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# Challenges Ahead

An artistic illustration of a man in a blue suit walking away from the viewer on a blue road that tapers into the distance. The road has a white dashed line down the center. The sky is a warm, hazy orange with soft, white clouds. A large, bright yellow sun is positioned at the horizon, directly in the center of the road's path. The overall mood is one of forward-looking challenge and hope.



# Current Status and Future Prospects for Chinese Energy

*By Yunhe Hou and Jin Zhong*

THE CHINESE GOVERNMENT AND POWER INDUSTRY FACE important challenges. In the past three decades, China has been experiencing a rapid growth in its economy, and energy consumption has increased dramatically as well. Although per capita energy consumption is lower than that of most developed countries due to the large population of China, total energy consumption is high. In addition, energy resources, fossil fuels, and renewable energy resources are geographically far from load centers. Furthermore, because China wants to contribute to the global effort to combat climate change, it must implement a carbon reduction target while pursuing economic growth and ensuring energy security for 1.3 billion people.

## Energy Consumption in China

China is experiencing remarkable energy consumption growth along with its 10% average annual gross domestic product (GDP) growth rate. According to the World Bank, total Chinese energy consumption in 1990 was about 863 million tons of oil equivalent (mtoe), followed by two slight declines in 1998 and 2000, respectively, as shown in Figure 1. In 2009, energy consumption reached 2,257 mtoe, which is 2.6 times higher than the 1990 figures. From 1990 to 2009, the average annual growth rate was about 5.29%. A balance was maintained during the 1990–2002 period if we compare energy consumption with energy production. But the recent rapid growth in energy consumption has resulted in an energy shortage, as shown in Figure 1. The energy shortage has to be balanced by imported energy.

Coal plays a critical role as an energy source in China. As of 2011, total explored coal reserves are 1.12 trillion metric tons (t), which represents the third-largest coal reserve in the world. The explored reserves for renewable energy resources are about 6,190 billion kWh. China has limited oil and gas resources, however. The total amount of available oil resources in China is about 3.14 billion t, while the total amount of available gas resources in China is 3.9 trillion m<sup>3</sup>. China's per capita coal and hydropower resources are about one-half of the world's average level. The per capita amount of oil and gas

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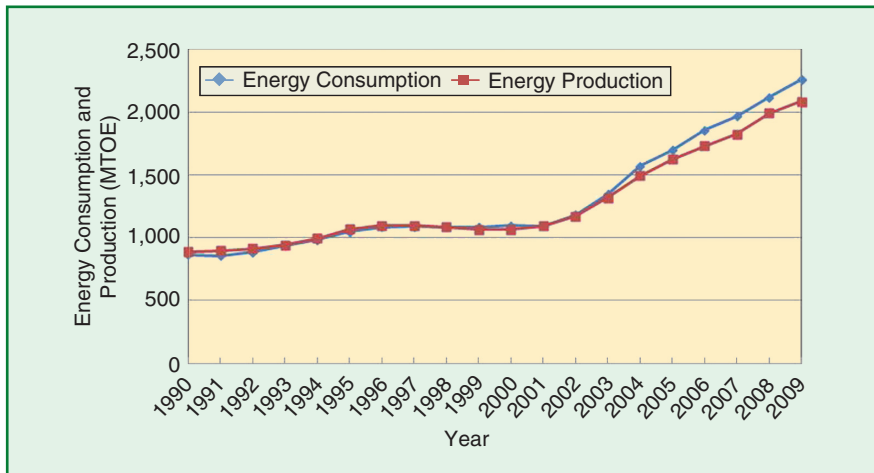


figure 1. China's energy consumption and production, 1990–2009.

table 1. Per capita energy consumption (kg of oil equivalent per capita).				
	1990	2000	2005	2009
China	760	867	1,301	1,695
European Union	3,461	3,487	3,613	3,307
Japan	3,556	4,090	4,074	3,700
United States	7,672	8,057	7,841	7,045

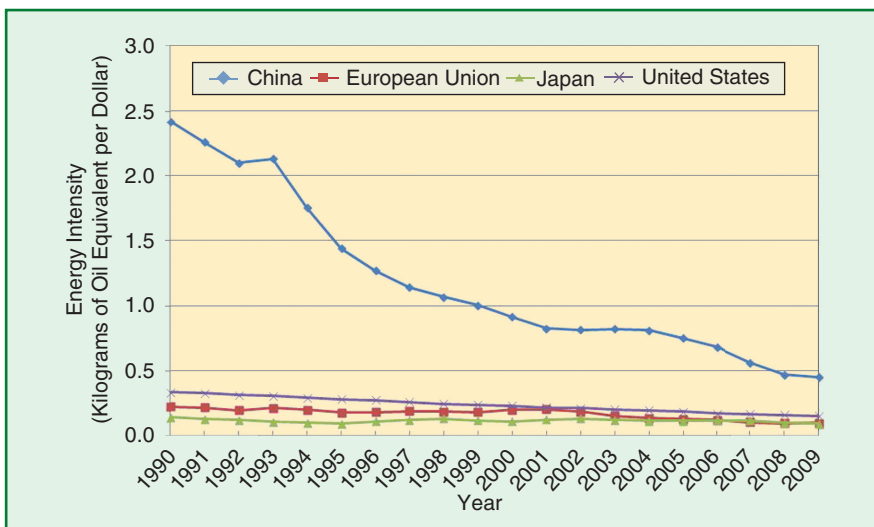


figure 2. Chinese energy intensity, in kg oil equivalent per U.S. dollar.

resources, however, is only about 1/15 of the world's average level.

Although total energy consumption in China is very large in order to support the country's impressive economic development, because of its huge population, the per capita energy consumption is still lower than that in other developed areas, as shown in Table. 1.

Energy efficiency has been the major priority with respect to the increase in Chinese energy consumption. In order to take into account the relationship between energy consumption and economic growth, energy

intensity, defined as energy consumption per dollar of GDP, is shown in Figure 2. As illustrated, China's energy intensity declined steadily during the past two decades, from 2.4 kg of oil equivalent per dollar in 1990 to 0.45 kg in 2009, a reduction of 81%. This progress was probably due to the energy efficiency improvement. But compared with developed areas, China still needs more energy to produce one unit of GDP. Take 2009 as an example: to generate one U.S. dollar of GDP, China needs 0.45 unit of energy, while U.S. needs only 0.15 unit, the European Union needs only 0.1 unit, and Japan needs only 0.09 unit.

## China's Major Energy Challenges

### Significant Energy Demand Increase

China's economy will continue growing at a sustained and rapid rate in the coming decades. This trend is a result of China's three-step development strategy. The country's average annual GDP growth rate from 2005 to 2050 is expected to be 6.4%. But China's significant economic growth also results in excessive consumption of resources and severe

In addition to China's impressive total energy consumption increase, the unequal distribution of energy production and consumption exacerbates the country's challenges.

environmental pollution. The primary energy demand forecast curves of the National Development and Reform Commission (NDRC) are based on three scenarios: an energy savings scenario, a low-carbon scenario, and an enhanced low-carbon scenario. These scenarios are all upward-sloping along the time line, as shown in Figure 3. Though the forecasts include the effects of energy savings and emission reduction, primary energy consumption, including coal, petroleum, natural gas, and other resources, will nevertheless expand to 5,022 million t coal equivalent (tce) in 2050, 2.5 times the 2005 figures.

Final energy consumption will shift continually with the urbanization process and industry development in China, based on guidelines contained in existing policies. China's urban population share leaped from 26.4% in 1990 to 46.6% in 2010, and it is predicted that it will exceed 70% by 2050. Urban residents prefer their own transportation vehicles and want their homes furnished with modern household appliances. Many new houses need to be built to satisfy the new housing demand. In addition, many more household appliances such as refrigerators, air conditioners, water heaters, and so on will be needed. According to the government, the number of privately owned cars has expanded from 1.1 million in 1990 to 85 million in 2010, and their rate of increase will remain high from now on. According to NDRC reports, the share of energy demand for transportation purposes will leap from 11.1% in 2005 to 22.6% 2050, with an average annual rate of increase of 4%. It is expected that the urban-

ization process will lead to a large amount of energy consumption for construction and transportation purposes.

In addition to China's impressive total energy consumption increase, the unequal distribution of energy production and consumption exacerbates the country's challenges. Using electric energy as an example, China's major electric energy resources are located in the western and northern parts of the country, while the load centers are in the north, east, and south. Table 2 shows generation and demand for different areas in China during 2010.

Energy transportation is a huge problem. On one hand, coal is the major energy source in China, with most reserves

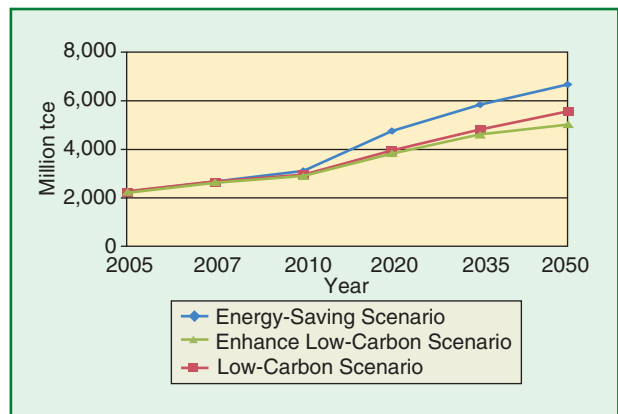


figure 3. Primary energy demand forecast for China under three scenarios, 2005–2050.

table 2. Distribution of China's installed capacity and load level in 2010. Some low-capacity renewable energy generation is not included in total installed capacity.

		North	Northeast	Northwest	East	Central	South
Installed capacity	Total (MW)*	217,360	85,020	87,380	203,880	199,650	168,900
	Types						
	Thermal	197,120	68,960	60,150	172,090	113,380	94,930
	Hydro	6,400	6,850	22,860	23,630	85,990	67,660
	Nuclear	0	0	0	5,790	0	5,030
	Wind	13,820	9,210	4,270	2,250	270	1,250
Load characteristics	Maximum load (MW)	147,290	43,180	42,550	166,060	111,180	104,360
	Annual load factor	0.886	0.895	0.909	0.894	0.871	0.887
	Annual maximum load utilization hours (hour)	6,516	6,631	7,189	5,866	6,009	6,111
	Daily minimum load factor	0.771	0.796	0.830	0.776	0.739	0.774
Total installed capacity/maximum load		1.4757	1.9690	2.0536	1.2277	1.7957	1.6184

## Since coal continues to dominate the Chinese energy mix, thermal power plants are still a major feature of the generation landscape in China.

located in the north or northwest. Around one-half of all rail capacity is used for coal transportation. On the other hand, for electric power systems, long-distance transmission systems have to be built to deliver electric power from west to east and from north to south. In China, the State Grid Corporation of China (SGCC) and China Southern Power Grid Company (CSG) operate power grids. Ultrahigh-voltage (UHV) 1,000-kV ac and 800-kV dc, long-distance transmission systems are used for power transmission. According to the strategic plan, by 2015 SGCC will invest US\$75.5 billion to extend its UHV grid to 40,000 km. By 2020, the UHV network capacity will act as the backbone of the whole system, with 400 GW of clean energy sources integrated into the transmission network. By 2020, operational transmission losses are expected to be 5.7%, dropping from 6.6% in 2010. By the end of 2009, China had already spent US\$600 billion to upgrade its power grid.

### Energy Security

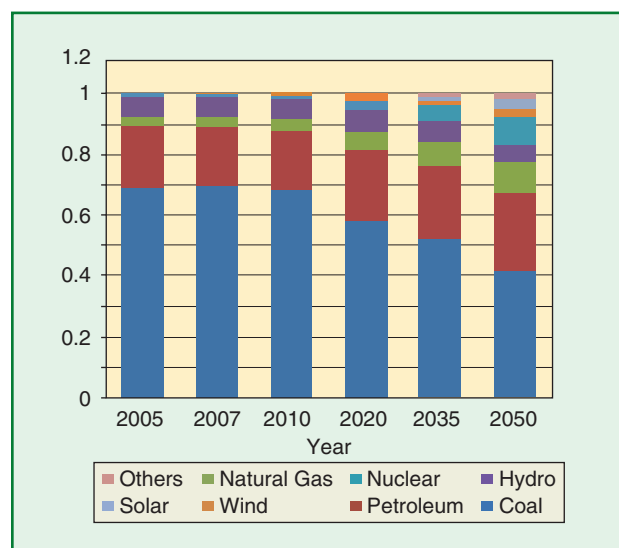
As described above, with the quick development of China's economy, its energy demand is increasing significantly while its fossil fuel reserves, including coal, oil, and natural gas, are limited. Coal is mainly used for power generation and heating. It is expected that the share of coal among the various generation sources will decline continually from 2005 to 2050, but coal will still account for around 40% of generation in 2050, as shown in Figure 4. Because of

the total energy consumption increase, the absolute value of coal demand will increase at an average annual rate of 0.93% from 2005 to 2050 and will reach nearly 3.9 billion t by 2050. This amount represents two-thirds of current global coal production. China's actual coal reserves are far smaller than this eventual demand.

As reported by NDRC's Energy Research Institute, oil demand will reach 770 million t in 2020, and this amount will increase to 1.25 billion t by 2050—nearly one-third of current world oil consumption. But according to multiple agencies' forecasting data, China's oil production will reach its peak of about 230 million t by 2020. It is probable that production in 2050 will not exceed 200 million t under any scenario. In contrast to oil, natural gas has great potential for development in China, considered not only from the viewpoint of total reserves but also with respect to construction capability for the future productivity of proven reserves. It is expected, therefore, that given projected demand curves, imports of oil and natural gas will reach 80% and 30%, respectively, by 2050. The high level of dependence on oil and natural gas imports in China will unavoidably decrease its ability to withstand international oil price volatility as it struggles to meet these challenges to the security of its the energy supply.

### Carbon Reduction

In addition to the challenges described above, reducing fossil fuel emissions to combat global warming is another important matter related to China's growing energy consumption. CO<sub>2</sub> emissions are generally adopted as a criterion for assessing a country's impact on climate change. In China, CO<sub>2</sub> emissions have increased continuously during the past two decades, especially after 2001 when the country's annual growth rate reached 12.83%. By contrast, in other developed areas like the United States, the European Union, and Japan, emissions remained at a steady level and even declined during some years. Looking at a measure that relates emissions to economic growth, China's carbon intensity, defined in terms of CO<sub>2</sub> emissions per thousand U.S. dollars and illustrated in Figure 5, declined fairly steadily from 1990 to 2009. As shown, there were two phases with clear drops in the curve, starting in 1993 and 2004, respectively. In the first stage, emissions probably declined due to the closure of some emission-intensive coal-fired plants in those years. In recent years, however, due to the rapid development of technologies and policy support for renewable energies, carbon intensity has again been decreasing



**figure 4.** Projected energy source structure in China through 2050.

## China, as a country under development, has made a bold commitment to creating a clean-energy economy.

gradually. But compared with other developed countries, the figures should be further reduced.

At the 2009 Copenhagen climate change summit, Chinese premier Wen Jiabao committed to reducing China's CO<sub>2</sub> emission per unit of GDP by 40–45% from its 2005 level by 2020. Furthermore, China will use nonfossil fuels for about 15% of its total energy by 2020.

In summary, to support its significant economic development, to secure its energy supply, and to achieve its carbon emission targets, China must overcome tremendous challenges.

### China on the Way

China, as a country under development, has made a bold commitment to creating a clean-energy economy. To fulfill this commitment, China must tackle its current unsustainable economic growth. At present, significant strategic planning and other efforts in this direction are under way. The rest of this article summarizes these efforts.

### Energy Resources Diversification

From 2005 to 2020, various targets are listed in every five-year plan (FYP), i.e., the 11th FYP (2006–2010), the 12th FYP (2011–2015), and the 13th FYP (2016–2020). In the 11th FYP, the Chinese government aimed to reduce its energy intensity by 20% as compared with the 2005 level, and this goal has been accomplished. In the coming 12th FYP, the target is to reduce energy intensity by 16% and reduce emission intensity by 17%. Total energy consumption is to be limited to less than 4.1 billion tce. The target for CO<sub>2</sub> emission is 8.46 billion t, which is 149% of the figure estimated for the United States over the same time horizon. The share of renewable energy in the total energy mix will be improved to more than 11.4%, with binding effect. In the 13th FYP, emission intensity is to be reduced by a further 16–17% of the 2005 level.

As for the energy industry, in the revised 2020 energy industry target, installed capacity will be increased from 793 GW (at the end of 2008) to 1,400–1,500 GW, with the clean and renewable energy share increased from 3% to around 18%, as shown in Figure 6.

In the long term—and due to the limited reserves of fossil fuels and the CO<sub>2</sub> emissions caused by fossil fuel usage—the share of renewable energy used to satisfy total energy demand will increase significantly. Figure 7 shows the planned installed capacity through 2050.

### Highly Centralized Renewables Integration

As a comparatively mature technology, wind generation has good economic performance and is considered to be a good choice for future large-scale renewable energy development. China has been pushing aggressively for the development of wind power. Its installed capacity in 2010 was more than 170% of the 2009 level, as shown in Figure 8. In late 2011,

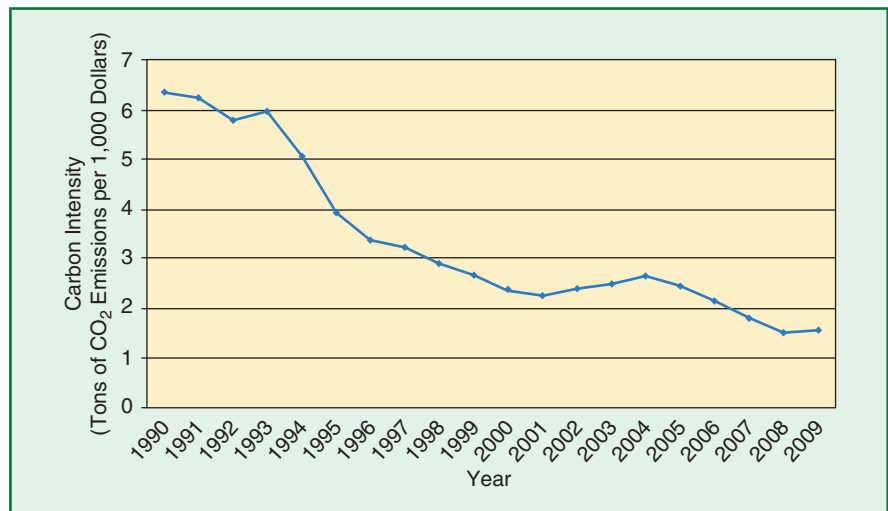


figure 5. Carbon intensity in China, 1990–2009.

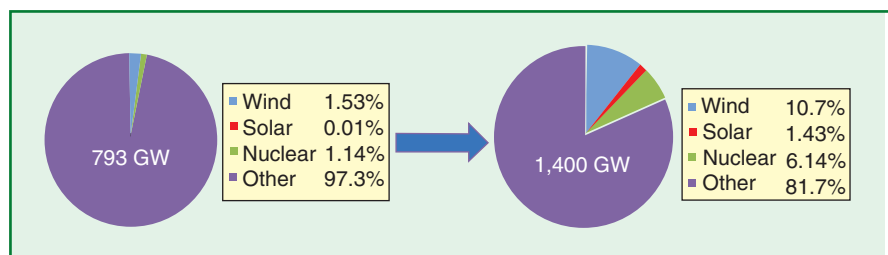
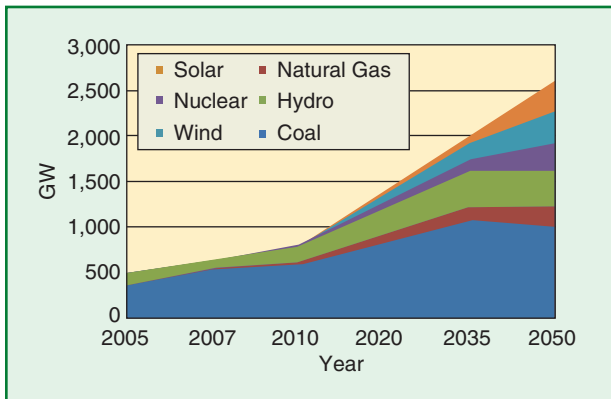
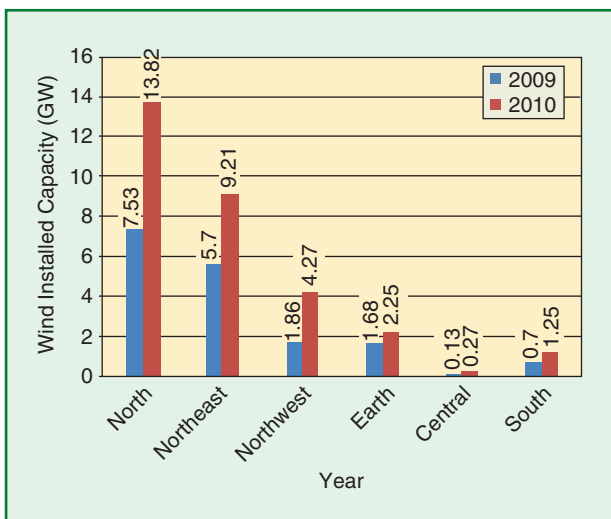


figure 6. Plan for growth of installed capacity in China, 2008–2020.



**figure 7.** Plan for growth of installed capacity in China, 2005–2050.



**figure 8.** Wind power installed capacity in 2009 and 2010 in various regions of China.

wind had more than 40 GW, the world's largest installed capacity, with a potential to reach 100–150 GW by 2020.

Due to the geographic distribution of its wind resources, China prefers a highly centralized method of utilizing wind power. Northeast, northwest, and north central China have plenty of wind energy resources. These areas are suitable for large-scale wind farm construction. Currently, eight large wind farms of more than 10 GW each have been planned in these regions.

Another renewable resource with good prospects for application and expansion in China is solar energy. Nowadays, methods of using solar energy include solar heating, solar photovoltaic power, solar thermal electricity generation, and solar architecture; these methods will all make great contributions to solving the most urgent energy issues China faces today. In 2008, China's installed solar capacity increased by about 50 MW, more than twice the 2007 increase. Yet this is still a relatively small amount. The government has announced plans to expand China's installed solar capacity to 1,800 MW by 2020.

This highly centralized method for renewable energy utilization can solve the energy resources distribution issue. The undefined and erratic characteristics of renewable sources, however, pose significant challenges for the planning and operation of the electric power system. In 2010, the average wind turbine operated at full load for only 2,082 hours. How to increase the utilization efficiency of renewables is still an open question in China.

### ***Nuclear Power: Vigorous and Steady Development***

Most of China's electricity is produced from fossil fuel and hydropower plants located far away from load centers. In this situation, nuclear power, which can be built close to demand, is able to play an important role. By 2011, China had 16 nuclear power reactors spread out over four separate sites, and 26 more nuclear reactors were under construction.

To meet its quickly developing load increase, China currently has one of the world's most ambitious nuclear power programs, designed to increase the percentage of China's electricity produced by nuclear power. China's National Nuclear Corporation has planned investments in nuclear power plants totaling \$75 billion by 2015 and about \$120 billion by 2020. In December 2011, the National Energy Administration stated that China would make nuclear energy the foundation of its power generation system within the next "10 to 20 years." As a result, the percentage of electricity produced by nuclear power will increase from the current 1% to 6% (at least 60 GW) in 2020 and 16% (200 GW) in 2030. Installed nuclear capacity is planned to reach 400 GW by 2050.

Under NDRC's strategic planning, China's nuclear expansion began with the Tenth FYP (2001–2005). It concentrated on the construction of eight nuclear reactors. The four units constructed in those five years were Ling Ao, Phase II (two units), in Guangdong Province, which was the first CPR-1000 plant (i.e., an improved Chinese pressurized water reactor); and Qinshan, Phase II (two units), in Zhejiang Province. Due to the time line extension, the last two projects, Sanmen (two units) in Zhejiang Province and Yangjiang (two units) in Guangdong Province, were transferred to the 11th FYP.

During the 11th FYP (2006–2010), more nuclear reactors were proposed, including reactors at Hongyanhe (four), Haiyang (two), Fuqing (two), and Taishan (two). The Sanmen and Yangjiang projects that ran over from the Tenth FYP were also started in this FYP. Two reactors at Lufeng and two at Hongshiding were delayed.

The 12th FYP (2011–2015) includes the construction of second-phase units for Tianwan, Hongyanhe, Sanmen, and Haiyang. The first phase of some inland sites, such as Taohuajiang, Xianning, and Pengze, will also be initiated. More than 16 provinces, regions, and municipalities have announced their intent to build nuclear power plants during the 12th FYP. The 12th five-year science and technology



plan, released in July 2011, calls for building a demonstration CAP1400 plant to be connected to the grid in 2015 and for a demonstration high-temperature reactor-pebble-bed module (HTR-PM) plant to begin its dry-run operation at Shidaowan before 2015. Its construction start-up was delayed after the Fukushima accident.

Safety is always a major concern with nuclear power, especially after the Fukushima Dai-ichi nuclear disaster in Japan that began on 16 March 2011. In response, China's State Council

began to suspend approvals for new nuclear power plants and started carrying out safety inspections in all nuclear projects that have been constructed and are under construction. The State Council also suspended construction of four units that had been previously approved and whose construction was begun in 2011.

Currently, a long-range, three-stage approval process has been implemented for nuclear power plants:

- 1) **Siting and feasibility study:** requires approval from NDRC
- 2) **Construction:** first requires a construction permit and later a fuel-loading permit from the National Nuclear Safety Administration (NNSA) under the China Atomic Energy Authority
- 3) **Commissioning:** leads to an NNSA operating permit.

Although the Chinese government has indicated that its nuclear energy strategy will continue, a rethinking of safety-related costs and further feedback from the public are urgently needed.

## Improvements to Current Technology

Since coal continues to dominate the Chinese energy mix, thermal power plants are still a major feature of the generation landscape in China. Various clean-energy technologies have been successfully applied to mitigate the CO<sub>2</sub> emission problem. Circulating fluidized bed boiler (CFBB) technology was widely applied during the 11th FYP period. At the end of 2009, the total installed CFBB capacity in China reached 72.87 GW, which was the largest in the world. By 2010, China had 33 operational 1,000-MW generation units, also number one in the world.

In addition, the following actions have guided China's efforts toward a cleaner and more efficient economy:

- 1) China has set up mandatory carbon and energy-intensity reduction targets at the national and provincial levels.
- 2) China has continued to close inefficient, outdated power plants and factories. In the 11th FYP period, approximately 76.825 GW's worth of small thermal power plants have been closed. Meanwhile, outdated

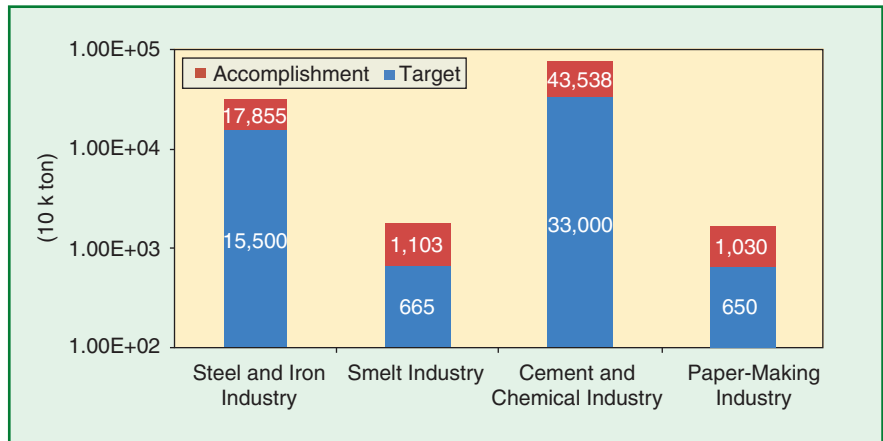


figure 9. Outdated production capacity closures in China, 2005–2010.

industry capacity has also been eliminated, as shown in Figure 9.

- 3) China has carried out its Top 1,000 Enterprises program, which aims to reduce the energy use of the 1,000 biggest industrial energy consumers. From 2005–2010, these top 1,000 industry consumers together accounted for a total reduction of 0.334 billion t of CO<sub>2</sub>

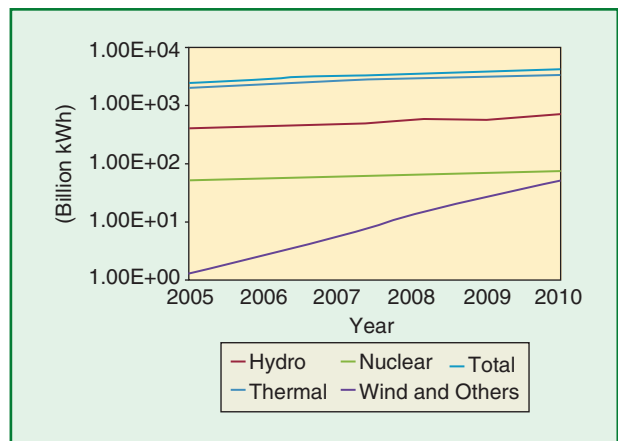


figure 10. Electric energy production in China, 2008–2010.

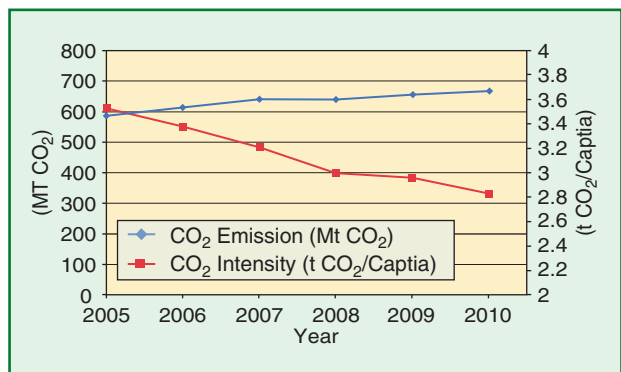


figure 11. Energy industry emissions and emission intensity in China, 2005–2010.

**table 3. Major technical challenges facing China's energy sector.**

Categories	Challenges	
Fossil fuel	Coal	<ul style="list-style-type: none"> <li>✓ Consumption of coal-related energy remains high.</li> <li>✓ Pollution problems are still far from fully solved.</li> <li>✓ Compared with the world's leading clean-coal systems, Chinese clean-coal technology still falls behind.</li> <li>✓ High-efficiency generation technology relies heavily on imports in the face of a shortfall in technological innovation and a qualified domestic equipment-manufacturing industry.</li> </ul>
	Oil	<ul style="list-style-type: none"> <li>✓ Chinese oil exploration and mining technology lags behind that of other leading countries.</li> <li>✓ The quality and structure of oil by-products are in dire need of improvement.</li> <li>✓ There is still great potential to improve production processes and reduce costs.</li> <li>✓ Alternative energy technologies are developing too slowly to meet clean-economy requirements.</li> </ul>
	Natural gas	<ul style="list-style-type: none"> <li>✓ Exploration technologies require further development and improvement.</li> </ul>
Electric energy	Electricity	<ul style="list-style-type: none"> <li>✓ Transmission losses remain high.</li> <li>✓ The security and stability of power grids need further improvement.</li> <li>✓ To accommodate a high percentage of renewable energy, R&amp;D on renewables integration and operation technology must be promoted.</li> <li>✓ It is an urgent requirement to develop advanced electric transportation with savings or alternate oil technologies.</li> <li>✓ New material technologies need further support and advancement.</li> </ul>
Renewable energy	Solar	<ul style="list-style-type: none"> <li>✓ The technical and quality specifications, standards, and regulations for solar thermal generation systems have not yet been established.</li> <li>✓ The high-quality and efficient solar-energy-integrated building has received little attention, and there have been few achievements in this area to date.</li> <li>✓ Certain critical production equipment, such as silicon-based solar cells and thin-film solar cells, is totally dependent on imports.</li> <li>✓ High-efficiency, low-cost, and environmentally friendly photovoltaic technologies need intensive work to permit a breakthrough.</li> </ul>
	Wind	<ul style="list-style-type: none"> <li>✓ Advanced ground-testing platforms and experimental wind farms have not yet been completed.</li> </ul>
	Biomass	<ul style="list-style-type: none"> <li>✓ The transformation efficiency from agricultural waste to energy is still at a low level.</li> <li>✓ R&amp;D on selecting and growing energy-related plants needs further promotion.</li> <li>✓ Biomass technology has fallen far behind the best technology used elsewhere.</li> </ul>
	Hydropower	<ul style="list-style-type: none"> <li>✓ Ecological problems with the hydropower facilities need to be addressed cautiously.</li> </ul>
	Ocean energy	<ul style="list-style-type: none"> <li>✓ Antistorm technology, anticauterization material, and stand-alone power system operation technologies need further development.</li> </ul>
Nuclear	Nuclear energy	<ul style="list-style-type: none"> <li>✓ China is not able to produce the major core modules of nuclear reactors independently on a large scale.</li> <li>✓ There is still a large gap between China and other leading countries with respect to R&amp;D for third- and fourth-generation nuclear reactors.</li> </ul>
New energy	Hydrogen energy	<ul style="list-style-type: none"> <li>✓ The technologies used to produce and store hydrogen require improvement. More research about fuel cells is needed. A network for producing, storing, and transmitting hydrogen must be established.</li> </ul>
	Nuclear fusion	<ul style="list-style-type: none"> <li>✓ Several key technology issues need to be solved, including the superconducting magnet, heating diagnostics, remote control, and materials.</li> </ul>

emissions, while other entities accounted for a total reduction of 0.386 billion t of CO<sub>2</sub> emissions.

- 4) China has strengthened other national energy conservation and efficiency programs, including improving the enforcement of building energy codes and industrial processes and vehicle and appliance efficiency standards.
- 5) China has adjusted its economic structure to limit the growth of energy-intensive industries and encourage

the development of the service sector. During the period 2005–2010, China saved energy consumption in the amount of 0.63 billion tce, 23% of which (0.143 billion tce) was contributed by the economic structure adjustment.

### China's Accomplishments

To reduce national CO<sub>2</sub> emissions and energy consumption, various programs and policies have been established.

## China's goals will lead to large challenges if its current economic development pattern continues over the next decade.

In the 11th FYP period, the Chinese government provided CNY126.1 billion in funding to increase its emission-reduction capacity. Private-sector funds in the amount of CNY554.8 billion (4.4 times the government funding) were also invested. The new emission-reduction capacity, compared with the 2005 level, has reached 753.61 t of CO<sub>2</sub>. Meanwhile, China has saved 0.63 billion tce in energy consumption, 69% of which (0.434 billion tce) was contributed by encouraging and applying clean and renewable technologies. To increase the share of nonfossil fuels in primary energy consumption, the following measures are being taken:

- 1) The Renewable Energy Law, which now requires power grid companies to fully purchase the qualified renewable energy sources within their region, will be amended.
- 2) A renewable energy development fund that will pay for incentive programs and R&D projects will be created. The fund will be primarily financed through surcharges levied nationally on electricity users.
- 3) Aggressive national capacity targets for wind, solar, biomass, and other technologies by 2020 will be established.
- 4) Feed-in tariffs that give preferential pricing to wind, solar, and biomass energy producers will be introduced.
- 5) Subsidies for renewable energy production will be created.

Due to China's efforts, in late 2010, nonthermal power production reached 813.2 billion kWh, which is 180% of the 2005 level. As shown in Figure 10, by the end of 2010, 19.2% of total energy production was contributed by nonfossil sources.

CO<sub>2</sub> emissions and the emission intensity of the energy industry during the period 2005–2010 are shown in Figure 11. Although CO<sub>2</sub> emissions increased by 19%, emission intensity was reduced by 21%.

### Conclusion

China's goals will lead to large challenges if its current economic development pattern continues over the next decade. In the short term, the accomplishment of the targets of the 12th FYP is critical. In the next five years, China must make strenuous efforts to reduce its energy consumption by 0.67 billion tce and reduce its CO<sub>2</sub> emissions by 1.6 billion t

China must keep its 7% GDP growth in balance with its 3.3% energy consumption growth. In other words, the elasticity coefficient of energy consumption will drop to 0.47, which represents a much more difficult situation than during the 11th FYP period.

Furthermore, due to the dispatch difficulties connected with wind energy and safety concerns about nuclear plants, the target of improving the clean-energy share in China's total energy mix to 11.4% relies on the construction of new hydropower plants. Unfortunately, the ecological problems with hydropower facilities have become more severe, which may restrict further development of hydro-power systems.

The biggest problem is the uncertainty of future Chinese GDP growth rates. If annual GDP growth is 7%, the 11.4% renewable energy consumption will amount to 0.43 billion tce. If annual GDP growth surpasses 8.5%, the renewable energy consumption will have to reach 0.467–0.502 billion tce, with an estimated insufficiency of 3.7 million tce by 2015.

In the long term, the major technical challenges facing China's energy sector may be summarized as shown in Table 3.

### Acknowledgments

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### For Further Reading

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### Biographies

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