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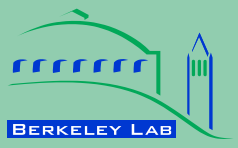

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The Greening of the Middle Kingdom: The Story of Energy Efficiency in China

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Environmental Energy

Technologies Division

May 2009

This work was supported by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

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The dominant image of China's energy system is of billowing smokestacks from the combustion of coal. More heavily dependent on coal than any other major country, China uses it for about 70 percent of its energy (NBS, 2008). Furthermore, until recently, China had very few environmental controls on emissions from coal combustion; recent efforts to control sulfur dioxide (SO_2) emissions appear to be meeting with some success (Economy, 2007, 2009).

Figure 1 shows the dominant use of coal in China's energy system from 1950 to 1980 (NBS, various years). However, this is just one side of China's energy story. Figure 2 illustrates the second part, and what may be the most important part of the story—China's energy system since 1980, shortly after Deng Xiaoping assumed full leadership. This figure compares the trends in energy consumption and gross domestic product (GDP) by indexing both values to 100 in 1980. The upper line shows what energy consumption in China would have been if it had grown at the same rate as GDP, since energy consumption usually increases in lockstep with GDP in an industrializing, developing country, at least until it reaches a high economic level.

The lower line in Figure 2 shows China's actual energy consumption, also indexed to 1980. The striking difference between the lines shows that GDP in China grew much faster than energy demand from 1980 to 2002. As a result, by 2002 energy and energy-related carbon dioxide (CO_2) emissions were more than 40% percent of what they would have been if energy and GDP had grown in tandem.

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In the next chapter of China's energy history, from 2002 to 2005, the increase in energy demand outstripped a very rapidly growing economy, and because of the large size of the Chinese economy, the increase had substantial impacts. The construction of power plants increased to 100 gigawatts per year; over the three-year period newly constructed plants had a capacity of more than 30 percent of total electricity-generation capacity in the United States. At the same time, energy-related CO_2 emissions in China increased dramatically.

In the latest stage, another abrupt change, this time for the better in terms of energy efficiency, began late in 2005. As senior officials in the government turned their attention to the problem of growing energy demand, the government set a mandatory goal for 2010 of a 20 percent reduction in energy intensity (defined as energy use per unit of GDP) from 2005 levels. To meet this goal, China undertook significant legislative, regulatory, and organizational reforms at the national, provincial, and municipal levels to ensure that measures to reduce energy intensity would be implemented in all sectors and activities in China.

At the time of this writing, it appears that China is on its way to meeting the 20 percent goal, thus reducing CO_2 emissions by 1.5 billion tones, as compared with consumption at 2005 energy-intensity levels. In this paper, we describe and assess these three significant periods in China's energy story and provide a context by briefly reviewing the three decades prior to 1980.

The Soviet Model: 1949 through 1980

From the beginning of the communist regime in 1949 until the ascendancy of Deng Xiaoping in 1979, China's energy policy and the system it created followed the Russian model—rapid increases in energy supply, low energy prices, centralized energy allocation to provide energy to heavy industry, and a disregard for environmental effects. The result of this policy was

one of the fastest growing and least efficient energy systems in the world, on both the supply side and demand side (Figure 3a).

The "Classic" Period of Energy Efficiency: 1980 through 2002

In 1980, in response to serious concerns in the academic community about Chinese energy policy, Deng Xiaoping adopted a strategy of reducing energy intensity. His stated goal was to quadruple GDP while only doubling energy consumption over the 20-year period, 1980–2000 (Lu, 1993).

China exceeded this goal both in the increase in GDP and the reduction of energy intensity (Figure 3b). This was achieved through a variety of innovative policies and programs, many of which were developed by the Chinese without any significant knowledge of what other countries had done to promote energy efficiency. Not until a decade after China had embarked on its program to reduce the energy intensity of its entire economy did officials begin to establish ties with the energy-efficiency community outside its borders. Two of these policies—one on investment in energy efficiency and the other on establishing centers of expertise in energy efficiency throughout the nation—were far ahead of their time. To this day, no other country has effectively implemented such policies at the level done in China.

As shown in Figure 4, investment in energy efficiency accounted for more than 10 percent of total energy investment in 1981, the first year of Deng Xiaoping's program.[1] Investment later increased to 12 percent before slowly declining to a sustainable level of 5 to 6 percent.

In the early and mid-1980s, energy efficiency could be achieved inexpensively by fixing leaky pipes, inefficient boilers, and other equipment and by changing sloppy energy-management practices. Thus a 10 percent investment led to a much larger reduction in the

increase in energy demand than a comparable investment led to increased supplies. The investment program alone—which was just one of a number of energy-efficiency policies—achieved a significant portion of Deng Xiaoping's goals.[2]

The investment program spurred the development of new institutions, such as the China Energy Conservation Investment Corporation, which developed branches throughout the country to channel investments into energy efficiency and co-generation (strongly supported by the Chinese government). At the national level, the Chinese created the Bureau of Energy-Saving and Comprehensive Energy Utilization in the State Planning Commission (SPC). Today, after various restructurings, SPC has become the National Development and Reform Commission (NDRC). NDRC and its forerunner commissions are half a level above ministries in the Chinese hierarchy. All major requests to the State Council from ministries are supposed to—and often do—flow through NDRC. The very existence in the 1980s of a bureau for energy efficiency at this level indicates its importance.

This bureau created a variety of programs to promote energy conservation (a term for energy efficiency that is still often used in China). One of the most significant of these new policies was the establishment of energy-conservation service centers throughout the country. At their peak, there were more than 200 of these centers, employing more than 7,000 people across China. For a more complete description of institutional reforms to promote energy efficiency see Sinton and Levine (1998).

It is instructive to ask what might have happened if China had not embarked on such an aggressive and innovative policy. As Figure 2 shows, Chinese actions going back to 1980

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[1] Data on investment in energy efficiency prior to 1981 are not available, but investments during these years were undoubtedly much smaller than the 10 percent figure of 1981.

[2] If one assumes a two-year payback on the investments in energy efficiency, then the investment level was sufficient to achieve more than half of the decrease in energy intensity sought by Deng.

enabled the country to avoid a situation in which global energy-related CO_2 emissions in 2007 would be three times higher than they are. This would have resulted in global emissions in 2007 at levels projected by the International Energy Agency for 2025 (IEA, 2008).[3]

Out-of-Control Growth in Energy Demand: 2002 through 2005

In spite of significantly slower increase in energy demand compared to GDP, there were signs in the late 1990s that energy efficiency was becoming less important to Chinese policy makers. Funding for the government effort to gather and analyze energy data was reduced significantly throughout the decade; as a result, the data were not only less comprehensive, but also less accurate. China's system for gathering data on energy consumption, which had been one of the best among developing nations, was much weakened by the end of the 1990s. However, data on energy supply, which come from a small number of energy-supply companies and are relatively easy to track, remained plentiful.

By the turn of the century, little attention was paid to energy efficiency at the industrial-enterprise level. By law, all key industries (i.e., industries that consume more than 10,000 tons of coal equivalent per year) were required to have an energy manager. However, by 2000, many large enterprises had energy managers in name only, if at all. This meant that the enterprises consuming the most energy had lost the expertise (and often the data) to assess and improve their energy efficiency.

Other signs that energy efficiency was being given lower priority included the decline of many of the energy conservation centers; a dispirited bureaucracy in the bureau and division responsible for energy efficiency at the central government level; reduction in budgets for energy efficiency; and most important, the lack of authority and/or willingness in national, provincial,

[3] This is based on forecasted growth of energy-related CO_2 emissions by IEA (2008).

municipal, and local government bodies to enforce laws and regulations intended to save energy.[4]

At the same time the Chinese government lost its focus on energy efficiency, China's accession to the World Trade Organization (WTO) had the inadvertent effect of undermining more than two decades of efforts to reduce energy intensity. Beginning in the early 2000s, and coinciding with China's membership in the WTO, there was a very rapid increase in exports, supported by rapid growth in industry to feed the export markets, which was heavily weighted toward energy-intensive products (i.e., products whose manufacture requires large amounts of energy and results in substantial CO_2 emissions) (Andrews-Speed, 2009).

In addition, China's internal demand for energy-intensive commodities like cement and steel to build infrastructure and cities to serve its rapidly urbanizing population outpaced the growth of less energy-intensive industries, also leading to increased overall energy use and energy-related CO_2 emissions.

These and other factors that contributed to the enormous output of energy-intensive industries in China resulted in energy demand that increased at breakneck speed and far exceeded the trajectory that would achieve the goal of quadrupling GDP while doubling energy demand from 2000 to 2020 (Figure 5).

Thus, as China developed its infrastructure, urbanized, and became the supplier of countless products to the world, its CO_2 emissions increased rapidly and dramatically. Clearly, the increase in CO_2 emissions was partially due to demand in importing nations that used the products and manufactured in China. But the commonly accepted system of accounting for greenhouse gas emissions (i.e., the convention used to assess compliance with the Kyoto treaty

[4] These statements are based on a large number of interviews by the lead author of this paper with government officials, researchers, industrialists, and academics during the 1990s and early 2000s.

of Annex I countries) attributes emissions to the country that produces products rather than to the country that imports them. Indeed, changing the attribution of greenhouse gas emissions from production to consumption would be difficult because of considerable uncertainties in assessing embodied energy in products.

In fact, in this three-year period, China's energy-related CO_2 emissions—which were 60 percent of those of the United States in 2002—approached the U.S. level by 2005 and surpassed them a year later (Figure 6) (Levine and Aden, 2008). Previous forecasts as late as 2004 by Chinese government research institutes, international agencies, and mainstream analysts from various countries had indicated that China was unlikely to overtake the United States in energy-related CO_2 emissions until 2015, or even 2020 (Levine and Aden, 2008). However, developments during the 2002 to 2005 period resulted in this wholly unexpected (and undesired) result for China.

How did this dramatic change come about, and what can the Chinese do about it? In brief, there were four major factors behind the dramatic rise in energy consumption in China:

- a gradual decline in the gathering of information on energy demand and in regulating demand by government institutions
- a rapid increase in the production of energy-intensive products for export as a result of China's membership in WTO
- increasing wealth and prosperity of a large portion of China (especially in the eastern provinces) and the associated construction of buildings and infrastructure, including transportation corridors (e.g., highways and canals for shipping freight and moving water) to serve this population
- ongoing rapid migration of people from rural areas, where they had consumed little energy, to urban areas, where energy consumption is much higher

One of the most dramatic indicators of this energy-intensive period is the increase in the production of cement. Figure 7 shows that China produces 50 percent of the cement produced worldwide (USGS, 2009). Although this is a startling statistic, it logically reflects the extraordinary pace of construction in China, which is a substantial portion of total world construction.

A Modern Re-enactment of the Early Days: 2005 to the Present

By 2005, officials at senior levels in the Chinese government had recognized that the rapid increase in energy demand presented serious problems and was unsustainable. The rate of construction of energy-supply infrastructure—hydroelectric facilities and power plants—was putting great pressure on China's industrial system and creating difficult problems with the safety and reliability of these complex systems.

As measured in investment cost per unit of industrial output, energy supply is one of the most capital-intensive industrial activities. Demand for capital to build new energy-supply and conversion systems is now in competition with the demand for capital to promote balanced economic and social development. In addition, senior leaders of the Chinese government and party were becoming increasingly concerned about the negative environmental effects of the rapid increase in energy supply to meet the burgeoning demand.

In November 2005, the Politburo issued a highly unusual statement setting a mandatory 20 percent reduction by 2010 in energy intensity (measured as energy consumption per RMB¥[5] of GDP**)**. The Politburo typically addresses broad issues and sets quantitative goals for the Chinese economy as a whole; setting goals for specific industry sectors is usually the purview of the government, rather than the party. Clearly, the announcement of a 20-percent decrease in

[5] RMB¥ is the Chinese currency, valued at 6.8RMB¥ per $U.S.

energy-intensity production indicated that the senior leaders perceived the energy problem to be extremely serious.

The level of activity that followed resembled the energy-efficiency initiatives of the early days that had led to the creative energy-conservation goals in the 6th Five-Year Plan and the intense activities that followed: legislation, regulations, government reorganization, and the creation of new institutions at the national, provincial, and municipal levels.

Nevertheless, there were important differences between the situation in 1980 and the situation in 2005. The economy in 2005 was approximately 10 times larger than in 1980 and was, therefore, much more difficult to manage. In 1980, most major energy-supply enterprises were government owned, while in 2005, although the government still exerted influence and retained some control over them, it did not own them.[6] The key difference, however, was on the demand side. By 2005, the government's ability to shape or restrain or, in many cases, even influence the demand for products, buildings, and services and the concomitant demand for energy services, was greatly limited.

In spite of these differences, the intensity and creativity of policy development for energy efficiency resembled the activity in China in the early 1980s, as well as the activity that followed the oil embargo in the United States and other industrialized countries. By 1975, three years after the embargo, many affected countries had enacted and were enforcing a variety of laws and regulations requiring or promoting energy efficiency in automobiles, buildings, and industry. The United States, Japan, and major economies in Europe had created new institutions in both

[6] Many of the energy-supply enterprises were still under the control of the state, either directly as state-owned enterprises or indirectly through the positions of their leaders in government (e.g., the heads of the national oil companies are officially government ministers, even though the companies are mostly privately owned).

the public and private sectors to carry out these laws and regulations and, for the first time, had provided government funding to promote energy efficiency.

Table 1 summarizes some of the key laws, regulations, and programs put into place in China since the Politburo directive of November 2005. These policies include the Top 1,000 Energy-Consuming Enterprises Program (Top 1,000 Program); the Ten Key Projects; allocations of government funds to support private investment in energy efficiency and pollution abatement; the creation of new government organizations and the strengthening of existing ones responsible for the design and implementation of energy-efficiency measures; and a variety of laws, regulations, and tax incentives.[7]

Many of these efforts are associated with the 11th Five-Year Plan, but some go well beyond it. Three of the most important policies are briefly described below.[8]

Ten Key Projects

In preparation for the intense focus on energy-efficiency policy that began with the November 2005 announcement by the Politburo, NDRC initiated the "Ten Key Projects," in 2004, and in 2005, the "Ten Key Projects" were incorporated into the 11th Five Year Plan. The four most significant of these projects are: the renovation of coal-fired industrial boilers; district-level combined heat and power projects; oil conservation and substitution; and energy efficiency and conservation in buildings. The expected impact of these four projects is up to 250 million tonnes carbon equivalent (Mtce) per year or about 40 percent of the 2010 target for energy

[7] Another interesting policy is the responsibility system (also called the "one vote veto") in which a government official or manager of a state-owned enterprise cannot advance without meeting an energy-intensity target. Thus an individual may meet all of the criteria except the energy-intensity target with very high marks and still flunk the performance evaluation, with significant adverse consequences (Zhou, et al., 2009).

[8] For a detailed review of energy-efficiency policies initiated during the 11th Five-Year Plan and after the announcement of the 20-percent intensity goal, see Lin et al., 2007.

intensity in China (NDRC, 2004)[9]. Twenty provincial energy-conservation centers (ECCs) were given financial support from the central government to assist in the implementation of these projects.[10]

Top 1,000 Energy-Consuming Enterprises Program

Launched in April 2006, the Top-1,000 Program was designed to improve industrial energy efficiency by targeting China's 1,000 highest energy-consuming enterprises, which account for almost 50 percent of total industrial-sector energy consumption and 30 percent of total energy consumption in China. The Top 1,000 enterprises are in nine sectors: iron and steel, petroleum and petrochemicals, chemicals, electric power, nonferrous metals, coal mining, construction materials, textiles, and paper.

During the summer of 2006, all participating enterprises signed energy-conservation agreements with local governments committing themselves to reaching the energy-savings target by 2010. In addition, the energy-saving target has been added to the provincial government cadre-evaluation system. Preliminary data indicate that the large majority of Top1,000 enterprises are meeting their interim targets (Price et al., 2009).

Government Funding for Private Investment

In 2007, the Chinese government allocated 23.5B RMB¥ (about $3 billion at that time) to projects for improving energy efficiency and reducing pollution (MOF, 2008). This funding supported the launch of the Ten Key Projects (described above), the elimination of inefficient facilities, and the installation of measures to protect the environment. These funds are also being used to award 200 to 250 RMB¥ ($26 to $33) for every tonne of coal equivalent an enterprise

[9] The other six have relatively small impacts.

saves through the implementation of five of the Ten Key Projects in energy-intensive industries, coal-fired industrial boilers, district heating using cogeneration systems, and buildings (Jiang; 2006; Lu 2006).

In 2008, the total allocation for energy conservation, emissions reduction, and ecological improvement was doubled to 42B RMB¥ (about $6 billion) (MOF, 2008). This funding includes 7.5B RMB¥ ($1 billion) for awards for the Ten Key Projects and 4B RMB¥ ($0.6 billion) for phasing out inefficient industrial plants.

Overall Results

In 2006, the energy intensity of the Chinese economy decreased by 1.7 percent, the first decrease in this measure since 2001 (Zhou et al., 2009). Although this was a significant achievement, the reduction was well below the trajectory needed to achieve the goal of a 20-percent reduction in energy intensity by 2010. In 2007, however, energy intensity declined by 3.7 percent, and in 2008, it was reduced by 4.6 percent (Zhou et al., 2009). In the first quarter of 2009, preliminary data indicate an even greater reduction (China View, 2009).

Although the impact of the world economic crisis on energy intensity in China is difficult to predict, it now appears that China is likely to meet its 20-percent energy-intensity reduction target for 2010. Such savings represents a decrease of 1.5 billion metric tons of CO_2 (Lin et al., 2007), a very large number by any measure.

References

Andrews-Speed, P. 2009. China's on-going energy efficiency drive: origins, progress, and prospects. Energy Policy 37(4): 1331–1344.

[10] In 2006, financial support from the government for this purpose was ~64M RMB¥ (~$8 million). The United Nations Development Program/Global Environmental Facility added about ~8M RMB¥ ($1 million) to the total

EPA (Environmental Protection Agency). 2008. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2006. Washington, D.C.: EPA.

China View. 2009. China's energy intensity down 2.9% in Q1: statistics office. Available online at *http://news.xinhuanet.com/english/2009-04/29/content*. April 29.

Economy, E.C. 2007. The Great Leap Backward. Foreign Affairs 86(5): 38–59.

Economy, E. 2009. Personal communication, May 4, 2009.

IEA (International Energy Agency). 2003. Energy Balances of non-OECD Countries. Paris: IEA.

IEA. 2008. World Energy Outlook. Paris: IEA.

Jiang, Y. 2006. Personal communication with Jiang Yun, China Energy Conservation Association, November 6, 2006.

Levine, M., and N. Aden. 2008. Global Carbon Emissions in the Coming Decades: The Case of China. Pp. 19–38 in Annual Review of Environment and Resources, Vol. 33. Palo Alto, Calif.: Annual Reviews.

Lin, J. 2005. Trends in Energy Efficiency Investments in China and the United States. LBNL-576921. Berkeley, Calif.: Lawrence Berkeley National Laboratory.

Lin, J., N. Zhou, M. Levine, and D. Fridley. 2007. Taking out 1 billion tons of CO_2: the magic of China's 11th Five-Year Plan? LBNL-62886. Berkeley, Calif.: Lawrence Berkeley National Laboratory.

Lu, Y. 1993. Fueling One Billion: An Insider's View. London, U.K.: Paragon Press.

Lu, X. 2006. Personal communication with Lu Xinming, director, Department of Environment and Resources Conservation, National Development and Reform Commission, September 9, 2006.

(Jiang, 2006). This is based on a currency conversion of $1 = 8.00419 RMB¥ (average rate of June 2006).

MOF (Ministry of Finance). 2008. Ministry of Finance sets aside 27 Billion RMB¥ for supporting energy saving and emission reduction. Available on line at *http://www.mof.gov.cn/caizhengbuzhuzhan/zhengwuxinxi/caizhengxinwen/200805/t20080519_29017.html*.

NBS (National Bureau of Statistics). 2008, and various years. China Statistical Yearbook. Beijing, China: China Statistics Press.

NDRC (National Development and Reform Commission). 2004. Medium and Long-Term Energy Conservation Plan. Beijing: NDRC

Price, L., W. Xuejun, and Y. Jiang. 2009. The challenge of reducing energy consumption of the top 1,000 largest industrial enterprises in China. Energy Policy (special issue). In press. Available online at *http://www.sciencedirect.com/science/article/B6V2W-4W329GD-1/2/a7612e71ef7f84b4cade01abbd34106b*.

Sinton, J., and M. Levine. 1998. Energy efficiency in China: accomplishments and challenges. Energy Policy 26(11): 813–829.

USGS (U.S. Geological Survey). 2009. Mineral Commodity Summaries: Cement. Washington, D.C.: USGS.

Zhou, N., M. Levine, and L. Price. 2009. Overview of Current Energy Efficiency Policies in China. Submitted to Energy Policy.

Figure Captions

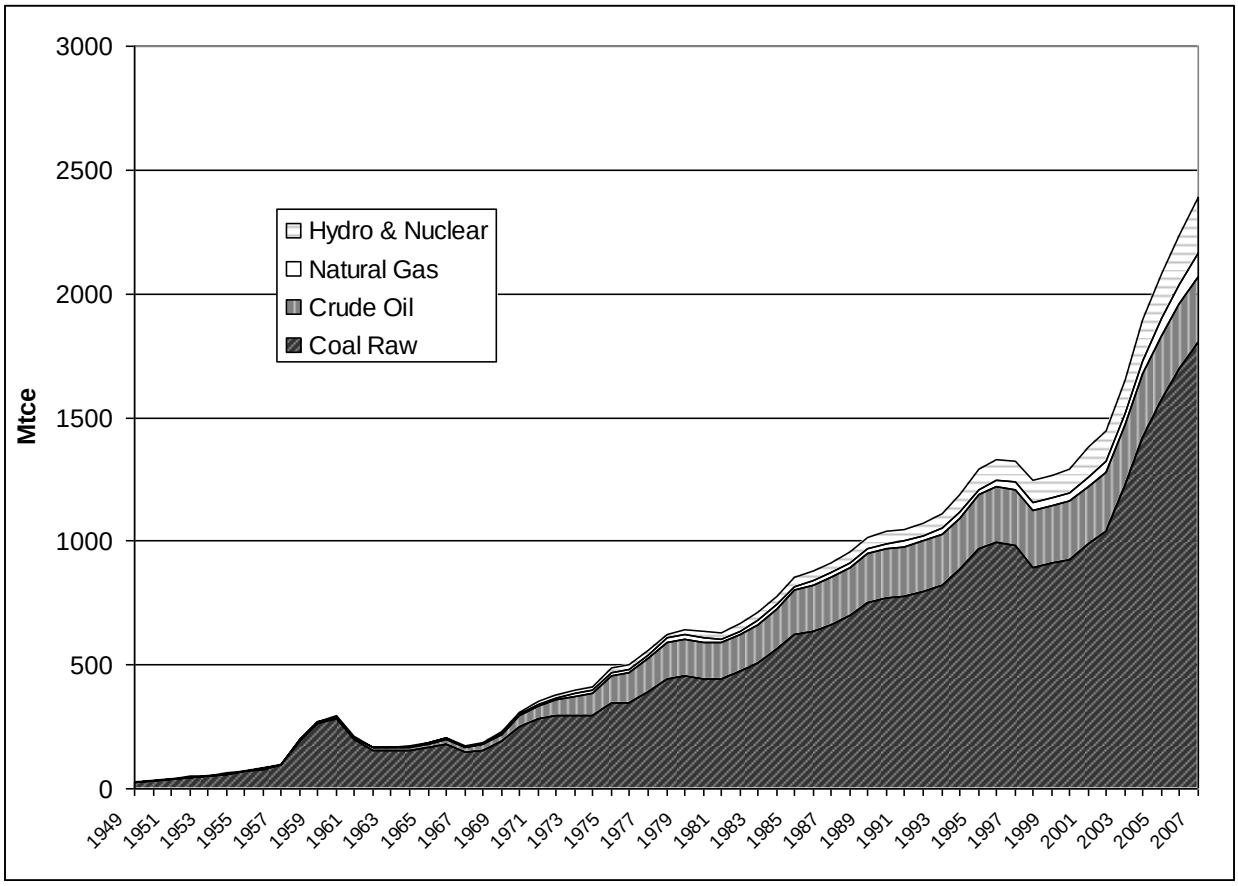

FIGURE 1 Coal dominates energy consumption in China. Source: NBS, various years.

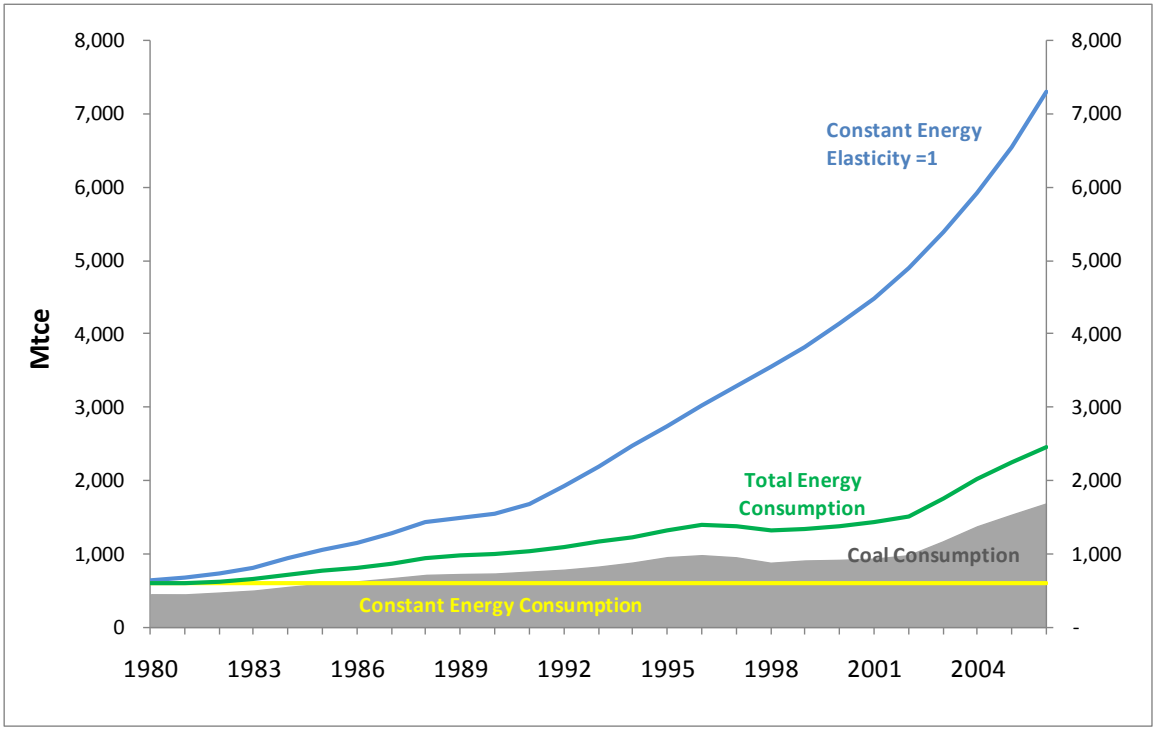

FIGURE 2 Actual energy demand in China is very much lower than energy demand at constant energy intensity, 1980–2006. Source: NBS, various years.

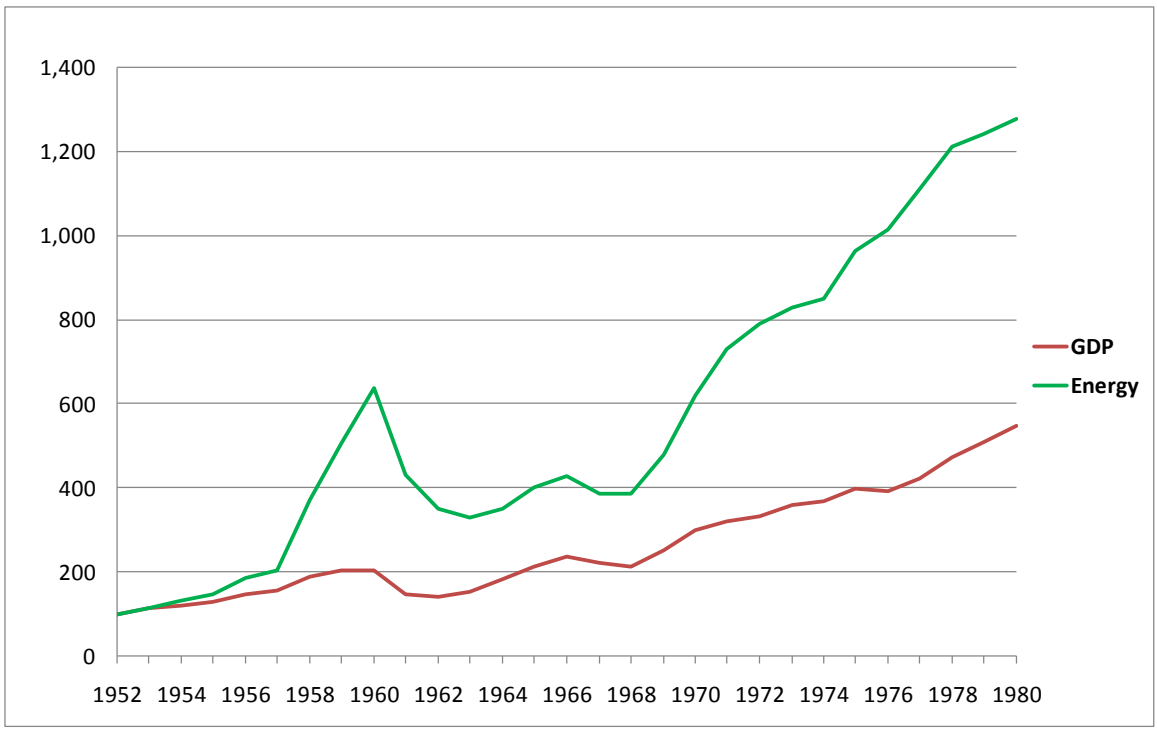

FIGURE 3a Energy demand grew twice as fast as GDP from 1952 to 1980. Source: NBS, various years.

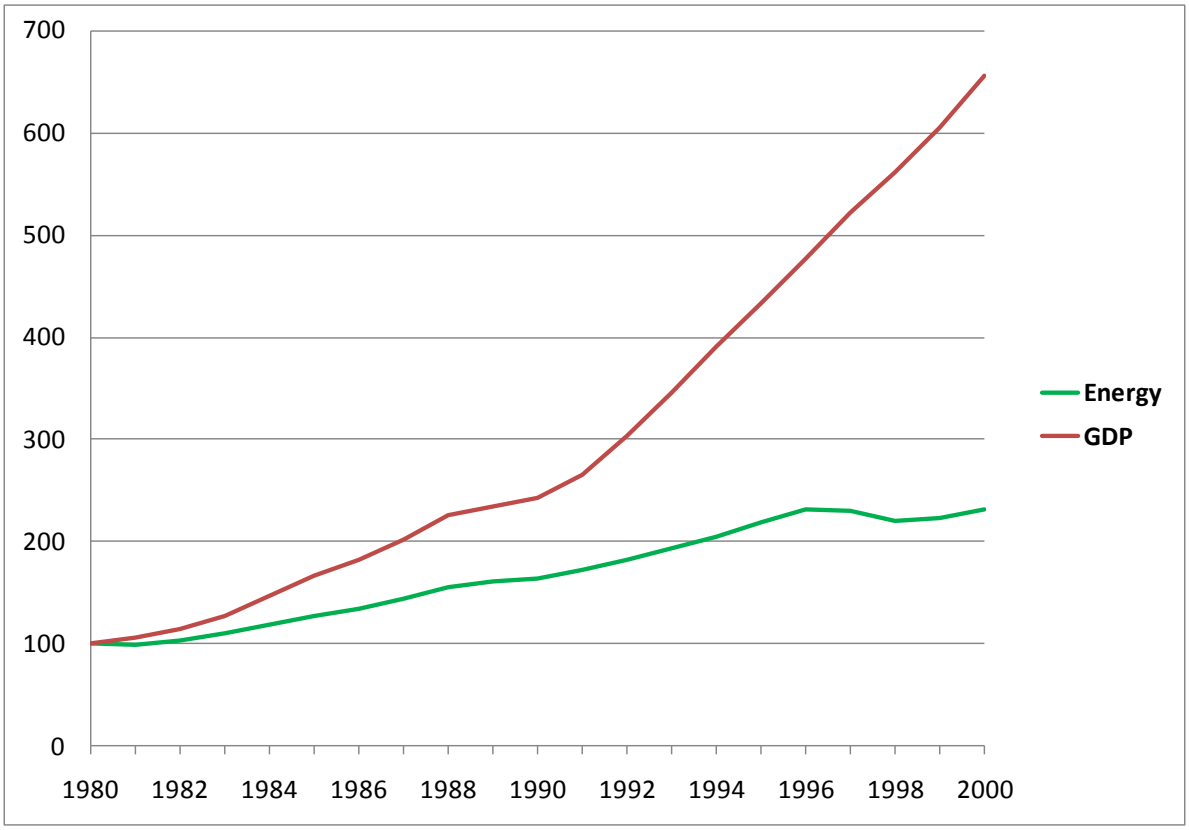

FIGURE 3b Energy demand grew 50 percent faster than GDP from 1952 to 1980, albeit from a very low level. Source: NBS, various years.

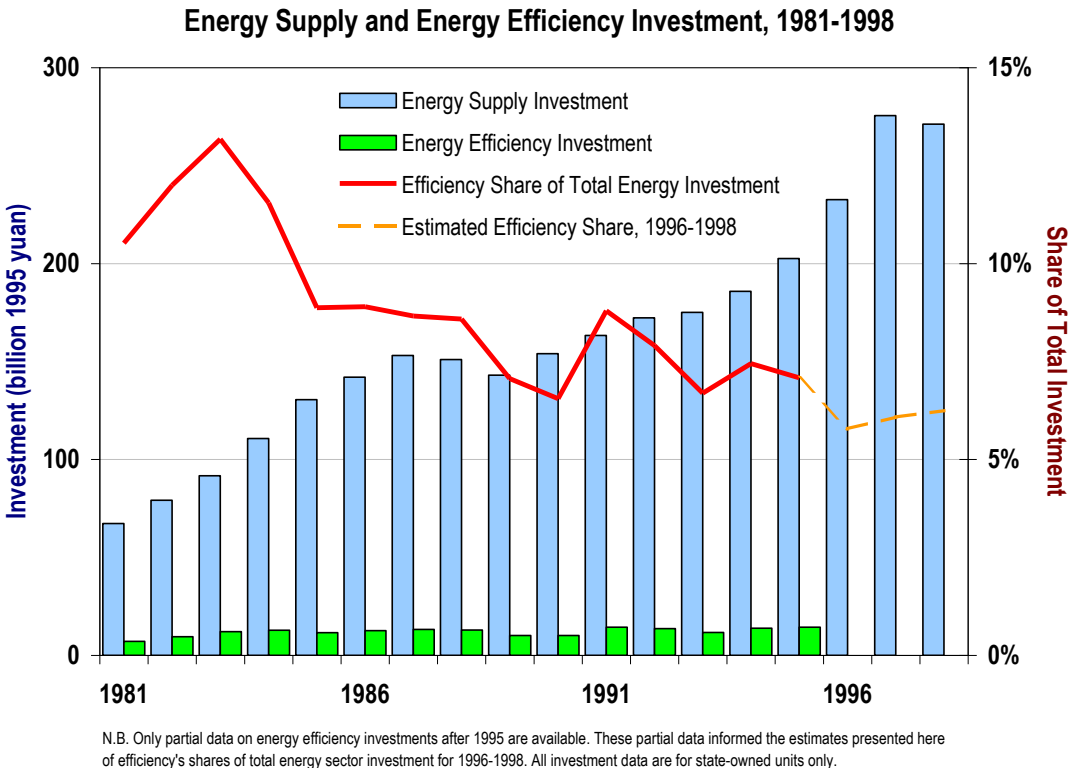

FIGURE 4 Investment in energy efficiency became a significant part of total energy investment in 1981. Source: NBS, various years.

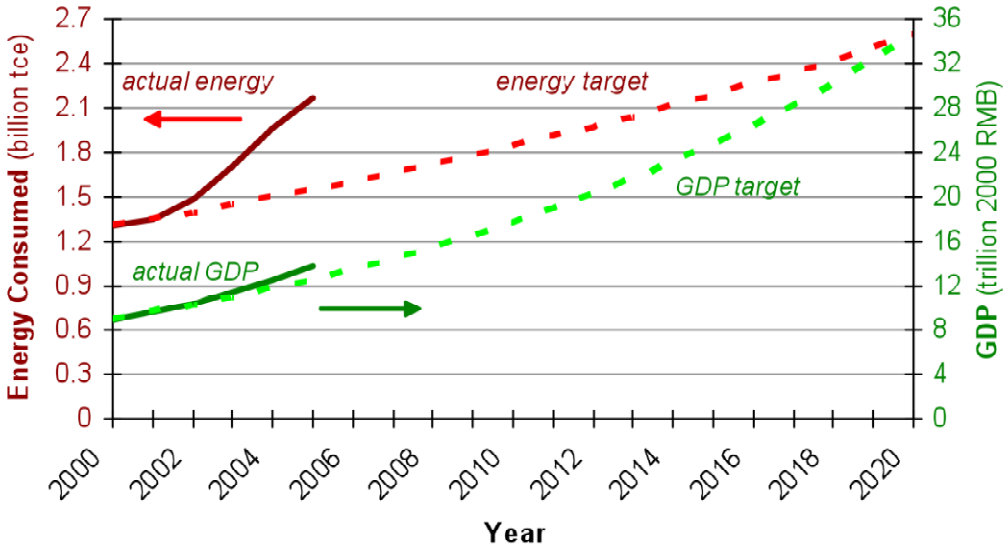

FIGURE 5 Beginning in 2002, increasing energy demand was on a trajectory to dramatically exceed the energy-reduction goals for 2020. Source: Lin, 2007.

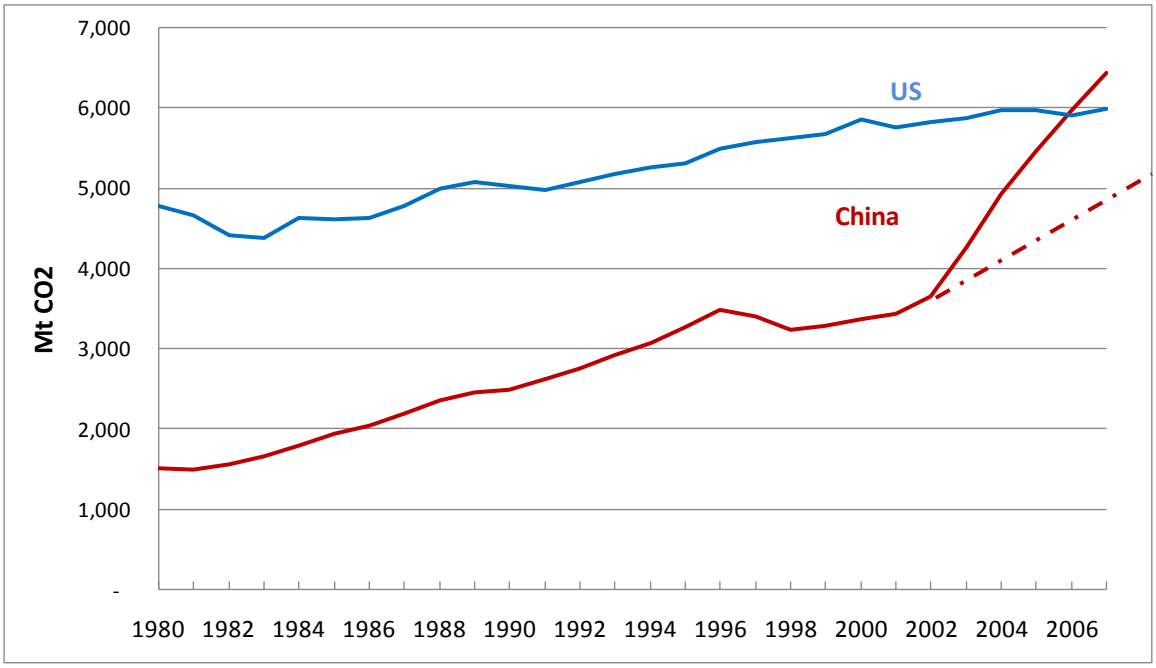

FIGURE 6 With the enormous increase in energy demand from 2002 to 2005, China became a larger emitter of energy-related CO_2 than the United States. Source: Levine and Aden, 2008.

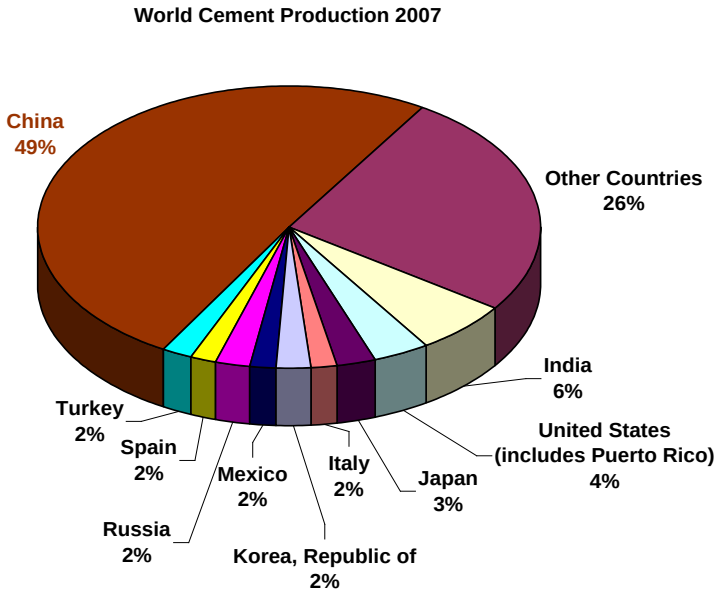

FIGURE 7 Cement production in China is 50 percent of world production. Source: USGS, 2009.

Energy Policies	Date Effective	Responsible Agency
Fuel Consumption Limits For Passenger Cars	2004	
Medium and Long-Term Plan for Energy Conservation	2005	National Development and Reform Commission (NDRC)
Renewable Energy Law	2005	
Government Procurement Program	2005	NDRC and Ministry of Finance (MOF)
National Energy Efficient Design Standard for Public Buildings	2005	Ministry of Construction (MOC)
Eleventh Five-Year Plan	2006	NDRC
The State Council Decision on Strengthening Energy Conservation	2006	State Council
Revised Consumption Tax for Larger, Energy-Inefficient Vehicles	2006	MOF and the State Administration of Taxation
Reduced Export Tax Rebates for Many Low-Value-Added But High Energy-Consuming Products	2006	MOF
Top-1000 Energy-Consuming Enterprise Program	2006	NDRC
"Green Purchasing" Program	2006	Ministry of Environmental Protection (MEP) and MOF
Revision of Energy Conservation Law	2007	National People's Congress and NDRC
Allocation of Funding on Energy Efficiency and Pollution Abatement	2007	MOF and NDRC
China Energy Technology Policy Outline 2006	2007	NDRC and the Ministry of Science and Technology
Government Procurement Program	2007	NDRC and MOF
National Phase III Vehicle Emission Standards	2007	
Interim Administrative Method for Incentive Funds for Heating and Metering and Energy Efficiency Retrofit for Existing Residential Buildings in China's Northern Heating Area	2007	MOF
Law on Corporate Income Tax (preferential tax treatment for investment in energy-saving and environmentally-friendly projects and equipment)	2008	NDRC
Allocation of Funding on Energy Efficiency and Pollution Abatement	2008	MOF and NDRC
Appliance Standards and Labeling	Various Years	General Administration of Quality Supervision, Inspection and Quarantine

Table 1. Recent key energy policies supporting China's 20% intensity reduction goal
Sources: (ref)