renewable energy closer to becoming a mainstream energy resource.

This report is designed to provide an independent review of China's achievements in promoting renewable energy and reducing the energy intensity of its economy. The key drivers behind China's efforts in these areas are the needs to boost energy security, tackle climate change, ease the pressure of environmental pollution, and improve energy supply in rural areas. The goal of this report is to facilitate international cooperation that can help China further improve its energy efficiency and deploy renewables more widely.

China's Energy Challenges: The Role of Renewable Energy and Energy Efficiency

As China continues on a path of rapid economic growth, it faces rising environmental challenges, including worsening air pollution and the threat of climate change. To address these concerns, the country has begun implementing ambitious programs in renewable energy and energy efficiency in recent decades. Through these efforts, China hopes to improve its energy supply and energy security, enhance the quality and competitiveness of its economy, reduce pressure on the environment, and mitigate the effects of climate change.

China's primary energy consumption has increased steadily in recent decades, reaching 3.1 billion tons of coal equivalent (tce) in 2009, up 5.2 percent from the previous year.^{1*†} In 2009, China accounted for nearly a fifth of global primary energy use—a share similar to that of the United States, which has just one-quarter of China's population.² Since 2000, as industrialization has accelerated and as living standards have improved, China's energy consumption has doubled, increasing by an unprecedented 180 million tce annually on average.³ Yet its per capita energy use remains well below the world average: 2.1 tce in 2008, compared with 6.6 tce in developed (OECD) countries and 11.1 tce in the United States.⁴

There is significant potential for further increase in the decades ahead. Despite China's low per capita energy use, demand continues to grow very rapidly, spurred in part by the infrastructure-intensive government stimulus pro-

gram launched in late 2008. Even with efficiency advances, demand for energy is expected to continue to rise in the coming decades.

The shortage of high-quality energy resources has constrained China's energy options. Coal continues to dominate the nation's energy mix, accounting for roughly 70 percent of total consumption.⁵ (See Table 1.) As the world's largest coal user, China consumed 2.7 billion tons in 2008, 43 percent of the world total and 2.5 times that of the United States, the second largest consumer.⁶ Although China ranks third worldwide in proven recoverable coal reserves, with an estimated 177 billion tons as of 2007, the country's growing population means that the coal supply may not be sufficient to meet rising energy demand.⁷ China's recoverable reserve per capita is only 134 tons, below that of many other nations; however, not all of the country's coal resources have been fully explored.⁸

China's second largest energy source is oil, and consumption reached 380 million tons in 2008.⁹ Since becoming a net oil importer in 1993, China has rapidly increased its reliance on imported oil and now obtains more than half of its supply from beyond its borders.¹⁰ China's recoverable oil resource in 2008 was 21.2 billion tons and is characterized as relatively low quality, with uneven regional distribution—making the issue of supply security increasingly prominent.¹¹ China's use of natural gas is small but is rising rapidly, and gas imports are projected to soar.

China's energy use varies considerably by region. An estimated 56 percent of household electricity use is in urban areas, located mainly in the country's north and east.¹² In rural

* Endnotes are grouped by section and begin on page 42.

† Units of measure throughout this report are metric unless common usage dictates otherwise.

China's Energy Challenges: The Role of Renewable Energy and Energy Efficiency

Table 1. China's Energy Consumption by Fuel Type, 2007

| Energy Source | Energy Consumption (Quadrillion Btus*) | Share of Total Energy Consumption (percent) | Energy Consumption per Unit GDP (Btus per dollar) |
|--------------------------|---|---|---|
| Coal | 51.3 | 69.5 | 15,170 |
| Crude Oil | 14.6 | 19.7 | 4,300 |
| Renewable Energy | 5.4 | 7.3 | 1,593 |
| Natural Gas | 2.6 | 3.5 | 764 |
| Electricity Use | 0.10 | 0.14 | 3 |
| Total Energy Consumption | 73.8 | 100.0 | 21,827 |

* Units have been converted to Btus to allow for international comparison.
Source: See Endnote 5 for this section.

areas, biomass—primarily the burning of fuel wood and crop wastes—accounts for just over half of household energy usage, with direct combustion of coal contributing most of the rest.¹³ China has made remarkable strides in extending access to electricity nationwide, but more than 8 million people in the central and western regions still lack connectivity.¹⁴ Per capita household electricity consumption in China averaged only 275 kilowatt-hours (kWh) in 2007, compared with 675 kWh worldwide and 2,434 kWh in developed (OECD) countries.¹⁵ The International Energy Agency projects that China will achieve 100 percent electricity access by 2030.¹⁶

Although technological advancements are evident along the entire coal supply chain, the sheer scale of China's coal usage has led to significant environmental consequences for the country and beyond. Coal burning is the main source of domestic air pollution and is also a major source of greenhouse gas emissions. Vehicle use is growing rapidly as well. As of August 2009, China was home to 180 million vehicles, a fleet that is estimated to increase by more than 1 million each month.¹⁷ As China's economy expands, rising personal incomes will lead to even higher vehicle demand, presenting a growing challenge to both air quality and the climate in the years ahead.

According to national statistics, Chinese emissions of climate-altering greenhouse gases increased from just over 4 billion tons of carbon dioxide (CO₂)-equivalent in 1994 to more

than 6 billion tons in 2006.¹⁸ In 2006, China overtook the United States as the world's top emitter of greenhouse gases.¹⁹ In per capita terms, however, China produced just 4.6 tons of CO₂ in 2007 while the United States produced 19 tons.²⁰

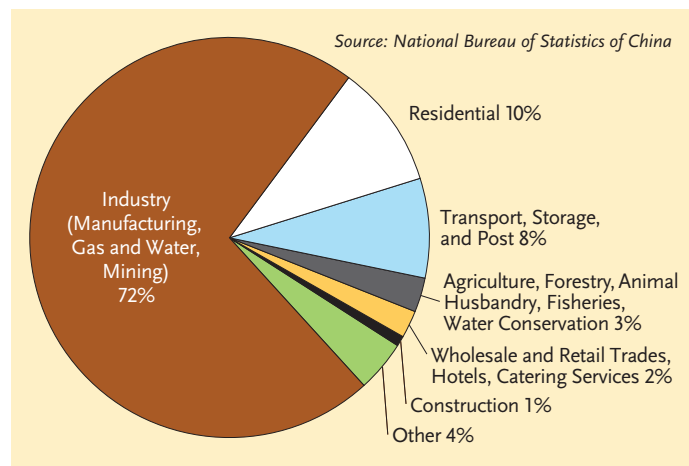


Traffic in the Huangpu District of Shanghai.

Industry is China's largest energy user, accounting for an estimated 72 percent of total energy use.²¹ (See Figure 1.) In 2007, the industrial sector—including manufacturing, utilities, and mining—consumed 1.9 billion tce, followed by the residential sector at 268 million tce (10 percent).²² The agriculture, forestry, animal husbandry, fisheries, and

China's Energy Challenges: The Role of Renewable Energy and Energy Efficiency

Figure 1. China's Energy Consumption by Sector, 2007



water conservation sectors together consumed only 82 million tce (3 percent), reflecting the low level of agricultural mechanization in China and suggesting that energy efficiency

in agriculture is not considered a nationwide priority.

As China takes further steps toward industrialization, it will need to take dramatic action to reduce the energy intensity of its economy and increase its use of non-fossil energy sources. Improving the efficiency of energy use, enhancing energy conservation, and promoting renewable energy will be critical tools to ease energy supply constraints, boost energy security, reduce environmental pollution, “green” the economy, and tackle the climate challenge. Already, China has embarked on a rapid and successful path toward increasing energy efficiency and the use of renewables; however, it remains to be seen whether the country will be able to ramp up its commitment to a level at which energy efficiency and renewables make a meaningful contribution to the domestic energy mix as well as global climate change mitigation.

Energy Efficiency in China

Addressing China's energy and climate challenges will require continued improvements in both energy efficiency and energy conservation.

Despite significant advances over the past three decades, domestic energy consumption per unit of gross domestic product (GDP) remains high, at four times that of the United States; seven times that of Japan, France, Germany, the United Kingdom, and Italy; and 1.5 times that of India.¹ This high energy intensity is due largely to wasteful economic growth, an unbalanced energy structure, a low level of energy technology and equipment, and poor management.

It should be noted that China's economy, and in particular its energy-intensive industrial sector, remains largely export oriented. Many of the products that are manufactured in China ultimately serve global markets. It is expected that as China continues to shift its economy toward a more service-based structure, the nation's energy intensity will decrease accordingly.

Key Policies

Over the past decade, the Chinese government has given greater attention to energy conservation and energy efficiency, elevating these efforts to basic state policy. President Hu Jintao, in his October 2007 report to the 17th National Party Congress of the Communist Party, stated as a strategic goal that China, "must adopt an enlightened approach to development that results in expanded production, a better life, and sound ecological and environmental conditions, and build a resource-conserving and environment-friendly society that coordinates growth rate with the economic

structure, quality, and efficiency."²

As such, the country has adopted a variety of measures to conserve energy and improve energy efficiency. As one of its main policies, the government has set a target in the 11th Five-Year Plan (2006–10) of cutting energy consumption per unit of GDP by 20 percent, or 4 percent annually.³ The plan also identifies targets for reducing emissions of sulfur dioxide (SO₂) and chemical oxygen demand (COD) by 10 percent. To achieve these goals, China has embarked on a comprehensive energy conservation program that covers all major economic sectors and has few equals in other countries, developed or developing.

One critical step has been to establish high-level leadership. In 2007, the State Council, China's cabinet, set up a leading working group on energy conservation and emissions reduction, headed by Premier Wen Jiabao. Premier Wen has also chaired the Council's executive session on various occasions to study and deploy energy-conservation work. Several Chinese provinces have set up similar high-level working groups on energy conservation and emissions reduction, headed by senior provincial officials with leadership in energy conservation management.⁴

To address the stipulations in the 11th Five-Year Plan, the government has broken down the Plan's energy-conservation and emissions-reduction targets and delegated responsibility for meeting them to various regions and sectors, as well as to thousands of energy-intensive businesses nationwide.⁵ Specific energy efficiency initiatives include:

- *Ten Key Energy-Saving Projects* to encourage energy conservation, including initiatives in

Energy Efficiency in China

the areas of public transport and alternative fuels, combined heat-and-power (CHP), surplus heat utilization, green lighting, high-performance appliances, and energy-saving buildings.⁶ Altogether, these efforts represent potential energy savings of 240 million tce between 2005 and 2010.⁷

Sidebar 1. Top-1000 Enterprises Energy Conservation Program

In April 2006, the Chinese government launched the Top-1000 Enterprises Energy Conservation Program, which aims to boost conservation in the country's largest energy-consuming businesses. The program follows relevant provisions under China's Energy Conservation Law and Key Energy Users Energy Conservation Management Measures.

The "top-1000 enterprises" refer to large businesses with independent accounting in nine energy-intensive industries: iron and steel, nonferrous metals, coal, electricity, petrochemicals, chemicals, building materials, textiles, and paper production. In 2004, China was home to some 1,008 such businesses with individual total energy consumption of 180,000 tce or more. Their combined energy use was 670 million tce, representing 47 percent of China's industrial energy use and 33 percent of total energy use.

The main objectives of the Top-1000 Program are: to significantly improve energy efficiency, to elevate the energy consumption per unit of major industrial product to an advanced international level for that industry, to elevate the energy usage of some businesses to the international advanced level or leading domestic industry level, and to save roughly 100 million tce during the 11th Five-Year Plan period (2006–10).

In 2006, China's National Development and Reform Commission signed letters of responsibility for energy conservation goals with roughly 1,000 businesses, setting clear objectives and responsibilities for conservation and holding a series of trainings in energy measurement, energy auditing, conservation planning, and advanced and applicable energy-saving technologies. As a result of these measures, the businesses saved a combined 20 million tce in 2006 and 38 million tce in 2007.

In November 2007, the State Council called on all provinces to evaluate and assess the progress of these businesses toward meeting the energy conservation targets. The assessment adopted a 100-point scale methodology, where meeting the target accounts for 40 points and implementing energy-saving measures accounts for 60 points. According to the assessment, 92.2 percent of businesses fulfilled their yearly targets and 41 percent "over-fulfilled" their targets. Some businesses met their targets for the 11th Five-Year Plan in 2008, two years early. Next steps for the program remain unclear, although many businesses continue to implement projects beyond their targets.

Source: See Endnote 10 for this section.

- *Energy Efficiency Benchmarking in Key Energy-Consuming Sectors* to oversee efficiency achievements in specific sectors of the economy.⁸ For example, in the construction sector, the task of saving energy, including connecting thermostats to 150 million square meters of building space, has been allocated to regional governments, while the transportation sector has issued energy conservation plans for railways, highways, waterways, and civil aviation projects.⁹
- A *Top-1000 Enterprises Energy Conservation Program* to encourage the nation's largest energy-consuming businesses to develop energy auditing, report on their energy usage, and prepare conservation plans.¹⁰ (See Sidebar 1.)

In addition to these specific projects, the Chinese government has formulated a comprehensive plan to conserve energy by eliminating obsolete production capacity in manufacturing.¹¹ The plan targets obsolete capacity in the areas of power generation, iron and steel, electrolytic aluminum, ferroalloy, calcium carbide, coke, coal, cement, and flat glass.

The government has also implemented a variety of economic policies that are conducive to energy conservation, such as higher taxes on coal, crude oil, and natural gas resources that vary from province to province.¹² A differentiated electricity pricing policy targets businesses with low energy efficiency in eight energy-consuming industry categories, raising the electricity price by 0.05–0.2 RMB (0.7–2.94 U.S. cents) on businesses that are below government standards or that the government wishes to eliminate.^{13*} To encourage technological progress in energy conservation, the government has adopted a "rewards instead of subsidies" policy, rewarding businesses financially in accordance with the amount of energy saved. Other economic policies related to energy conservation include adjusting oil consumption taxes to help regulate the price of refined oil.¹⁴

* All dollar and cent amounts in this report are expressed in U.S. dollars. Conversion from Chinese currency units is done at the exchange rate of 6.8 RMB = 1 U.S. dollar.

Energy Efficiency in China

China is working to improve its energy efficiency regulations and standards as well. In October 2007, the Standing Committee of the National People's Congress passed a revised Energy Conservation Law, and in 2008 the government promulgated two new regulations, on Energy Savings in Civil Buildings and Energy Conservation by Public Institutions.¹⁵ It also released mandatory national standards that place an energy consumption limit on 22 energy-intensive products, including crude steel and cement, as well as mandatory national energy efficiency standards for 19 major energy consuming end-use products, including refrigerators.¹⁶ Various regions have adopted similar revised regulations and standards. Shandong province, for example, has developed a long list of standards that includes regulations on public buildings, standards for industrial heat exchangers, and limits on marine and truck fuel consumption.¹⁷

In addition to regulating industries directly, the government is putting increased pressure on local and regional officials to better enforce China's energy and climate policies. The revised Energy Conservation Law holds local governments and their officials responsible for implementing the national energy-intensity reduction target (decoupled to the local level) by making completion of the target one of the standards for performance evaluation.¹⁸ Certain regions have conducted similar breakdowns of their conservation targets and established performance evaluation and assessment systems, including a mechanism for publicly reporting on entities that do not meet the targets.

One accountability measure, the Energy Conservation and Emission Reduction Statistical Monitoring and Implementation Assessment Plan and Methods, is designed to assess the performance of various regions and businesses in achieving the nation's energy conservation and emissions reduction goals.¹⁹ The regulations include three main components: (1) a system for evaluating energy consumption per unit of GDP, which aims to strengthen government and corporate responsibility by implementing quantitative assessment and enforcement measures on provincial

governments and energy-intensive companies; (2) a statistical index and system for monitoring energy consumption per unit of GDP, which enables the creation of a comprehensive survey of energy consumption and energy efficiency; and (3) a system for statistical analysis, which includes monitoring and evaluating total emissions of major pollutants, such as sulfur dioxide and carbon dioxide; and methods for assessing compliance with emissions-reduction targets.

These new regulations are having an effect on the behavior of local governments and officials. Zhejiang province, for instance, now requires municipal and county-level mayors to include the energy-reduction goal as a standard for performance assessment.²⁰ Shandong and Guangdong provinces also plan to incorporate environmental responsibility into the performance assessments of government officials.²¹ In Beijing, the city government has designated the first workday of each month as "Energy Conservation Day," during which all air conditioners and elevators in city governmental offices are powered down and government officials are encouraged to take mass transportation, ride bicycles, or walk to work.²² Overall, the integration of energy conservation into performance assessments is having a significant impact on local government compliance.

In addition to regulations and policies, China is developing an extensive public awareness and mobilization plan to increase support for reducing energy use. The country has organized a nationwide Universal Energy-Saving and Emission-Reduction Action to mobilize communities to participate in energy conservation, as well as initiated nine "special actions" to this end, including a school-based action on energy conservation and emissions reduction.²³ Since 1991, an Energy-Saving Publicity Week has been organized every June to raise awareness.²⁴

Another important policy component of China's energy strategy is the Medium and Long-Term Energy Conservation Plan, adopted in 2004 by the National Development and Reform Commission (NDRC), China's

Energy Efficiency in China

macroeconomic planning body.²⁵ The plan serves as the guidance for China's future energy conservation work and is the basis for developing energy-saving projects. Its goals are to encourage energy conservation, improve energy efficiency, accelerate the creation of an energy-saving society, ease resource constraints and environmental pressures, and meet the overall goal of building "a moderately prosperous society."

The Medium and Long-Term Energy Conservation Plan focuses on energy conservation targets and development priorities through 2010 and proposes goals for 2020. When fully implemented, the measure has the potential to save an estimated 1.4 billion tce of energy, enough to cover the projected 1.26 billion tce of additional energy production capacity needed during the period 2003–20.²⁶ The Plan's four priority goals are to:

- **Improve national energy efficiency.** According to the Plan, energy consumption per 10,000 Yuan of GDP (1990 fixed price) should decrease from 2.68 tce in 2002 to 2.25 tce by 2010, registering an average annual energy efficiency rate of 2.2 percent from

2003 to 2010, with the capacity to save 400 million tce. By 2020, energy consumption per 10,000 Yuan GDP should be 1.54 tce, with an average annual energy efficiency rate of 3 percent from 2003 to 2020.²⁷

- **Improve the energy efficiency of major industrial products.** Energy consumption per unit of major industrial products, such as ammonia, steel, cement, and aluminum, should "reach or be close to the international advanced standard of the early 1990s by 2010 and reach or be close to the international up-to-date level by 2020."²⁸ (See Table 2.) By 2010, large and medium-sized businesses should reach the international advanced level for energy consumption of the early 2000s.
- **Improve the energy efficiency of major energy-consuming equipment.** By 2010, the energy efficiency of new major energy-consuming equipment should reach or approach the international advanced level.²⁹ (See Table 3.) For some vehicles, electric motors, and household appliances, efficiency should reach the highest international level.
- **Improve energy conservation management.** By 2010, China should establish a fairly com-

Table 2. Energy Consumption Per Unit of Major Product, 2000 and Targets for 2010 and 2020

| Major Product | 2000 Actual Energy Consumption | 2010 International Benchmark | 2020 International Benchmark |
|--|--|------------------------------|------------------------------|
| | (kilograms of coal equivalent per ton, unless indicated otherwise) | | |
| Caustic soda | 1,553 | 1,400 | 1,300 |
| Large synthetic ammonia | 1,372 | 1,400 | 1,300 |
| Steel | 906 | 730 | 700 |
| Ethylene | 848 | 650 | 600 |
| Steel | 784 | 685 | 640 |
| Thermal power supply (coal consumption) (kgce/kWh) | 392 | 360 | 320 |
| Cement | 181 | 148 | 129 |
| Flat glass | 30 | 24 | 20 |
| Refinery unit energy consumption factor (kgce/t·Factor) | 14 | 12 | 10 |
| Building ceramics (kgce/square meter) | 10.0 | 9.2 | 7.2 |
| Aluminum | 9.9 | 9.5 | 9.2 |
| Non-ferrous metals (10 types) | 4.8 | 4.6 | 4.5 |
| Copper | 4.7 | 4.3 | 4.0 |

Source: See Endnote 28 for this section.

Energy Efficiency in China

Table 3. Energy Efficiency of Major Energy-Consuming Equipment, 2000 and Targets for 2010

| Equipment | 2000 Actual Energy Efficiency | 2010 International Benchmark |
|---|----------------------------------|---------------------------------|
| | (percent) | |
| Coal-fired industrial boiler (in operation) | 65 | 70–80 |
| Small electric motor (designed) | 87 | 90–92 |
| Fan (designed) | 75 | 80–85 |
| Pump (designed) | 75–80 | 83–87 |
| Gas compressor (designed) | 75 | 80–84 |
| Room air conditioner (COP*) | 2.4 | 3.2–4.0 |
| Refrigerator (COP) | 80 | 62–50 |
| Household gas stove (thermal efficiency) | 55 | 60–65 |
| Household gas water heater (thermal efficiency) | 80 | 90–95 |
| Average vehicle fuel consumption (passenger cars) | 9.5 liters/100 km | 8.2–6.7 liters/100 km |

* *Coefficient of Performance*

Source: See Endnote 29 for this section.

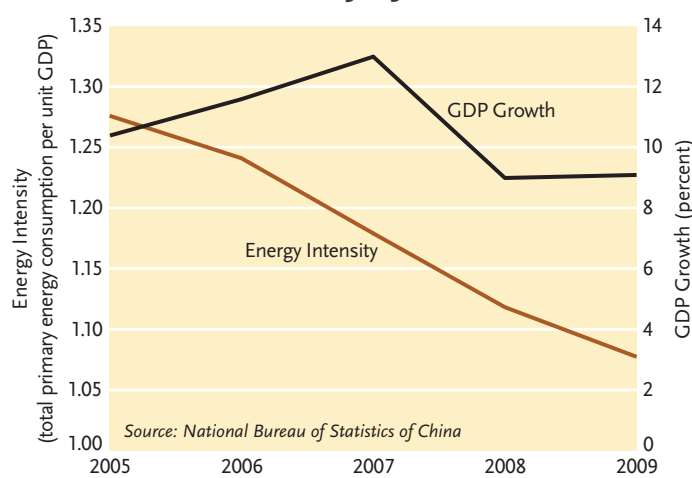
plete system of energy-saving regulations and standards, policy support, supervision and management, and technical service that is adapted to the country's economic system.

Energy Efficiency Status

Spurred by the above policies and targets as well as key technological changes in a variety of sectors, China's energy efficiency improved significantly between 2005 and 2009.³⁰ (See Figure 2.) According to official figures, energy consumption per unit of GDP decreased 2.7 percent in 2006 (the first decline since 2003), 5.0 percent in 2007, 5.2 percent in 2008, and 3.6 percent in the first half of 2009.³¹ All of these savings occurred despite an average GDP increase of 10.7 percent annually over the period.³²

Overall, China's energy intensity fell by just over 10 percent during the first three years of the 11th Five-Year Plan (2006–10), saving 290 million tce of energy and reducing greenhouse gas emissions by 750 million tons of carbon dioxide-equivalent, achieving half of the plan's target.³³ In 2008, nearly all of the country's major cities, provinces, and autonomous regions registered savings in energy consumption per unit of GDP, energy consumption per unit of industrial added value, and power consumption per unit of GDP.³⁴ (See Table 4.)

Figure 2. China's Energy Intensity versus GDP Growth, 2005–09



Although China has achieved considerable progress in improving its energy intensity, there remains significant potential for efficiency improvements in all major economic sectors, including industry, buildings, and transportation.

Industry

Industry is China's largest energy consumer, accounting for 72 percent of total primary energy consumption in 2007.³⁵ The industrial sector covers such activities as electricity generation by coal-fired power plants, mining, and

Energy Efficiency in China

Table 4. Change in Energy Consumption per Unit GDP Index by Province, Autonomous Region, and Municipality, 2008

| | Energy Consumption per Unit GDP | | Energy Consumption per Unit Industrial Added Value | | Power Consumption per Unit GDP | |
|----------------|---------------------------------|------------------------------|--|------------------------------|--------------------------------|------------------------------|
| | Index Value (tce/10,000 RMB) | Increase or Decrease (+/- %) | Index Value (tce/10,000 RMB) | Increase or Decrease (+/- %) | Index Value (kWh/10,000 RMB) | Increase or Decrease (+/- %) |
| National | 1.1 | -4.6 | 2.2 | -8.4 | 1,375 | -3.3 |
| Beijing | 0.7 | -7.4 | 1.0 | -12.7 | 720 | -5.1 |
| Anhui | 1.1 | -4.5 | 2.3 | -9.9 | 1,101 | -0.9 |
| Chongqing | 1.3 | -5.0 | 2.1 | -10.4 | 1,090 | -5.0 |
| Fujian | 0.8 | -3.7 | 1.2 | -10.1 | 1,099 | -5.0 |
| Gansu | 2.0 | -4.5 | 4.1 | -5.7 | 2,539 | 0.09 |
| Guangdong | 0.7 | -4.3 | 0.9 | -11.3 | 1,086 | -6.2 |
| Guangxi | 1.1 | -4.0 | 2.3 | -10.4 | 1,254 | -1.9 |
| Guizhou | 2.9 | -6.1 | 4.3 | -11.6 | 2,452 | -7.9 |
| Hainan | 0.9 | -2.6 | 2.7 | -1.9 | 979 | -2.1 |
| Hebei | 1.7 | -6.3 | 3.3 | -14.3 | 1,493 | -5.5 |
| Heilongjiang | 1.3 | -4.8 | 1.9 | -6.6 | 866 | -4.7 |
| Henan | 1.2 | -5.1 | 3.1 | -10.8 | 1,266 | -2.8 |
| Hubei | 1.3 | -6.3 | 2.7 | -12.7 | 1,104 | -5.6 |
| Hunan | 1.2 | -6.7 | 2.0 | -11.8 | 976 | -9.9 |
| Inner Mongolia | 2.2 | -6.3 | 4.2 | -14.1 | 1,887 | -10.2 |
| Jiangsu | 0.8 | -5.9 | 1.3 | -10.4 | 1,149 | -5.9 |
| Jiangxi | 0.9 | -5.5 | 1.9 | -14.1 | 942 | -5.1 |
| Jilin | 1.4 | -5.0 | 2.0 | -7.0 | 886 | -7.5 |
| Liaoning | 1.6 | -5.1 | 2.4 | -8.4 | 1,224 | -8.2 |
| Ningxia | 3.7 | -6.8 | 7.1 | -12.2 | 5,084 | -10.9 |
| Qinghai | 2.9 | -4.2 | 3.2 | -6.5 | 4,062 | -2.7 |
| Shaanxi | 1.3 | -5.9 | 2.0 | -11.5 | 1,256 | -6.3 |
| Shandong | 1.1 | -6.5 | 1.7 | -10.2 | 1,001 | -6.3 |
| Shanghai | 0.8 | -3.8 | 1.0 | -5.1 | 884 | -3.3 |
| Shanxi | 2.6 | -7.4 | 4.9 | -9.3 | 2,289 | -10.0 |
| Sichuan | 1.4 | -3.6 | 2.5 | -5.5 | 1,156 | -6.2 |
| Tianjin | 1.0 | -6.9 | 1.1 | -13.9 | 910 | -10.5 |
| Xinjiang | 2.0 | -3.2 | 3.0 | -4.3 | 1,331 | 4.5 |
| Yunnan | 1.6 | -4.8 | 2.9 | -9.8 | 1,655 | -2.9 |
| Zhejiang | 0.8 | -5.5 | 1.2 | -9.2 | 1,202 | -3.6 |

Source: See Endnote 34 for this section.

the manufacturing of steel, cement, chemicals, paper, and other industrial products. With its key significance in China's economic development, the sector is critical to any efforts to improve energy efficiency nationwide.

China is home to a variety of equipment that leads the world in energy efficiency. How-

ever, the nation's industrial sector remains widely dispersed. The average factory size is small, and in many instances the most advanced equipment co-exists with obsolete or outdated equipment. Because of wide disparities within and among industries, China's average level of industrial energy efficiency is

Energy Efficiency in China

Table 5. Energy Consumption of Major Energy-Consuming Industrial Products, 2000, 2005, and 2008

| Industrial Product (Unit of Measurement) | 2000 | 2005 | 2008 |
|--|--------|--------|--------|
| Coal production, power consumption (kWh/t) | 30.9 | 26.7 | 25.5 |
| Thermal power generation, coal consumption (g/kWh) | 363 | 343 | 325 |
| Thermal power supply, coal consumption (g/kWh) | 392 | 370 | 349 |
| Steel, comparable energy consumption for large and medium enterprises (kgce/t) | 784 | 714 | 691.8 |
| Electrolytic aluminum, AC consumption (kWh/t) | 15,480 | 14,680 | 14,323 |
| Copper smelting, total energy consumption (kgce/t) | 1,277 | 780 | 564 |
| Cement, total power consumption (kWh/t) | | 92 | 90 |
| Flat glass, total energy consumption (kgce/weight box) | 25 | 22 | 16.6 |
| Crude oil refinery, total energy consumption (kgce/t) | 118 | 114 | 108 |
| Ethylene, total energy consumption (kgce/t) | 1,125 | 1,073 | 941.8 |
| Soda ash, total energy consumption (kgce/t) | 406 | 396 | 378 |
| Calcium carbide, power consumption (kWh/t) | | 3,450 | 3,213 |
| Paper and paperboard, total energy consumption (kgce/t) | 1,540 | 1,380 | 1,153 |

Note: Chinese statistics calculate power consumption based on the coal consumption of power generation.

Source: See Endnote 38 for this section.

still far behind that of developed countries.

Nevertheless, the country has made progress in its efforts to eliminate obsolete production capacity. During the first three years of the 11th Five-Year Plan, from 2006 to 2008, it shut down more than 34 gigawatts (GW) of small thermal power units and eliminated nearly 61 million tons of obsolete iron production capacity, 44 million tons of steel production capacity, and 140 million tons of cement production capacity—saving 72 million tce.³⁶

In general, China's energy-conversion efficiency, as well as the efficiency of its most energy-intensive products, has improved gradually since 2005. For instance, the amount of coal used for thermal power generation declined by an average of 4 grams per kWh annually during 2000–05, and 6 grams per kWh during 2005–08—1.5 times the previous rate of decline.³⁷ Other major energy-consuming products and industries showed similar improvements, including steel, copper, cement, and paper.³⁸ (See Table 5.)

Buildings

China is currently a global leader in construction and registered the world's fastest growth

in building output in 2009.³⁹ During the 10th Five-Year planning period (2000–05), the country added roughly 1.6–2 billion square meters of new building area each year.⁴⁰ The demand for new construction will only increase as the population continues to grow and as incomes rise.

Buildings currently account for an estimated 42 percent* of China's total energy use, including energy for lighting, heating, air conditioning, office equipment, and appliances.⁴¹ The main energy sources used in buildings are biomass (mainly in rural areas) and coal (mainly in urban areas), although use of electricity and oil are rising. Building energy consumption has seen rapid growth in recent years, increasing 1.3 times between 1996 and 2006—from 243 million tce to 563 million tce.⁴² Despite this rise, China's per capita energy use for buildings, at 0.3 tce, is still much lower than in developed countries.⁴³

The average home size in China is 95 square

* In China, the official methodology used to determine the energy share of buildings is different from that used for industry; hence, the 72 percent share for industry and the 42 percent share for buildings are both accurate but are calculated using different categories of measurement.

Energy Efficiency in China

meters, well below that in the United States and Japan (at 200 and 130 square meters, respectively) but more than twice that in India (40 square meters).⁴⁴ The largest energy demand in a typical Chinese household is for space heating, followed closely by lighting and appliances. But differences between urban and rural residences are significant: according to a 2009 study, heating intensity in China's urbanized north is more than 13 times that of the country's rural areas.⁴⁵

Although China's energy use for space heating—in both residential and commercial buildings—approximates that of the United States, its energy use for non-space heating is significantly lower per unit area.⁴⁶ (See Table 6.) Overall, Chinese per capita energy consumption for residential heating, including water heating and cooking, is only about 20 percent that of the United States, 25 percent that of Japan, and 50 percent that of European countries.⁴⁷ China's electricity consumption per unit of residential area is about one-quarter the U.S. level.⁴⁸ Energy consumption in typical Chinese office buildings is also generally lower than that in developed countries, per unit area.

These differences are due mainly to the low level of energy services, such as hot water, air conditioning, and electrical appliances, per unit area in China. But this does not mean that China's building sector has higher energy efficiency. Also, although energy consumption per unit of area is the common index used for international comparison, different buildings are affected by local weather conditions, indoor comfort requirements, standards of living, and consumption patterns. Chinese homes tend to be maintained at lower temperatures in the winter than homes in many industrialized countries. Because energy consumption factors can vary greatly, international comparison can be difficult.

China's Ministry of Construction oversees the regulation and permitting of all new construction in the country. Different departments within the Ministry work together to develop energy standards with input from institutes, developers, and other experts.

China's first building energy code was established in 1986, setting standards for residential buildings in the northern part of the country known as the "heating zone." Initially, the national target was to reduce building energy consumption by 30 percent, and to minimize heat losses.⁴⁹ However, this standard, and most subsequent standards, have since been superseded by 2006 regulations that require new buildings to meet a 50-percent reduction in energy consumption from the baseline year of 1980–81.⁵⁰

As technology advances, the energy efficiency of China's buildings is improving. In Beijing, progress in energy-saving technologies has led to a gradual decline in the heating needed per unit of area for residential structures, improving the efficiency of buildings significantly. Sample projects indicate that Chinese buildings that comply with building energy efficiency standards have heating requirements close to or below the average in industrialized countries.⁵¹ (See Table 7.)

Unfortunately, nationwide compliance with existing building efficiency standards is low, and new construction represents a huge untapped potential. As in many developed countries, building energy efficiency standards are difficult to implement in China. Highly technical standards need to be translated into guidance that is usable by architects and building contractors. Building operators need incentives to run buildings in a manner that takes advantage of energy efficiency features, and the burden of implementation typically falls on local governments that vary widely in their capacity.

Transportation

Transportation, including roads, railways, waterways, and aviation, accounts for an estimated 10 percent of China's total energy consumption.^{52*} The main energy sources used in transportation are gasoline, diesel, aviation kerosene, and other liquid fuels, as well as a growing amount of electricity for rail and public transport. Road transportation accounts for

* The energy value of feed for draft animals is not included.

Energy Efficiency in China

Table 6. Energy Consumption per Unit Area of Buildings in China, the United States, and Japan, 2008

| Country | Residential Buildings | | | Commercial Buildings | | |
|---------------|-----------------------|---------------------|--------------------|----------------------|---------------------|--------------------|
| | Space Heating | Non-space Heating | | Space Heating | Non-space Heating | |
| | | Residential Heat | Home Appliances | | Residential Heat | Home Appliances |
| | kgce/m ² | kgce/m ² | kWh/m ² | kgce/m ² | kgce/m ² | kWh/m ² |
| United States | 9.7 | 3.9 | 49.6 | 9.5 | 5.5 | 205 |
| Japan | 5.3 | 6.6 | 61.1 | 7.4 | 11.3 | 165 |
| China (urban) | 10.2 | 2.6 | 15.6 | 10.2 | n.a. | 120 |

Source: See Endnote 46 for this section.

Table 7. Residential Heating Requirements per Unit Area in Beijing

| Surrounding Structure Type | Heating Requirement (kilowatt-hours per m ²) |
|--|---|
| Brick-concrete structures built in the 1950s and 1960s | 96–155 |
| Buildings built in the 1960s–1980s (100 millimeter concrete slab and single-layer steel windows) | 111–167 |
| Buildings built after the mid-1990s | 60–100 |
| Buildings in industrialized countries in Europe and North America (for comparison) | 95–154 |

Source: See Endnote 51 for this section.

Table 8. Transportation Energy Consumption in China, by Mode, 2000–05

| Transport Mode | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|----------------|----------------------------------|-------|-------|-------|-------|-------|
| | (10,000 tons of coal equivalent) | | | | | |
| Road | 3,804 | n.a. | n.a. | 5,345 | 6,891 | n.a. |
| Railway | 1,860 | 1,917 | 1,992 | 2,031 | 2,156 | 2,248 |
| Aviation | 720 | 780 | 874 | 881 | 1,149 | 1,279 |
| | (10,000 tons of fuel) | | | | | |
| Waterway | 1,175 | 1,253 | 1,009 | 1,022 | n.a. | n.a. |

Source: See Endnote 53 for this section.

the bulk of transportation energy use, followed by rail; however, China lacks consistent and systematic data on various transport modes to allow for adequate comparison over time.⁵³ (See Table 8.)

As a developing country where private vehicles are prohibitively expensive for a large share of the population, China's transport-related energy consumption is relatively low in absolute terms. The country is home to large num-

bers of two- and three-wheeled vehicles (mopeds, motorcycles, etc.), and, compared to the global average, it relies on a higher share of rail travel and a lower share of air transport and automobiles. However, energy efficiency within China's transportation sector is still lagging, particularly with regard to trucks, air transport, and inland waterways.⁵⁴ (See Table 9.)

Energy efficiency in China's transportation sector is gradually improving as technologies

Energy Efficiency in China

advance; however, there is significant room for further gains, especially with regard to the country's rapidly expanding vehicle fleet. Between 2005 and 2008, the number of private cars in China more than doubled; even so, the

national rate of car ownership in 2008 was less than 20 vehicles per 1,000 Chinese, compared to rates exceeding 600 in Europe and 700 in the United States.⁵⁵ Although China will likely never reach these very high levels of ownership, the projected rise in energy use required by the nation's burgeoning vehicle fleet makes energy efficiency an even more urgent task.

With regard to vehicle performance and fuel economy, China's mainstream sedan models are smaller than those in industrial countries, yet their gasoline consumption is generally higher, resulting in low fuel economy.⁵⁶ (See Table 10.) For the same sedan model, the fuel economy of new vehicles in China is 10–15 percent lower than in Europe, 5–20 percent lower than in the United States, and 20–25 percent lower than in Japan.⁵⁷

China has taken important steps to promote more efficient vehicles. The government has raised the fuel economy standard for new cars produced in its factories from 12.3 kilometers per liter in 2002 to 15.3 kilometers per liter in 2009.⁵⁸ Some regions are also increasing promotion of electric vehicles: the city of Shenzhen, for example, recently deployed 40 battery-powered taxis and plans to expand the program if it succeeds.⁵⁹ Meanwhile, China is

Table 9. Transportation Energy Efficiency in China, by Mode, 2006

| Transport Mode | Energy Efficiency |
|---|-------------------|
| Railway | |
| Locomotive fuel consumption (10,000 t-km) | 24.3 |
| Electric vehicle power consumption (kilowatt-hours/10,000 t-km) | 110.0 |
| Road (liters/100t-km) | |
| Private cars | 10.8 |
| Buses | |
| Gasoline buses | 12.8 |
| Diesel buses | 11.2 |
| Trucks | |
| Gasoline trucks | 7.9 |
| Diesel trucks | 6.5 |
| Waterway (kilograms of fuel/1000 t-km) | |
| Inland | 3.7 |
| Ocean | 5.9 |
| Aviation (tons of fuel/10,000 t-km) | |
| | 3.5 |

Source: See Endnote 54 for this section.

Table 10. Vehicle Performance and Fuel Economy in China versus Industrial Countries

| Country | Vehicle Weight (kilograms) | Engine Displacement (milliliters) | Engine Rated Power (kilowatts) | Transmission | Fuel Consumption (liters/100 km) |
|---------------|-------------------------------|--------------------------------------|-----------------------------------|---|-------------------------------------|
| China | 1,187 | 1,650 | 73 | 23% AT (A4, A3) 76% MT (M4, M5) 1% CVT | 9.1 |
| United States | 1,472 | 2,900 | 145 | 70% AT (A4, A5) 30% MT (M5, M6) | 9.7 |
| Germany | 1,349 | 1,898 | 97 | 61% AT (A4, A5) 38% MT (M5, M6) 1% CVT | 8.5 |
| Japan | 1,329 | 1,999 | 111 | 64% AT (A4, A5) 22% MT (M5, M6) 14% CVT | 7.9 |

Note: AT is automatic transmission, MT is manual transmission, CVT is continuously variable transmission. A3–A5 and M4–M6 refer to vehicle chassis types.

Source: See Endnote 56 for this section.

Energy Efficiency in China

readily embracing mass transit systems, including the use of Bus Rapid Transit (BRT) in major metropolitan areas.⁶⁰ (See Sidebar 2.)

China has also invested heavily in a “rail revolution” to connect its major cities. In 2008, the government revised its Medium and Long-term Railway Development Plan, expanding the

nationwide target for operational track length from some 100,000 kilometers to 120,000 kilometers by 2020, with a special focus on high-speed rail.⁶¹ China aims to expand its current 6,500 kilometers of high-speed rail to 16,000 kilometers by 2020.⁶² A total of eight new high-speed lines, half horizontal and half vertical in

Sidebar 2. Yutong Bus: Building China’s Mass Transit Bus System

With an urban population two times that of the United States, China is by far the largest potential market for municipal buses. Today, an estimated 45 percent of the population lives in urban areas, and that share continues to rise. Major international events, such as the 2008 Olympic Games in Beijing and the 2010 Shanghai World Expo, have accelerated the “greening” of China’s transportation sector, particularly in improving energy efficiency.

Since preparing for the Olympics, the Beijing city government has committed \$17 billion to environmental projects, a key component of which is city transport infrastructure. Another significant greening initiative launched in 2009 is the “10 cities, 1,000 buses” project, which aims to place 1,000 alternative fuel vehicles in 10 large cities, including Shanghai, Beijing, Chongqing, Shenzhen, Wuhan, and Zhuzhou. In addition, the initiative calls for public transit services to adopt at least 60,000 alternative-fuel vehicles by 2012. The goal is to develop a clean urban transit system, both to reduce pollution and to help China achieve its goal of running 10 percent of domestic vehicles on alternative fuels by 2012.

Zhengzhou Yutong Bus, the largest bus manufacturer in China and the world’s second largest, is a dominant player in hybrid-electric technology. In 1999, long before government policy initiatives promoted clean energy for buses, Yutong began researching energy-efficient bus technologies. In 2007, it cooperated with U.S. company Alcoa to develop a new bus for the Olympics that incorporates Alcoa’s spaceframe technology and requires less fuel, in part through a more-than 1,000 kilogram weight reduction per vehicle. According to Germany’s Institute for Energy and Environmental Research, a weight reduction of 1,000 kilograms in a diesel-powered city bus saves 2,550 liters of fuel and reduces 100 tons of CO₂-equivalent greenhouse gas emissions over its lifetime. In 2010, Yutong also debuted a hydrogen fuel cell electric metro bus, currently being tested in Xinxiang City, that is expected to produce zero emissions.

As China urbanizes, Bus Rapid Transit (BRT) has become an ideal solution for mass transportation in metropolitan areas. Currently, some 11 Chinese cities have developed or plan to develop a BRT system, including Beijing, Guangzhou, Hangzhou, Jinan, Xiamen, and Zhengzhou. Yutong Bus has embraced the arrival of BRT by equipping its BRT buses with low-emissions and low-energy consumption technology. Its model ZK6126EGA9 uses automatic transmission technology to avoid frequent gear shifts and electric-driven mute technology to reduce noise.

Yutong is the main supplier of BRT buses in Zhengzhou City, home to an estimated 336,000 motor vehicles and 130,000 private automobiles, with annual fleet growth of 10–20 percent. Although data on energy and emissions savings from Zhengzhou’s BRT system, launched in 2009, are not yet available, the program is expected to be extremely worthwhile given that ridership on the city’s public transit systems nears 2 million per day.

Yutong is setting the bar internationally, and its buses have been chosen for public transportation systems in Cuba, Russia, South Africa, and the United States. The company’s success is indicative of China’s overall achievement in incorporating energy efficiency in mass transportation systems. With continuous improvement of BRT and energy efficient buses in major urban centers, including cities like Hangzhou and Shenzhen, China hopes to reduce the use of private vehicles and slow greenhouse gas emissions.

Source: See Endnote 60 for this section.

Energy Efficiency in China



Jan Reurink

High-speed train traveling through Tibet, north of Yangbajain.

direction, will be added, with an investment of 700 billion RMB (about \$103 billion) in 2010 alone.⁶³ High-speed lines are to connect all Chinese cities with more than 500,000 inhabitants, providing access for a stunning 90 percent of the population.⁶⁴

Rail upgrades already in place in China have reduced travel times between regions drastically and provided a viable alternative to buses and some flights.⁶⁵ The Harmony Express, the world's fastest train, now covers more than 1,000 kilometers in three hours.⁶⁶ Within the next decade, China is looking toward even larger high-speed rail projects that could potentially connect the country to Europe, with a travel time of two days between Beijing and London.⁶⁷

Renewable Energy in China

Even as energy efficiency continues to advance, China has recognized the need to diversify its energy supplies. As such, the country has embarked on an ambitious path of renewable energy deployment.

In the span of just a few years, China has become a globally important manufacturer of renewable energy products as well as a substantial renewables market in its own right. The country began developing hydropower as early as 1949, and starting in the 1950s it launched a variety of micro-hydro and biogas programs to improve access to modern energy forms. As economic reforms got under way in the 1980s, the government identified modern renewable energy technologies as worthy of scientific and engineering investment, and research and development (R&D) has grown steadily since then. For hundreds of millions of rural Chinese, however, traditional biomass forms such as fuel wood and crop residues continue to be the main source of energy.

Since the 1990s, Chinese renewable energy production has experienced remarkable expansion. Wind energy in particular has seen unprecedented annual growth, followed by solar photovoltaics (PV). Other renewable energy technologies gaining prominence include solar water heating, biomass power generation, biomass pellet production, and geothermal and ocean energy.

Despite rising domestic interest, Chinese renewable energy companies continue to rely heavily on export markets to fuel their growth. This is particularly true in the case of solar PV, where most production is exported, but both the wind and solar hot water industries are



Scott Zhang

Solar photovoltaic-powered street lighting in Beijing.

also expanding their exports rapidly. This has led to growing tensions with European and North American companies that are losing market share. Analysts attribute this trend in part to the unusually strong state support that Chinese companies receive.¹

Key Policies

China unveiled its plan to ramp up renewable energy production in 2004, at the International Renewable Energy Conference in Bonn, Germany.² The following year, China enacted its milestone Renewable Energy Law, which took effect in early 2006.³ This law, along with its supporting amendments for implementation, comprises the legal framework for China's renewable energy policies. It covers all relevant regulations, sectoral targets, development plans, fiscal and subsidy policies, and national standards. Further additions to

Renewable Energy in China

the law continue to be deliberated.

The second most important strategy to support renewable energy development in China is the Medium and Long-Term Development Plan for Renewable Energy.⁴ The Plan, drafted by the NDRC and passed in 2007, lays out the guiding principles to “speed up the development of renewable energy, promote energy conservation and reduce pollutants, mitigate climate change, and better meet the requirements of sustainable social and economic development by 2020.”⁵

Key stipulations for renewable energy in both the Renewable Energy Law and the Medium and Long-Term Development Plan for Renewable Energy include:

National targets. According to both plans, renewable energy should account for 10 percent of China’s total energy supply by 2010 and 15 percent by 2020.⁶ By writing these targets into national law, China has indicated its long-term commitment to the development of renewable energy.

Mandatory grid access. The Renewable Energy Law stipulates that grid companies have to purchase all of the power generated from renewable energy sources within their coverage areas.⁷

Feed-in-tariffs/ Power pricing. In July 2009, the NDRC divided China into four regions according to their wind energy resources and set fixed benchmark power prices at 0.51, 0.54, 0.58, and 0.61 RMB (7.4 cents, 7.9 cents, 8.5 cents, and 8.9 cents) per kilowatt-hour, effectively establishing a feed-in tariff for wind power.⁸ China is moving gradually toward a system of fixed tariffs for solar PV as well. For ground-mounted PV projects, the government now pays a set price of 1.09 RMB (15.9 cents) per kWh for a 10 MW solar PV power plant, which is nearly three times the rate paid to coal-fired generators but still not high enough to spur a sizable domestic market.⁹

For biomass power generation, the price is fixed according to: (1) the cost of operating local coal-fired power plants, including the installation and operation of flue gas desulfurization equipment, and (2) a premium of 0.35 RMB (5.1 cents) per kWh.¹⁰ The premium was

increased from 0.25 RMB (3.6 cents) in late 2008 due to low financial viability, which resulted in too many biomass power plants competing for the same amount of feedstock.¹¹

Special subsidies for solar PV installation. The government’s “Golden Sun” program, launched in July 2009, as well as an older subsidy scheme for grid-connected PV on urban roofs, provide financial subsidies for the installation of solar PV systems. For urban roof systems of 50 kW and above, the government provides a maximum subsidy of 20 RMB (\$2.90) per peak watt installed.¹² For large grid-connected systems of 300 kW and above, and for off-grid systems in remote areas, subsidies cover 50 and 70 percent of the total investment, respectively.¹³

This support has helped spur China’s stagnant PV market. By November 2009, some 111 projects covering 33 provinces, with a combined capacity of 91 MW, had been approved under the Golden Sun program.¹⁴ The total subsidy for the initiative is 1.27 billion RMB (\$186 million), of which 890 million RMB (\$130 million) has already been allocated.¹⁵

Price balancing. According to Chinese policy, the additional cost of renewable power above conventional power sources is to be shared nationwide by collecting a surcharge on all retail electricity sales of non-renewable energy. This surcharge is currently around 0.002 RMB (.03 cents) per kWh but can be increased if deemed necessary.¹⁶ It is collected by grid companies and then allocated by the Ministry of Finance according to local conditions, and is the major source for renewable energy subsidies. The Ministry redistributes surcharges from regions where the collected total is large to regions where this amount is small, to achieve nationwide balance.

Other Chinese policies that support renewable energy development include subsidies for the production of bio-pellet fuel; reduction and exemption from the value-added tax for renewable energy equipment; a preferential import tax on key renewables components; and the “Home Appliances to the Countryside” project, which promotes and/or subsidizes the use of appliances such as evacuated tube solar

Renewable Energy in China

water heaters in rural areas.¹⁷

In addition, the Ministry of Science and Technology provides financial support for R&D on key renewable energy technologies and has established a reward system for independent equipment R&D.¹⁸ For example, for an innovative wind turbine with full intellectual property rights, the Ministry will grant a reward for each unit of project production. In 2008, the Ministry of Finance announced another reward system for wind turbine manufacturing, awarding the first 50 wind turbines using innovative technology with 600 RMB (\$88) per kW, to be split evenly between the manufacturers of the turbines and the components.¹⁹

A draft revision to the Renewable Energy Law, submitted in August 2009, proposes setting up a new fund to support development of China's renewable energy industry and establishing a system of purchasing all power generated from renewable energy sources.²⁰ The proposed "renewable energy development fund" would be financed through the government budget and would support R&D on renewable energy technologies as well as development of a

"smart grid" power transmission system.²¹

In addition to the general policies and regulations enacted by the central government, local governments have formulated their own policies for renewables, including development plans, targets, and subsidies that are suitable to local conditions.²² For example, several provinces—including Hebei, Jiangsu, and Xingjiang—have adopted local wind energy targets and developed plans for project implementation.²³ (See Table 11.)

Outside of China, renewable energy policies in other countries have provided markets for Chinese-produced renewable energy equipment. A \$1.5 billion wind farm in the U.S. state of Texas, for example, plans to use imported turbines manufactured by A-Power Energy Generation Systems Ltd., a company based in Shenyang.²⁴ According to early 2010 estimates, as much as 80 percent of the nearly \$2 billion in funding from the 2009 American Recovery and Investment Act that was spent on wind power had gone to foreign manufacturers of wind turbines.²⁵ The Texas project alone is expected to create some 2,000 manufacturing jobs in China.²⁶

Table 11. Important Local Wind Energy Targets in China, 2010 and 2020

| Province | 2010 Target | 2020 Target |
|-----------|---|--|
| Hebei | During the 11th Five-Year plan, total wind power installation should reach 2,400–3,000 MW, including 1,600 MW from Zhangjiakou, 500 MW from Chengde, and 50 MW each from Tangshan, Qinhuangdao, and Baoding. | Total installation during 2010–20 should reach 7,500 MW, including 4,500 MW from Zhangjiakou, 2,000 MW from Chengde, 640 MW from Cangzhou, 60 MW from Qinghuangdao, and 30 MW from Tangshan. |
| Jiangsu | By 2010, total wind power installation should reach 1,500 MW. | By 2020, total wind power installation should reach 10 GW, including 3,000 MW of on-shore and 7,000 MW of off-shore. The long-term target is 21 GW. |
| Xingjiang | By 2010, total wind power installation should reach 3,550 MW, including 1,550 MW to be consumed within Xingjiang and the rest provided to other provinces. The first phase of large-scale wind bases should also be completed, with total capacity of 2,000 MW. | |

Source: See Endnote 23 for this section.

Renewable Energy in China

Table 12. China's Renewable Energy Development and Use, 2008

| | Production (million tce/year) | Consumption | Annual Production Capacity | Estimated Cost Range (RMB/kWh) |
|----------------------------|----------------------------------|----------------------------|-------------------------------|--------------------------------------|
| Power Generation | 210.74 | 187 GW | 595 TWh | |
| Hydro | 207.78 | 172 GW | 563.3 TWh | |
| Wind | 5.33 | 12 GW | 14.8 TWh | 0.45–0.77 |
| Solar PV | 0.08 | 150 MW | 220 million kWh* | 3.45–1.2 |
| Biomass | 2.55 | 3 GW | 7.5 TWh | 0.55–0.9 |
| Gas Supply (biogas) | 10.00 | | 14 billion m ³ | 0.77–1.1 |
| Household Biogas | | 30 million units | | |
| Large-scale Biogas | | 1,600 units | | |
| Thermal Supply | 28.30 | | | |
| Solar Hot Water | 25.00 | 125 million m ² | | |
| Solar Cookers | 0.10 | 450,000 units | | |
| Geothermal | 3.20 | 40 million m ² | 800 million GJ | 1.2 (average) |
| Ethanol | 1.55 | 1.65 million tons | | |
| Total | 250.59 | | | |

*Calculated by average sun hours

Source: See Endnote 28 for this section.

Renewable Energy Status

By the end of 2008, annual renewable energy use in China totaled some 250 million tons of coal equivalent, excluding traditional biomass.²⁷ Renewables accounted for 9 percent of the country's total primary energy use, up from 7.5 percent in 2005.²⁸ (See Table 12.) Hydropower dominated China's renewable energy usage—at 180 million tce, or 72 percent of the total—followed by solar, wind, and modern biomass energy, which together comprised 70 million tce.²⁹ With strong growth expected to continue, China is likely to reach its target of generating 10 percent of primary energy from renewables by the end of 2010.³⁰

According to the China Electricity Council, total electricity generation from renewable sources in 2009 was 599.5 terawatt-hours (TWh), including 571.7 TWh from hydropower, 27.6 TWh from wind power, and 152 gigawatt-hours (GWh) from solar PV, geothermal, and biomass power combined.³¹ In total, renewably generated electricity accounted for 16 percent of total national electricity production of 3,681 TWh.³²

Before 2006, electricity prices in China were

set based on each power plant's investment and payback period. Currently, plants that run on traditional energy sources (including large hydropower) have a different pricing mechanism than plants powered by renewables. The grid-connecting price for most coal-powered electricity, for example, is based on region-specific benchmarking prices set by the NDRC and the State Electricity Regulatory Commission.

On average, the price levels for electricity from renewable energy sources are higher than those from traditional energy sources because they reflect a combination of the local benchmarking price and a renewable subsidy price.³³ (See Table 13.) By contrast, the prices paid for electricity generated from nuclear energy and hydropower are still generally cost-based.

Hydropower

Water resources account for roughly 40 percent of China's remaining exploitable energy reserves.³⁴ According to a 2003 review, the technically exploitable installed capacity of China's water resources is 542 GW, with an annual power generation capacity of 2.47 trillion kWh.³⁵ The economically exploitable installed

Renewable Energy in China

capacity is roughly 400 GW, with annual power generation of 1.75 trillion kWh.³⁶

China has traditionally invested heavily in large hydropower development, as exemplified by initiatives such as the Three Gorges Project. Large hydropower continues to represent the bulk of Chinese renewable energy usage. In 2009, China's hydropower generation (both small and large) reached 196 GW.³⁷

The country has also been vigorously developing small hydropower, defined as installations less than 50 MW in capacity. Small hydropower is an important renewable energy source in China and is often referred to as "rural hydropower" because of its close link to economic development and electrification in rural areas.³⁸ China is now a world leader in small hydro systems, which have been fully commercialized.³⁹ Investment is growing every year, and more than 20 GW is under construction annually.⁴⁰

The Medium-and-Long Term Development Plan for Renewable Energy sets a target for 50 GW of installed small hydro capacity by 2010, a level that was reached by the end of 2008, two years ahead of schedule.⁴¹ (See Figure 3.) By the end of 2009, some 45,000 small hydropower stations had been built in China, with a total installed capacity of 55.1 GW.⁴² Power generation from small hydro reached 160 TWh, accounting for about 30 percent of total hydropower generation.⁴³

China's small hydro capacity is roughly equivalent to the small hydro installed capacity in the rest of the world combined.⁴⁴ Although the country's small hydropower stations are limited in scale, they have a large combined impact and play a significant role, particularly in rural and mountainous areas.

Wind Power

According to the Chinese Academy of Engineering, China has total wind energy resources of 700–1,200 GW, of which 600–1,000 GW is on land and 100–200 GW is offshore.⁴⁵ If these resources were fully exploited, annual wind power generation would reach an estimated 1.4–2.4 trillion kWh, equal to 40–70 percent of China's 2005 total power generation, depending on the variables measured.⁴⁶

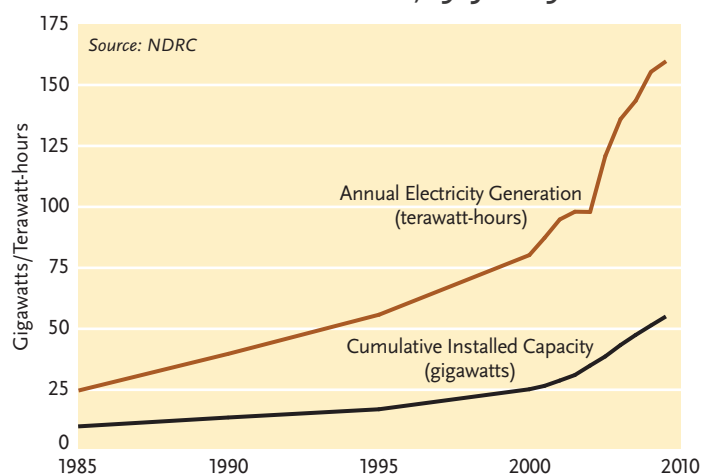
Table 13. Grid-Connected Electricity Prices in China, by Energy Source

| Energy Source | Price | | |
|---------------------------|-----------|------|---------|
| | High | Low | Average |
| | (RMB/kWh) | | |
| Renewable Energy | | | |
| Solar PV | 3.45 | 1.2 | 1.5 |
| Tidal | n.a. | n.a. | 1.5 |
| Geothermal | n.a. | n.a. | 1.2 |
| Biomass | 0.9 | 0.55 | 0.7 |
| Wind | 0.77 | 0.45 | 0.6 |
| Traditional Energy | | | |
| Natural Gas | 1.1 | 0.77 | 0.8 |
| Nuclear | 0.77 | 0.37 | 0.44 |
| Coal | 0.45 | 0.32 | 0.38 |
| Hydropower | 0.76 | 0.12 | 0.22 |

Note: Because a standard methodology for collecting cost-related data is lacking at the plant level, it is difficult to perform an accurate comparison of the average costs of power generation technologies in China.

Source: See Endnote 33 for this section.

Figure 3. China's Small Hydropower Installed Capacity and Power Generation, 1985–2009



China's wind power industry has gone through three key stages and is now moving toward large-scale development.⁴⁷ (See Sidebar 3.) Prior to 2003, the country's cumulative installed wind power capacity was only 470 MW, and newly added capacity was less than 100 MW annually.⁴⁸ A series of successful consecutive wind power concession projects have since ignited China's wind

Sidebar 3. China's Wind Power Development: Three Stages

In recent years, China's wind power industry has seen the fastest growth among all energy sectors, and wind energy equipment manufacturing has become one of the country's pillar home-grown industries. The development of China's wind industry has gone through several key stages:

Stage 1: Burgeoning (1970s–1997). In the 1960 and 70s, China began researching and developing the use of small, off-grid wind power to provide electricity to remote rural areas. The government started to subsidize small-turbine use. R&D on large, grid-connected turbines started in the late 1970s, thanks to official development assistance. Although this assistance still continues today, it is no longer a major driving force. Prior to 1997, most initiatives were pilot projects, most wind turbines were imported from abroad, and there was no obvious market demand.

Stage 2: Nurturing (1997–2005). During this period, China nurtured its wind power market and industry by implementing several national projects, including the Riding the Wind Program. The government aimed to bolster market demand through planning. Domestic industries were just starting up and became capable of independent manufacturing, creating the potential for lowering both costs and the price of wind power through competition. Due to the small-scale nature of manufacturing and use, however, there was no market pricing mechanism and the government determined the price of wind power.

Stage 3: Blossoming (2005–present). China's 2005 Renewable Energy Law has encouraged the development of wind power through measures such as national goals, grid pricing, mandatory grid access, and cost-sharing. Wind power concession projects have also injected vitality in the market. The NDRC organized five consecutive concession projects with the aim of reducing the grid price of wind power and encouraging the rapid development of large wind farms. The government provided preferential policies and building conditions, and builders and operators of wind farms were chosen through bidding. The smooth progress of the concession projects expanded the scale of China's wind farms to a domestically unprecedented 100 MW, and also introduced a grid-pricing system based on market competition. The projects attracted powerful state-owned enterprises to invest in wind farm development and opened up the domestic market for equipment manufacturing.

Source: See Endnote 47 for this section.

energy market and manufacturing base.

Since 2005, as a result of strong national and provincial policies, China's newly added wind power capacity has doubled for four consecutive years. The country added 13.8 GW of new capacity in 2009, accounting for nearly one-third of the world total and surpassing the

United States to become the largest market for wind power.⁴⁹ By the end of 2009, China's total installed wind power capacity was 26 GW, more than double the 12 GW of 2008 and up from only 1.3 GW in 2005—making wind the country's second largest renewable energy source after hydropower.⁵⁰ (See Figure 4.) In 2009, China's total installed wind capacity surpassed Germany's, trailing only the United States in the global rankings.⁵¹

China's wind manufacturing industry has matured as well and is now developing even faster than the wind energy market. Many foreign turbine manufacturers have established their own factories or joint ventures, and more than 70 domestic manufacturers have emerged, including leading enterprises such as Sinovel, Goldwind, Dongfang Steam Turbine Works, and Huiteng.⁵² These companies are capable of producing turbines ranging in size from 0.75 MW to 3 MW.⁵³ With more than 100 manufacturers producing parts and components, domestically produced equipment has begun to dominate the Chinese market.⁵⁴ Total turbine production capacity in 2008 neared 10 GW, enough to meet domestic demand and enable exports to other countries, including in East Asia and Latin America.⁵⁵

Under the 11th Five-Year Plan (2006–10), China plans to pursue some 30 large wind power projects of more than 100 MW each in areas with abundant wind resources, such as the east coast and north.⁵⁶ These projects will eventually form seven wind power bases with gigawatt-size capacity in six provinces, stimulating a wider market for wind energy development.⁵⁷ (See Table 14.)

Meanwhile, China's small-scale wind power industry has been growing at a rapid rate. Annual production of small wind turbines increased from 12,000 units in 2000 to 78,000 units in 2008. Total installed capacity increased by an average of 35 percent annually from 1999 to 2008. Compared to large-scale wind power, however, the electricity contribution from small-scale wind is still very limited, accounting for only about 1.3 percent of total wind generation.⁵⁸

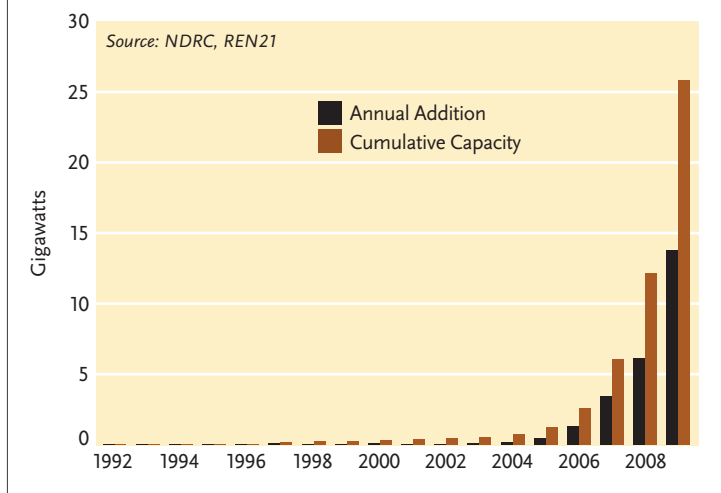
To encourage further development, the

Renewable Energy in China

Chinese government has included small-scale wind power in its upcoming New Energy Development Plan, scheduled for release in late 2010. Detailed incentive policies are expected as well, with a focus on promoting complementary solar and wind generation projects. In remote rural areas that lack grid access, the subsidy rate for such complementary generation has been increased from 50 percent to 70 percent.⁵⁹ With stronger incentive policies, China's installed capacity of small wind turbines could exceed 10 GW by 2020.⁶⁰

Compared with conventional energy, wind power is still an emerging industry in China and faces ongoing challenges. Wind power development is restricted by the capacity of the electrical grid, which continues to lag. Moreover, because wind is an intermittent energy source, it can undermine the stability and security of grid operation. In addition, China's wind turbine manufacturers need to catch up on core technologies, such as design capabilities and control systems.

Figure 4. China's Installed Wind Power Capacity, 1992–2009



Solar PV

China is blessed with rich solar resources across most of its territory. In the roughly three decades between 1971 and 2000, annual solar radiation averaged 1,050–2,450 kWh per square meter, depending on the region.⁶¹ More

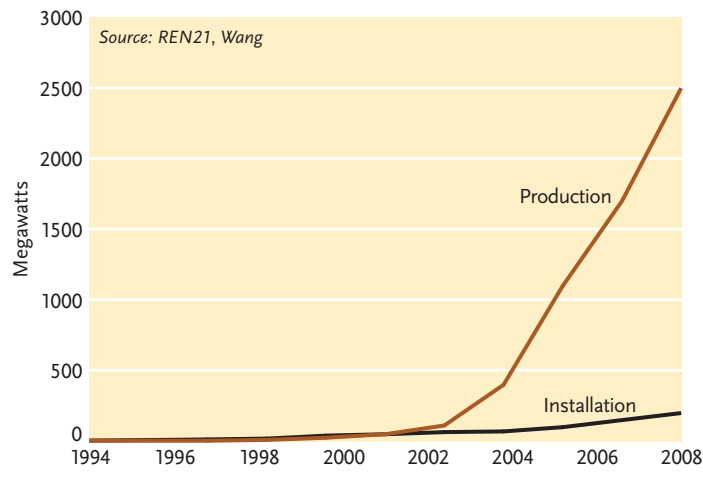
Table 14. Planned Large-Scale Wind Energy Bases in Six Chinese Provinces

| Province | Wind Bases and Targets |
|----------------|---|
| Gansu Jiuquan | Nine wind farms are planned with a combined capacity of nearly 13 GW by 2015. At 2,200 operation hours, annual power generation would reach 28 TWh. |
| Hebei | Wind resources are rich in Zhangjiakou, Chengde, and along the east coast. Planned capacity is 3.4 GW by 2010, 7.6 GW by 2015, and 12 GW by 2020. |
| Inner Mongolia | Most of the province is rich in wind resources, and two bases are slated for the west and east in accordance with grid coverage. The overall target is 8 GW by 2010, 35 GW by 2015, and 58 GW by 2020. By 2020, 37 percent of the power generated will be exported to other provinces. At 2,250 operation hours, annual power output would reach 130 TWh by 2020. |
| Jiangsu | Wind resources are distributed mainly along the coast. The target is 10 GW by 2020, of which 7 GW is near offshore. At 2,000 operation hours, annual power output would be 20 TWh by 2020. |
| Jilin | Regions such as Songyuan and Baicheng have rich wind resources. Planned capacity is 4.4 GW by 2010, 10.9 GW by 2015, and 23 GW by 2020. At 2,200 operation hours, power generation would be nearly 51 TWh by 2020. |
| Xinjiang Hami | Wind farms are planned for southeast of Hami, Santang Lake, and Zhuomao Lake. Planned capacity is 2 GW by 2010 and nearly 11 GW by 2020. At 2,200 operation hours, annual power output would be 26 TWh by 2020. |

Source: See Endnote 57 for this section.

Renewable Energy in China

Figure 5. Chinese Solar Cell Production and Installation, 1994–2008



than 96 percent of China's land area receives more than 1,050 kWh of solar radiation per square meter, and two-thirds of the land area receives 2,200 sunshine hours on a yearly basis.⁶² In total, China's land surface absorbs an estimated 1.7 trillion tce of solar energy.⁶³

Rooftop solar generation offers significant potential nationwide. China has a total roof area of nearly 10 billion square meters, not including building facades and vertical surfaces.⁶⁴ If 20 percent of this area were devoted to solar PV, this would replace 340 million tons of coal, or 11.4 percent of the country's 2008 coal consumption.⁶⁵ Two percent of China's deserts—or approximately 20,000 square kilometers—could be used for solar PV as well.⁶⁶ Altogether, the country has the potential to install 22,000 square kilometers of solar PV systems, with a total power-generation capacity of 2,200 GW and annual output of 2.9 trillion kWh.⁶⁷

The Township Electrification Program, implemented between 2002 and 2004, was a milestone in China's solar PV development. The government invested 4.7 billion RMB (\$691 million) to set up 721 small-scale power stations in 1,065 villages and towns in 12 provinces that lacked access to electricity, mainly in western China.⁶⁸ Most of the stations rely on solar PV, although some use hybrid wind-and-solar systems or small

hydropower. In total, some 17 MW of PV cells was installed through this program.⁶⁹

The township program and subsequent efforts have stimulated China's PV market. Solar cell production expanded from less than 100 MW in 2005 to 2.6 GW in 2008, experiencing a 20-fold increase in just four years.⁷⁰ (See Figure 5.) China is now the world's largest solar PV producer, accounting for one-third of the world total and equaling the combined production of Germany and Japan.⁷¹

Despite these high production levels, China installed less than 50 MW of solar PV systems domestically in 2008.⁷² Ninety-eight percent of the products—totaling some 150 billion RMB (\$22 billion)—were exported.⁷³ Domestic manufacturers now offer complete production lines, from raw materials to solar modules. By 2009, Chinese PV companies held 40 percent of the global market, with most production being exported to Europe.⁷⁴ More than 20 Chinese solar PV companies have successfully engaged in initial public offerings (IPOs), and five of these companies rank among the world's top 10 in solar PV production.⁷⁵

China's total installed PV capacity has increased rapidly from only 19 MW in 2000 to 150 MW in 2008 and 310 MW in 2009.⁷⁶ In 2008, cumulative installations increased 50 percent and new installations by 100 percent. Roughly 40 percent of the installed capacity is provided by independent PV power systems that supply electricity to remote districts not covered by the national grid.⁷⁷ Market shares of solar PV for communications, industrial, and commercial uses have also increased, and building-integrated PV systems (BIPV) and large-scale installations in desert areas are being encouraged.

In just a few years, China's solar PV industry has become an emerging strategic industry and a new engine of economic growth for many regions. By 2010, some 300 MW of new installations were planned in priority regions, including Tibet and Inner Mongolia.⁷⁸ (See Table 15.) Together, China's wind and solar energy industries have bolstered domestic demand for renewable energy and provided a new source of employment, creating more

Renewable Energy in China

Table 15. Solar PV Installation in Key Sectors and Regions, Targets for 2010

| Sector | 2010 Target (MW) | Priority Regions |
|---|---------------------|---|
| Grid-connected systems | 100 | Tibet, Gansu, Inner Mongolia, Ningxia, Xingjiang |
| Building-Integrated PV and large landmark building projects | 50 | Beijing, Shanghai, Guangdong, Jiangsu, Shangdong |
| Grid-connected PV stations | 50 | Lasa, Dunhuang, Erduosi |
| Remote area uses | 150 | Tibet, Qinghai, Gansu, Xingjiang, Yunnan, Sichuan |
| Solar thermal power generation | 50 | Inner Mongolia |
| Total | 300 | |

Source: See Endnote 78 for this section.

than 400,000 jobs nationwide in recent years.⁷⁹ For 2010, there were an estimated 246,000 job opportunities in PV alone.⁸⁰ Production has grown so rapidly that by mid-2010, industry insiders were concerned that overcapacity would cause problems for the industry, notwithstanding a projected 50 percent growth in global demand in 2010.⁸¹

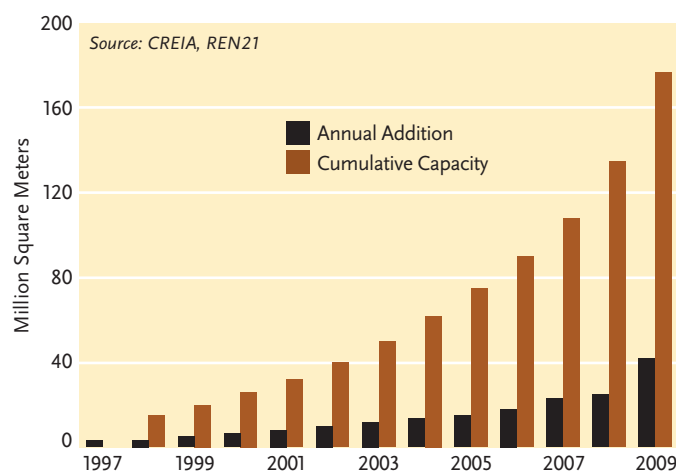
China's national targets for solar PV, announced in 2007, call for 400 MW of capacity by 2010 and 1.8 GW by 2020.⁸² These targets are expected to be exceeded substantially. According to industry experts, China's installed PV capacity could reach 1 GW in 2010 and 20 GW in 2020.⁸³

Solar Hot Water

Over roughly a decade and a half, China has seen breathtaking development in solar water heating. In 2008, solar hot water accounted for half of China's renewable energy use of 50 million tce (excluding hydropower and traditional biomass).⁸⁴ The national goal, as outlined in the Medium-and-Long Term Development Plan for Renewable Energy, is to expand the total collection area of solar water heaters to 150 million square meters by 2010.⁸⁵ China already exceeded this goal in 2009, adding some 42 million square meters that year for a total of 177,000 square meters—representing more than 80 percent of global installations.⁸⁶

Solar water heating, together with other solar thermal applications such as solar cookstoves and solar houses, is expected to replace more than 50 million tce of China's energy use annu-

Figure 6. China's Installed Solar Hot Water Capacity, 1997–2009



ally.⁸⁷ And there is significant potential for further growth. Estimates suggest that if just 20 percent of the nation's roof area were devoted to solar water heating systems, this would replace 340 million tons of coal, or 11.4 percent of the country's 2008 coal consumption.⁸⁸

From an industry perspective, China is now the world's leading manufacturer of solar water heaters, with domestic production capacity of more than 40 million square meters in 2009.⁸⁹ (See Figure 6.) Solar water heaters are widely commercialized nationwide. As of 2008, more than 1,300 solar water heater manufacturers were operating at scale, including the Himin Group, a prominent domestic producer.⁹⁰ (See Sidebar 4.)

China is positioning itself as the world

Sidebar 4. The Himin Group: Pioneering Solar Hot Water in China

Established in 1995 in Dezhou City in Shandong Province, Himin Solar Energy Group is China's largest solar water heater manufacturer. The group manufactures more than 2 million square meters of collector area annually, equivalent to the combined production in the European Union and more than twice that in North America. Himin Group specializes in solar technology products including solar water heaters, vacuum tubes, solar panels, and solar lights for outdoor lighting.

Himin Group has contributed significantly to the development of solar water heaters in China. When the company was founded, solar energy was still a novel concept in the country. To cultivate the market and nurture potential consumers, Himin initiated a series of publicity campaigns. It published a periodical on solar energy in 1996 and has since disseminated roughly 100 million copies. In 1997, the company organized the "5,000-Kilometer Journey for Solar Energy," dispatching dozens of vehicles nationwide to lecture, consult, and disseminate materials on solar energy. Himin's outreach fleet has since covered more than 80 million kilometers. Himin has also organized environmental protection activities nationwide to promote solar energy.

Himin Group is dedicated to the high quality of its products. In October 1997, to better control quality, the company established a professional testing center that evaluates more than 1,000 items ranging from raw materials to components and finished products.

Source: See Endnote 90 for this section.

leader in both technological advancement and production of vacuum-tube solar heating systems, with annual output exceeding 16 million square meters.⁹¹ These systems are widely applied domestically and are also being exported to Asia, Europe, and Africa. Chinese manufacturers now have a remarkable 90 percent of the global market for these products.⁹²

Biomass

Biomass has been an important energy source in China for many thousands of years. Today, potential feedstocks for biomass energy include crop and forestry residues, household and other organic wastes, oilseed plants, and dedicated energy crops.

Each year, China generates roughly 150 million tce of crop residue (straw stalk) and 200 million tce of forest residues, both of which can be processed into fuel for biomass power.⁹³ The country could also potentially produce 50

million tons of liquid biofuel annually on oil-seed and energy crop plantations, cultivating feedstocks such as *Jatropha curcas*, rapeseed, *Ricinus communis*, lacquer tree, Chinese gold-thread tree, and sweet sorghum.⁹⁴ In addition, China could produce nearly 80 billion cubic meters (57 million tce) of biogas—primarily methane—using wastewater from industry and from livestock and poultry farms.⁹⁵

From a technical perspective, China's total annual biomass resources are 500 million tce, although actual consumption today is approximately 250 million tce, used primarily for traditional fuel.⁹⁶ An estimated 220 million tce of biomass energy is available to be used for rural household energy purposes; however, actual rural consumption is considerably less.⁹⁷ An estimated 90 percent of rural families currently use improved biomass stoves, which are more efficient for cooking than the direct burning of wood and crop wastes and other biomass sources.⁹⁸

The use of modern biomass energy in China dates back to the 1950s, when the country began exploring the application of household-scale biogas digesters in rural areas. Key areas of development today are biogas, biomass power, and liquid biofuels. The major uses of biomass in China are for heat and power generation, rather than for biofuel production as in Europe and the United States.

Chinese biogas technology is well advanced. By the end of 2008, the country was home to some 32 million rural household biogas digesters, 140,000 biogas digesters on wastewater purification pools, and more than 28,300 biogas projects on livestock and poultry farms and industrial wastewater treatment sites.⁹⁹ Annual biogas (methane) production was roughly 10 billion cubic meters, providing quality cooking and heating fuel for some 80 million rural residents.¹⁰⁰

Other biomass energy applications are still in the early stages of development. Although China has mastered the technologies of producing biomass pellets and generating biomass power from farming, forestry, and municipal wastes, these have not yet reached commercialization. However, venture capital

Renewable Energy in China

firms have begun seeking out viable biomass technology projects in the country, which may speed industrialization of these applications nationwide.¹⁰¹

In 2006, the installed capacity of biomass power in China was roughly 2.2 GW, including 1.7 GW from bagasse (stalk residue), 400 MW from municipal waste, and 50 MW from rice hulls, as well as contributions from several small biomass gasification demonstration projects.¹⁰² By the end of 2008, China had just over 3 GW of biomass power in operation.¹⁰³ However, the scale of development and use remains small, and the country faces difficulties in reaching its biomass power capacity targets of 5,000 MW for 2010 and 30 GW for 2020.¹⁰⁴ The main challenge for domestic biomass development is feedstock collection.

Because biofuels are considered a potential substitute for oil, China has introduced incentive schemes to stimulate biofuel R&D, hoping to close the gap between petroleum supply and demand. However, in 2007, the government restricted production of biofuel from food feedstocks, and Chinese ethanol development has since slowed. The production capacity of ethanol and biodiesel are projected to reach 2 million tons and 200,000 tons, respectively, by 2010.¹⁰⁵

Geothermal Energy

China's potential for geothermal power development is limited, and the known resources for this exist mainly in Tibet. Most regions of the country, however, have the potential to tap geothermal energy for heating purposes, and development in this area is rapid. China's recoverable geothermal reserve is an estimated 463 billion tce, nearly 8 percent of the global total.¹⁰⁶

Geothermal power has undergone three decades of development in China. By the end of 2009, the country's total geothermal installed capacity reached 9 GW, with most of this located in Tibet.¹⁰⁷ Globally, China ranks second in installations after the United States, and first in annual geothermal energy produc-

tion (21 TWh).¹⁰⁸ The country has gradually developed aquifer thermal energy storage technologies as well as cascade utilization (waste heat utilization) of its geothermal resources.¹⁰⁹

Tianjin City in northeastern China, for example, uses some 25 million cubic meters of geothermal water annually. If this water, at 40 degrees Celsius, were reduced to 10 degrees Celsius before being discharged using heat pump technology, this 25 million cubic meters of geothermal water would produce 300,000 kW of renewable energy, expanding the heating area to a maximum of 100 million square meters.¹¹⁰

China is experiencing 10 percent annual growth in geothermal applications in space heating, hot water, and farming.¹¹¹ Geothermal energy currently provides space heating over some 30 million square meters and supplies 600,000 families with hot water.¹¹² At present, residential heating accounts for 18 percent of domestic geothermal use; additional uses include medical care and bath and tourism resorts (65 percent), greenhouse cultivation and aquaculture (9 percent), with irrigation and industrial production accounting for most of the remainder.¹¹³

Ocean Energy

With more than 18,000 kilometers of coastline, China and its nearby islands are rich in ocean energy resources that have not been sufficiently tapped. Development of ocean energy, such as tidal and wave power, is currently in the pilot and demonstration stages in the country.

According to estimates, some 190 tidal power plant sites could be developed to achieve more than 500 kW installed capacity. However, these resources are unevenly distributed, with some 61 percent in Zhejiang province, 22 percent in Fujian province, 5 percent in Guangdong province, and 4 percent in Liaoning province.¹¹⁴ The country's total recoverable ocean energy resources could reach 1,000 GW.¹¹⁵ But due to technical barriers, these resources have not been actively tapped.

Prospects for 2020

The direction of the Chinese energy economy over the next decade will be shaped by many factors, including government policy decisions, the effectiveness of implementation at the national and provincial levels, and broader macro-economic trends within China and globally. It is therefore impossible to make any simple projection for energy efficiency or renewable energy in China; however, it is useful to consider potential scenarios and the factors that will influence them.

The dramatic acceleration of Chinese energy growth rates to over 10 percent per year—more than doubling between 2002 and 2009—has exceeded all predictions and has made forecasting very difficult. China's two-decade trend of steadily rising energy efficiency levels has been interrupted, and the country's consumption of coal has doubled in just nine years, while oil consumption tripled.¹ Figures for early 2010 suggest that the government's massive economic stimulus program has further accelerated energy demand in China's highly energy-consumptive industrial sector.

According to the Chinese Academy of Engineering, China's energy demand will reach a projected 3.5 billion tce in 2020, 4.2 billion tce in 2030, and 5.0 billion tce in 2050.² Those figures are likely underestimates given the country's recent high rates of economic growth, which have increased air pollution dramatically and made China the world's largest emitter of greenhouse gases decades ahead of most forecasts.

The surge in Chinese energy demand over the past decade has temporarily overshadowed the impressive advances in the nation's energy

efficiency and renewable energy policies. These include important reforms to energy pricing and other legislation. Over the coming decade, there will be time for China's new energy policies to take their full effect; at the same time, macro-economic trends may shift due to deliberate government decisions or external economic changes. Buildings and transport, for example, still claim an unusually small fraction of Chinese energy consumption compared with other countries, and the inevitable growth in these sectors' energy needs in the coming years will have a big impact on energy efficiency and renewable energy trends.

After initially falling short of the 4 percent annual rate of advance in national energy efficiency called for in the 11th Five-Year Plan (2006–10), the pace of advance has recently increased, surpassing the goals laid out in the Medium and Long-Term Energy Conservation Plan and putting China within reach of meeting the five-year goal of reducing national energy intensity 20 percent by 2010.³ It is fair to say that no other national government gives as much policy prominence or political visibility to a national energy intensity target as China. In 2010, Premier Wen Jiabao expressed frustration with energy efficiency improvements to date and said he would use an “iron hand” to accelerate those efforts.⁴

As government planners work to finalize China's 12th Five-Year Plan (2011–15), all indications are that it too will include a national energy intensity target, which will in turn be used to spur additional policy changes at the national and provincial levels. It remains to be seen what that target will be, but President Hu Jintao foreshadowed the goal when, shortly

Prospects for 2020

before the Copenhagen climate summit of December 2009, he announced that China would unilaterally reduce its carbon emissions per unit of economic output 40–45 percent by 2020.⁵ With continued policy advances, further reform of energy prices, and favorable macro-economic trends, energy intensity improvements could well exceed those during the previous five-year period, with further acceleration in the years leading up to 2020.

Although China is working hard to meet targets for energy efficiency in the industrial sector, a gap remains.⁶ The country is still burdened with a large number of energy-intensive factories, many of which benefit from subsidized energy prices and other forms of local government support. In August 2010, the Ministry of Industry and Information Technology announced plans to close 2,087 inefficient steel mills, cement plants, and paper mills by year's end.⁷ While this seems like a heavy-handed way to improve energy efficiency, it may be the only choice given the incentives that have kept many of these plants operating longer than they should.

In the building sector, construction is expected to continue at a rapid pace in China. Forecasts to 2020 indicate that domestic construction growth will remain strong and that the country will lead the global market by 2018.⁸ By 2020, China's construction market is projected to be worth nearly \$2.5 trillion and to represent more than 19 percent of global construction output.⁹ Between 2000 and 2020, China is projected to add the equivalent of two times the office space currently in the United States.¹⁰ Rising demand for air conditioners and other appliances in both workplaces and homes is expected to increase energy demand significantly, leading to a tripling of total building energy consumption by 2020 even with improvements in efficiency.¹¹

Rapid urbanization will also contribute to rising building demand and related energy usage, as China's population shifts from under 40 percent urban in 2005 to an estimated 60 percent urban by 2030.¹² Increased urbanization is typically associated with higher residential energy usage including space heating and

cooling, water heating, and appliance use.¹³ This surge in energy demand could be mitigated substantially if China continues to tighten and strictly enforce its energy efficiency standards for buildings, lighting, and appliances—particularly for heating, ventilation, and cooling.



Ongoing construction in Shanghai.

Energy consumption in transportation will almost certainly rise dramatically in the coming decade. During the last decade, China worked hard to build the world's largest automobile industry virtually from scratch, yet today, national automobile ownership is still only 3 percent of the European level.¹⁴ China's government has recognized the energy-security dangers of soaring oil dependence and now has some of the strictest fuel-economy standards in the world, as well as ambitious national programs to build highly efficient electric cars and a high-speed rail network, both of which will advance energy productivity and reduce the rate of energy growth. However, these initiatives require further strengthening and will need to be bolstered with higher energy prices and other financial incentives if China is to prevent its security and environmental goals from being undermined by an oil-thirsty transportation sector in the decade ahead.

Although China has considerable potential to increase energy efficiency in all sectors of the economy, it faces a variety of challenges,

Prospects for 2020

many of which are similar to those in other countries. These include:

- **Lack of prioritization of energy conservation by businesses.** Many Chinese businesses in the early stages of development are focused more on expanding their scale and market share than on energy conservation, resulting in less attention to and investment in improving the efficiency of resource use.
- **Lack of awareness among local governments about the value of efficiency.** Some local governments focus more on short-term economic benefits than on resource conservation, resulting in the prioritization of investments in highly energy consumptive projects in all sectors.
- **Incomplete laws, regulations, and economic incentive policies.** Despite implementation of China's national Energy Conservation Law, many of the supporting laws, regulations, and management systems are not yet complete. For example, the government has not enacted the Regulations on Energy Conservation Assessment and Review for Fixed Asset Investment Projects, a mandate that prevents energy conservation from serving as a barrier to entry for project construction. Moreover, energy prices in China do not reflect the cost of environmental externalities, and resource taxes remain low. With low prices, businesses have little incentive to invest in energy savings. Meanwhile, policies that encourage the diffusion of more efficient, energy-saving products remain narrow in their coverage.
- **Lagging capacity building.** China lacks both a sound energy efficiency standard and effective energy metering equipment for businesses. And due to a lack of uniform methodologies, basic statistical work on the energy consumption of buildings and transportation is insufficient.

The prospects for renewable energy in China over the next decade are a bit clearer than those for energy efficiency, given the country's defined targets and strong promotion of renewables in recent years. However, the renewables sector is starting from a small base, and its capacity to significantly reduce China's heavy dependence on coal by 2020 is

therefore limited. For example, even though China's remarkable 13.8 GW of newly installed wind generating capacity in 2009 would have made wind the leading source of power generation in most other countries, in China it is still dwarfed by the roughly 48 GW growth in coal-fired power capacity that year.¹⁵

Developments in early 2010 appear to signal a strong push by the Chinese government to make renewable energy a major contributor to the nation's energy economy. At a time when many other countries have found it hard to finance renewable energy projects, the state-run China Development Bank provided \$23 billion in loans to Chinese renewable energy companies in the first half of 2010. Most of this was provided in the form of massive loans and credit lines to the country's largest solar and wind companies. Provincial loans and subsidies for land purchases and construction ensure that the country's renewable energy production capacity will continue to surge in the next two years.¹⁶

In order to maintain these robust, world-leading growth rates and provide a market for the expanded production of renewable energy equipment, China's national and provincial governments will need to further reform energy laws and close the economic advantage that coal still holds over most renewables. Making the transition to renewables will require a full accounting of the environmental costs of fossil fuel usage in energy prices. In the meantime, China must continue to implement supporting policies such as R&D, subsidies for market creation, and infrastructure improvements, particularly of the electricity grids, as well as to take full advantage of emerging technologies.

China's domestic energy needs are expected to peak and gradually decline between 2030 and 2050.¹⁷ The gap between conventional energy supply and demand (including fossil fuels, large hydropower, and nuclear) is projected to reach 18 percent in 2020, 20 percent in 2030, and 30 percent in 2050.¹⁸ Renewable energy beyond large hydropower will be needed to fill in this gap, which would otherwise be met with imported fossil fuels that would make China's energy system even less

Prospects for 2020

sustainable and more destructive to human health and the environment.

According to 2007 estimates by the Chinese Academy of Engineering, renewables are projected to be a viable energy alternative—representing 5–10 percent of total energy consumption (16–20 percent if hydropower is included)—by around 2020.¹⁹ (See Table 16.) Under the Academy’s “intermediate” scenario, China’s renewable energy use will increase from the current 250 tce in 2008 to a projected 620 million tce in 2020, with hydropower

accounting for 58 percent, biomass 19 percent, solar 14 percent, wind 8 percent, and other renewable sources 1 percent.²⁰ Fossil fuels will still dominate the nation’s energy mix, but renewable energy will account for a growing share of supply and gradually replace the increase in domestic energy demand. Looking toward mid-century, renewable energy (including hydro) will account for 28–32 percent of China’s energy mix by 2030 and 30–45 percent by 2050, depending on the scenario.²¹ Achieving these targets will require close

Table 16. Renewable Energy Development in China: Three Scenarios for 2020

| Category | Base Year (2005) | 2020 | | |
|-------------------------------------|---------------------|-------------------------------|--------------------------|-------------------|
| | | Business-as-Usual Scenario | Intermediate Scenario | Ideal Scenario |
| Total Supply | | (million tce) | | |
| Power Generation | 162.4 | 399.5 | 441.2 | 471.7 |
| Hydro | 158.5 | 355.7 | 355.7 | 355.7 |
| Wind | 1.2 | 19.7 | 52.4 | 65.5 |
| Solar PV | 0.0 | 0.7 | 1.9 | 3.7 |
| Biomass | 2.7 | 23.4 | 31.2 | 46.8 |
| Heating/Gas | 24.0 | 119.3 | 143.6 | 174.3 |
| Gas | 7.9 | 34.6 | 34.6 | 34.6 |
| Solar Hot Water | 14.1 | 67.3 | 84.5 | 108.0 |
| Geothermal | 2.1 | 10.3 | 10.3 | 10.3 |
| Solid Particle | 0.0 | 7.1 | 14.3 | 21.4 |
| Transport Fuel (biofuels) | 1.1 | 23.2 | 32.6 | 42.6 |
| Total Supply | 187.5 | 542.0 | 617.4 | 688.6 |
| Share | | (percent) | | |
| Power Generation | 86.6 | 73.7 | 71.5 | 68.5 |
| Hydro | 84.5 | 65.6 | 57.6 | 51.7 |
| Wind | 0.6 | 3.6 | 8.5 | 9.5 |
| Solar PV | 0.0 | 0.1 | 0.3 | 0.5 |
| Biomass | 1.5 | 4.3 | 5.1 | 6.8 |
| Heating/Gas | 12.8 | 22.0 | 23.3 | 25.3 |
| Gas | 4.2 | 6.4 | 5.6 | 5.0 |
| Solar Hot Water | 7.5 | 12.4 | 13.7 | 15.7 |
| Geothermal | 1.1 | 1.9 | 1.7 | 1.5 |
| Solid Particle | 0.0 | 1.3 | 2.3 | 3.1 |
| Transport Fuel | 0.6 | 4.3 | 5.3 | 6.2 |
| Share of Total Energy Demand | | (percent) | | |
| Excluding Hydro | 1.2 | 5.3 | 7.5 | 9.5 |
| Including Hydro | 7.6 | 15.5 | 17.6 | 19.7 |

Source: See Endnote 19 for this section.

Prospects for 2020

attention to China's renewable energy policy framework. Although this framework is nearing completion, relevant policies still must be adapted to specific situations due to varying resource endowments, levels of wealth, and technical and administrative capacities among regions. Some implementation rules will need to be clarified, and some policies must be implemented more thoroughly.

A major obstacle for renewable energy distribution is grid access. Although utility companies are willing (and required under law) to accept electricity generated from renewable sources, they face outdated and inadequate grid infrastructure. Inner Mongolia, for example, is China's largest wind energy base, with a total installed capacity of 5 GW, or about a third of the national total.²² However, more than one-third of all electricity generated from wind in the region must be abandoned due to limited transmission capacity.²³

Adding to the difficulty of expanding grid access is the fact that China's most abundant wind sources often lie in economically less-developed provinces, such as the northeastern triple provinces (Hei Long Jiang, Ji Lin, and Liao Ning) and Inner Mongolia. Here, local grid companies simply lack the financial capacity to boost the grid infrastructure to match installed wind capacity. Moreover, to maintain a constant winter heat supply in these colder regions, local grids must give priority to coal-fired power plants, which further limits wind energy's access to the grid.

To overcome these barriers, China needs to invest heavily in grid infrastructure, in particular super-high-voltage transmission lines. Meanwhile, the central government needs to improve its oversight and management of local governments' renewable energy initiatives to ensure that investment in electricity grids and other infrastructure is sufficient to support the rapid growth in renewable energy in the years ahead.

Several rules need further clarification as well. Article 14 of the revised Renewable Energy Law, for example, requires grid companies to enter into grid-connection agreements with renewable power-generation companies

that have legally obtained licenses; to buy all of the grid-connected power produced from renewable energy; and to provide grid-connection service for this power.²⁴ However, the article omits several key details:

- There is no specific target for electricity generated from renewables in proportion to total electricity generated, and none of the stakeholders (local governments, grid companies, power utilities) are clearly identified as having responsibility for achieving this goal;
- Buying all of the grid-connected power produced from renewable energy is unrealistic. In extreme weather conditions, it is often necessary to cease electricity generation from wind turbines temporarily;
- In some cases, the renewables target is lower than actual development. For example, the Mid to Long-Term Plan for Renewable Energy sets a target for wind energy installations of 5 GW by 2010; however, actual installations had already reached 25 GW in 2009.²⁵
- For both wind energy and solar PV, the bidding price offered by grids remains too low to create a reasonable fixed price.

More support is needed in R&D endeavors as well. China lacks uniform industry standards, and its renewable energy product testing certification system is flawed, preventing effective monitoring and control of product quality. Existing certification organizations lack independence and are either owned by or affiliated with the companies that are manufacturing the testing devices. Moreover, most of the testing and certifying organizations are new and lack both equipment and expertise. The absence of certification systems that are linked to existing international testing systems may increase transaction costs as well, as products may need to be re-certified under the international systems.

Meanwhile, China's national renewable energy targets and subsidy systems have led to the pursuit of installed capacity over actual power generation. Although precise data are not available, a significant amount of the installed renewables capacity has never been used. This is because government subsidies and the metrics used to monitor progress focus

Prospects for 2020

mainly on installed capacity rather than on the actual electricity transmitted to the grid. China's lagging national grid capacity contributes to this discrepancy as well.

At the same time, reform of the country's value-added tax has dampened enthusiasm among local governments for developing renewable energy projects. Most of the equipment needed for these projects comes from other regions, and taxation rules state that the value-added tax for these items must be deducted from the local tax. Because of the decline in income that could result, local governments have had less incentive to pursue renewables projects, leading to increased protectionism.

Despite the challenges ahead, there is good reason to be optimistic about the future of

energy efficiency and renewable energy in China. The country has demonstrated its ability to adapt quickly to changing realities and to correct its strategies and policies based on experience. Over the past five years, China's progress in advancing new energy technologies has exceeded most forecasts and boosted the country to a world-leading position that is the envy of many nations.

What is required now is to take these efforts to the large scale needed to address China's economic, security, and environmental challenges. This will require accelerating the pace of innovation in both the government and private sector and going beyond successful adaptation of other countries' experiences to breaking new ground in a uniquely Chinese way.

The Way Forward

As the world's largest developing country, China has significant domestic market potential for renewable energy and energy efficiency. The development of green sectors in China—in industry, transportation, and elsewhere—will push transformation of the global economy, benefiting not just China but the world.

China's emphasis on energy efficiency and renewables will become even more important as the population and income levels grow, causing domestic energy consumption to surge. Policy implementation will be a critical factor affecting the outcome. Another important issue will be how to prevent the potential disconnect in incentives and priorities between a national government that sets critical policies and the local governments that implement them.

To encourage greater energy efficiency and the development of renewable energy in China, policymakers and other stakeholders should consider the following recommendations:

1. Give equal weight to both the scale and quality of renewable energy development.

The early development of renewable energy in China has benefited greatly from preferential policies. As the pace of development has accelerated, however, many industries in both the energy efficiency and renewable energy sectors have experienced blind expansion. Rather than focusing its actions on merely attracting investment and expanding scale, the government should pay equal attention to the quality of development. One important step is to formulate effective product quality standards and to establish a national testing and certification system for renewable energy and energy-saving

products. Although China is pursuing some pilot projects, there is a need to establish nationwide standards and to improve the current certification system.

2. Enact long-term, stable fiscal policies.

To finance renewable energy development, the government should establish additional energy efficiency and renewables funds, raising support through such sources as a special earmarked fund, an energy efficiency levy, renewable power surplus fees, and a “special tax” on fossil fuel consumption (essentially a carbon tax levied on fossil energy consumption). It should also reform the pricing and taxation structure for both energy resources generally and the renewable energy sector specifically, to reflect their full environmental costs. This will help create a “win-win-win” situation for manufacturers, sellers, and users of energy efficient and renewable energy equipment.

3. Allow for sufficient market competition.

China should establish a sound market mechanism for energy efficiency and renewable energy to encourage industry concentration and consolidation and to improve economies of scale. This would help prevent large manufacturers from dominating the market and nurture small firms that can serve less-profitable market segments, allowing for a more diverse and healthy market. China should also increase transparency in the national bidding process, creating a fair environment for competition to enable the introduction of high-quality products and to encourage renewable energy development. The government should continue to encourage contract

The Way Forward

energy management, such as through energy service companies, to accelerate development of the energy-saving service sector.

4. Direct more effort to the basic work of resource assessment and statistics. China currently lacks reliable data on both its renewable energy resources and its overall energy consumption—information that is indispensable for further developing renewables and improving energy efficiency. In particular, the country should carry out a thorough assessment of its solar and wind resources to provide a basis for national planning and to improve on past assessments. It should also enhance statistical work on energy consumption and energy efficiency in buildings, transportation, and key industrial sectors to provide a basis for conservation planning. Special focus should be given to the tracking and analysis of energy efficiency in power-consuming equipment.

5. Support creation of a large talent pool for development of the renewable energy and energy efficiency sectors. At present, China's talents do not meet the demand from its industries. A sound, need-based mechanism is needed to nurture talent in a variety of professions, including energy auditors and energy-saving managers in companies, financial analysts for energy saving and renewable energy, bank staff for energy saving and renewable energy loans, skilled technical workers, R&D and innovation personnel, and strategic decision makers. A sound system is also needed to nurture and introduce talent through training, exchanges, and university education to ease the current constraints on the renewable energy and energy efficiency sectors.

As global climate change attracts increasing attention, the twin solutions of improving energy efficiency and developing renewable energy sources are receiving unprecedented attention worldwide. Tackling climate change is a global undertaking that cannot be solved by a few countries alone. As effective solutions, renewable energy and energy efficiency require concerted efforts from all players, working both alone and in partnership. As countries strengthen the exchange of information and technology and break technical and trade barriers, this will help bring more capital and advanced technology to China. By embracing its huge potential for technology transfer and diffusion, the country can more rapidly realize its energy conservation and emission reduction targets and effectively address the climate threat.

Already, China's active improvement of energy efficiency and development of renewable energy are having a significant and far-reaching impact on global sustainable development. Through its efforts to conserve energy and reduce emissions, China is improving the living environment of its own people. It is also creating the world's biggest market for energy efficiency and renewable energy industries, contributing to the recovery of the global economy after a severe financial crisis.

Over the long term, China's development path will have a significant impact on global economic trends. The country is now actively exploring a low-carbon development path that hinges on energy efficiency and renewable energy. If a low-carbon economy can be developed and extended in China, it will set a model for other countries to follow.

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China has adopted a host of new policies and regulations aimed at encouraging energy efficiency and expanding renewable energy deployment. Taking lessons from its own experience as well as the experiences of countries around the world, China has built its clean energy sector in synergy with its unique economic system and institutions of governance. Around the world, governments and industries now find themselves struggling to keep up with the new pacesetter in global clean energy development.

This report provides an independent review of China's achievements in promoting renewable energy and reducing the energy intensity of its economy. The goal of the report is to facilitate international cooperation that can help China further improve its energy efficiency and deploy renewables more widely. If a low-carbon economy can be developed and extended in China, it will set an important model for other countries to follow.