CHAPTER 6

Energy Policy

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Having negotiated a tortuous path through sweeping reform and rapid economic development for 25 years, Chinese society finds itself coping with the relatively new phenomena of rapid urbanization and soaring demands for energy. As with so many other challenges in recent Chinese history, these new challenges have emerged as by-products of earlier societal achievements—the inevitable offshoots of phenomenal economic growth—accelerating at previously unimagined speed. This chapter explores the nature of an urbanizing China's rapidly accelerating demand for energy, the complexities involved in meeting that demand, and the even broader policy and institutional challenges surrounding long-term resource and environmental sustainability.

The Nature of the Challenge

In 1980, China's urbanization rate hovered just below 20 percent, a rate lower than Pakistan (28.1 percent), India (23.1 percent), and Indonesia (22.1 percent) (see table 1.1). By 2005 China's levels had surged to 42.9 percent, outstripping Pakistan (34.9 percent) and India (28.7 percent) and almost reaching the level of Indonesia (48.1 percent).

During this period, Chinese energy consumption soared. In 1973 China consumed 7.9 percent of the world's energy; by 2005 the figure had risen to 14.2 percent, making China the world's second-largest consumer, trailing only the United States (IEA 2007a). Since 1993 China has been a net importer of oil, and it continues to be the world's largest consumer (and producer) of coal, which accounted for more than 76.4 percent of China's primary energy supply in 2004 (IEA 2007b).

Certainly since 2002, China's electric power sector has been growing at a torrid pace. Total generating capacity increased by nearly a third between 2003 and 2006 (MIT 2007). In 2005, the system added about 70 gigawatts (GW) of generating capacity, an amount on par with the scale of the entire British power grid (MIT 2007). Many observers doubted that China could increase its capacity by another 70 GW. Nonetheless, the following year witnessed an additional 102 GW of capacity expansion (McGregor 2007). Concomitantly, and far more quickly than previously predicted, in 2006 China became the world's largest global emitter of carbon dioxide (Landsberg 2007).

In theory, the connection between urbanization and rising energy consumption appears obvious. As people shift from rural lifestyles to high-density, multistory urban dwellings, demand for energy-intensive climate control and extensive lighting should surge. So, too, should demand for energy-intensive appliances, automobiles, and the extensive long-distance transportation networks needed to channel goods into urban markets. Urban lifestyles presumably also generate demands for entirely new, and decidedly energy-intensive, production systems, such as the refrigerated food supply chain, from upstream industrial-scale preparation to supermarket retailing.

China's soaring energy consumption have not yet reflected these new drivers of energy demand (Rosen and Houser 2007; Zheng 2007); that is, the long-term consumption ramifications of urbanized lifestyles have not yet begun to kick in. Chinese per capita energy consumption remains well below levels found in advanced industrial societies: in 2005, annual per capita energy consumption stood at 1.56 tons of oil equivalent (toe) (Zheng 2007), a fraction of levels in Europe (3.46 toe), Japan (4.12 toe), and the United States (7.88 toe) (Rosen and Houser 2007). Within China, however, the per capita energy consumption of urban citizens is 3.5 times that of rural citizens. Given the country's accelerating pace of urbanization, it would be foolish to assume that over the long run, residential energy consumption in China will not rise, in all likelihood substantially. There is every reason to believe that the China of tomorrow will exhibit an energy-demand pattern similar to that of urbanized societies throughout the world.

For the time being, industrial consumption drives Chinese energy demand—to a greater extent than virtually anywhere else in the world. In 2005, the industrial sector accounted for 71 percent of China's energy demand, with the remainder split between transport (10 percent) and residential, commercial, and agriculture use (19 percent). In India the industrial sector accounts for 49 percent, transport accounts for 21 percent, and residential, commercial, and agriculture use accounts for 30 percent. Far at the other end of the spectrum, in the United States industry accounts for only 25 percent of energy demand, while transport accounts for 33 percent and residential, commercial, and agricultural uses for 43 percent (Rosen and Houser 2007).

The fact that the effects of urbanization on energy consumption have yet to be felt has sweeping implications. At the very least, it means that China's accelerating demand for energy—with all the pressures it is exerting on global resources and the global environmental commons—is unlikely to be anywhere close to peaking. Chinese energy demand rose steeply through the 1990s and will likely continue to do so in the coming decades, even if reductions in energy intensity are achieved (tables 6.1–6.3).

Although residential energy consumption can be expected to rise, little reason exists to believe that industrial consumption will fall substantially, either in the aggregate or as a portion of total consumption. The expansion of energy-intensive heavy industry in China, a phenomenon that began in the 1990s, is related to the build-out of urban infrastructure on a national scale. Chinese firms are churning out the steel, aluminum, concrete, and other basic building materials going into the nation's new roads, mass-transit systems, and vast urban residential and commercial real estate development projects. Conceivably, this phenomenon could peter out over time once basic infrastructure is established, but the time frame for this will likely extend across decades.

Moreover, beyond just supplying domestic infrastructural needs, Chinese industry is increasingly producing for global markets. Indeed, urbanization has moved hand in hand with the development of technology and energy-intensive manufacturing for the global market. It is not just that the world's electronics, automotive parts, and consumer goods are being assembled in China. The most energy-intensive components for these products—everything from steel and aluminum to semiconductors—are being produced in China. The globalized supply chain now permits the most energy-intensive (and often lowest value added) production aspects of global products to be delinked from the less energy-intensive but often highest-value production aspects (design, research and development, marketing, and so forth) of those products. It is precisely these energy-intensive but often low-value production activities that are now concentrating so heavily in China. These activities make China a critical link in global supply chains but also a repository

Table 6.1. Energy Production and Consumption, 1991–2005

Item	*1991*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*
Primary energy production												
Raw coal (tens of thousands of metric tons)	108,741	136,073	139,670	137,282	125,000	104,500	99,800	116,078	138,000	166,700	199,232	220,473
Crude oil (millions of barrels)	14,099	15,004	15,733	16,074	16,100	16,000	16,300	16,396	16,700	16,960	17,587	18,135
Natural gas (10^8 cubic meters)	161	179	201	227	233	252	272	303	327	350	415	493
Hydro (10^8 kilowatts)	1,251	1,906	1,880	1,960	2,080	2,038	2,224	2,774	2,880	2,837	3,535	3,970
Nuclear (10^8 kilowatts)	n.a.	128	143	144	141	149	167	175	251	433	505	531
Total energy consumption												
Raw coal (tens of thousands of metric tons)	110,432	137,677	144,734	139,248	129,492	126,365	124,537	126,211	136,605	163,732	193,596	216,723
Crude oil (millions of barrels)	12,384	16,065	17,436	19,692	19,818	21,073	22,439	22,838	24,780	27,126	31,700	32,535
Natural gas (10^8 cubic meters)	159	177	185	195	203	215	245	274	292	339	397	479
Hydro (10^8 kilowatts)	1,251	1,906	1,880	1,960	2,080	2,038	2,224	2,774	2,880	2,837	3,535	3,970
Nuclear (10^8 kilowatts)	n.a.	128	143	144	141	149	167	175	251	433	505	531

Source: NBS various years.
n.a. Not available.

Table 6.2. Projected Demand for Primary Energy and Oil in Selected Countries in 2025
(millions of barrels of oil equivalent a day)

	Primary energy		Oil	
Country	*2001*	*2025*	*2001*	*2025*
United States	96.3	132.4	19.6	27.3
China	40.9	109.2	4.9	14.2
Japan	21.9	24.7	5.4	5.3
India	13.8	29.3	2.2	4.9
World	403.9	644.6	78	119.2

Source: U.S. Department of Energy 2007.

for the indirect energy demands of global consumers. To the extent that global demand for consumer products remains robust, so, too, will China's demand for energy.

That China's energy demands for the foreseeable future are linked to the dual phenomena of urbanization and globalization is important in two respects. On the urbanization front, it means that nonproduction-related energy consumption will likely increase significantly only in the future, particularly once the growing numbers of urban residents begin consuming at levels comparable to global norms. On the globalization front, it means that China's appetite for energy is in many ways a reflection of the global appetite—particularly in advanced industrial markets—for consumer goods, production of which is increasingly concentrating in China. In this sense, the problem of Chinese energy demand, both in its origins and its potential solutions, must be understood as global in nature. In essence, Chinese and global sustainability have become one in the same.

Energy Intensity and per Capita Consumption

Energy intensity (consumption per unit of GDP) in China is one of the highest in the world: in 2002, it was more than 7.0 times that of Japan, 3.5 times that of the United States, and 1.7 times that of Indonesia (Sun 2003). Historically, as economies shift from agriculture to industry, energy intensity rises steadily; peaks with the deepening of heavy industry; begins dropping as technological transformation occurs; and then continues to descend with the shift into the more service-oriented, less manufacturing-intensive activities typical of postindustrial economies. Energy intensity peaked in the United States in 1920 and globally in 1955 (Sun 2003).

Table 6.3. Alternative Projections of Growth in Final Energy Demand in China, by Sector

	Asia Pacific Energy Research Centre			*International Energy Agency*			*Tsinghua University*		
End-use sector	*Projected demand in 2020 (Mtoe)*	*Annual growth 1999–2020 (percent)*	*Share of total demand (percent)*	*Projected demand in 2030 (Mtoe) (percent)*	*Annual growth 2000–30 (percent)*	*Share of total demand in 2030*	*Projected demand in 2030 (Mtoe)*	*Annual growth 1999–2030 (percent)*	*Share of total demand in 2030 (percent)*
Industry	605	2.7	46	553	1.9	43	696	1.6	41
Transport	205	5.3	16	236	4.1	23	339	4.0	20
Residential	397	1.5	30	217	3.1	17	464	1.8	27
Commercial	73	4.7	5	111	4.8	9	97	2.8	6
Other	43	3.2	3	97	1.6	8	101	4.1	6
Total	1,322	2.7	100	1,264	2.6	100	1,697	2.2	100

Source: APERC 2004.

Whether China has reached peak levels is debatable; the trends are ambiguous. In the first two decades of reform, particularly in the late 1990s, energy intensity declined, partly as a result of technological upgrading in heavy industry and power generation and partly as a result of the shutting down of obsolete firms (table 6.4). The decline may also have been an artifact of statistical anomalies surrounding underreported coal production and consumption. Whatever the cause, energy intensity appeared to be on the rise by 2002, the point, not coincidentally, at which the growing gap between the supply of and demand for electric power generation began resulting in more frequent service interruptions in booming manufacturing centers.

The globalization of production and the fragmentation of industrial supply chains—phenomena intimately linked to China's economic development—may have substantially changed the traditional relation between development and energy intensity. Because energy-intensive production activities can be geographically delinked from production-related services and management that are not energy intensive, countries like China may end up with disproportionately high levels of

Table 6.4. Energy Intensity, 1991–2005
(tons coal equivalent / GDP)

Year	*Energy intensity*
1991	5.12
1992	5.12
1993	4.42
1994	4.18
1995	4.01
1996	3.88
1997	3.53
1998	3.15
1999	2.90
2000	1.40
2001	1.33
2002	1.30
2003	1.36
2004	1.43
2005	1.22

Source: NBS various years.
Note: GDP for 1991–99 calculated at 1990 prices; GDP for 2000–04 calculated at 2000 prices; 2005 GDP calculated at 2005 prices.

energy-intensive production, while advanced industrial societies continue to produce higher-value services that are not energy intensive. Whole industries need not move globally, only particular segments of those industries. For prolonged periods, economies such as China's are therefore not likely to attract a full-package of industrial activities (services and production) but a package heavily tilted toward energy-intensive activities. This is true both regionally and globally: more advanced economies, particularly in northeast Asia, have moved both manufacturing assembly operations and their industrial-driven energy needs and energy externalities to China (Gaulier, Lemoine, and Unal-Kesenci 2006). Although China is more energy intensive than advanced industrial economies, its per capita energy consumption is nevertheless relatively modest. Low per capita consumption figures, however, do not suggest that China, even if it were to achieve its efficiency targets, could simply do with its energy crunch what it has in so many other areas of economic and institutional reform—that is, grow its way out of the problem. To the contrary, low per capita consumption suggests that energy demand in China is likely to rise substantially. Although high U.S. consumption patterns might not presage China's future, the more modest patterns associated with Japan, the Republic of Korea, or the European Union—already several times China's current consumption levels—probably serve as indicators of the direction in which China is heading.

Moreover, because of several factors—some specific to China, others related to broader changes in the global organization of production—energy intensity is unlikely to decline as quickly as that of previous modernizers. Because it enjoys the mixed blessing of vast domestic coal reserves, for the foreseeable future China will probably continue to rely on coal as the main source of energy. With its high carbon content, coal burns less efficiently than other hydrocarbons (such as oil or natural gas). The more carbon in a hydrocarbon fuel, the less energy it has (lower hydrogen to carbon ratios entail lower efficiency of combustion). To the extent that China remains dependent on coal, it will have to forgo the efficiency gains associated with the switch even to alternative fossil fuels. In addition, higher quality coal is concentrated in the north and northwest, thus necessitating energy-consuming (often oil-consuming) transport to industrial centers along the eastern and southeastern coast (60 percent of railroad transport is powered by coal). China's problem, therefore, is not just that fuel has to be transported over great distances but that the material being transported is not energy dense.

China's Unique Energy Security Challenge

The nature of China's "energy security" challenge goes beyond the fact that growth and modernization alone are not solutions to the supply-demand gap. In the broadest sense, energy security involves the accommodation of difficult-to-reconcile objectives: adequate energy for long-term economic growth, energy that can be secured without exposure to undue geopolitical risk, energy supply and utilization consistent with long-term public health, and energy supply flexible enough to meet rising popular expectations for public and private goods.

Under normal circumstances, these demands would be difficult to meet. China's circumstances are not "normal," however, for several reasons. First, on the domestic front, the variables feeding into the energy security calculus are shifting with extreme rapidity. China is simultaneously experiencing an industrial revolution, an economic boom, a rapid phase of urbanization, and, in many respects, an information revolution, particularly at the level of the individual citizen. Citizens have increasingly come to expect not only macroeconomic growth and the energy necessary to fuel that growth but also a wide array of goods associated with advanced economies (consumer goods, ranging from refrigerators to automobiles, and public goods, ranging from clean air to comprehensive health care). This expectation means that energy provision—in terms of both quantity and quality—has become central to the issue of good governance. Put simply, good governance in China today entails fueling an industrial revolution as dramatic as anything experienced by 19th century England but doing so in a manner acceptable to a public whose living standard expectations are decidedly 21st century and cosmopolitan.

Second, these challenges must be resolved at a time when at least one key global energy resource, petroleum, appears to be approaching depletion in the medium term. Optimistic forecasts suggest that peak global oil production (Hubbert's Peak, or the point at which expansion of production ceases and a depletion curve ensues) will occur around 2035; more pessimistic views assert that this point has already been reached (Deffeyes 2005). The amount of oil recorded each year as known reserves peaked in 1961. Since then, technological advances have permitted commercially sustainable drilling in the North Sea, Africa, and the Arctic. Much of the "easy oil" appears to have been extracted, however, and new finds are becoming smaller and smaller. The "easy oil" that does exist remains primarily in the Persian Gulf and more broadly in member nations of the Organization of the Petroleum Exporting Countries (OPEC).

In 2006 Gulf countries accounted for 31.1 percent of global crude oil production. Saudi Arabia alone accounted for 12.9 percent of global production (IEA 2007a). Given political instability in the region, the security and reliability of these flows are uncertain. Precisely as China moves toward becoming a modern economy, the future availability of petroleum is in serious doubt.

Whether and when peak global oil production will be reached is uncertain. What is clear, however, is that China is viewed by many of the world's largest energy producers and consumers alike as putting a major new strain on global energy resources and markets. China's consumption patterns, and the choices China makes to secure the resources needed to meet those consumption needs, have become matters of concern for a number of countries. Geostrategically, "business as usual" on the energy front for China may entail increased competition and conflict with other major consuming nations, particularly the United States. China has little choice, then, but to seek to redefine traditional developmental paths and chart an alternative energy course into the future.

Internalizing Externalities

Charting a path to the future involves complex decisions, ultimately about price. In the case of energy, however, calculation of price entails the internalization of extensive and highly ambiguous externalities. Coal, for example, appears inexpensive in the near term for China. But if coal is burned without environmental cleanup mechanisms, flue gas desulfurization systems, and related technologies, it imposes a costly public health toll. To the extent that the public deems urban environmental conditions unacceptable, such sentiments also have political ramifications.

Factoring these costs in raises the cost of domestic coal. But replacing coal with alternative energy sources, such as imported petroleum or natural gas, also creates negative externalities, such as the need to invest in military assets to protect sea lanes or in diplomatic relationships with suppliers. Taking these considerations into account, coal—albeit coal produced using sophisticated decarbonization, gasification, or liquefaction processes—may be the least costly fuel after all.

Some "clean-coal" technologies, while promising, are unproven technologically and commercially. Development costs may be high, but they may permit the realization of positive externalities in industrial innovation and global competitiveness. Even in the relatively near term—the 5- to 10-year horizon—externalities make the calculation of cost in the energy sector exceedingly complex, enough so to force policy makers to consider all options.

Given the scope of its energy needs, and its centrality in global production networks, China appears likely to be the place where "new to the world" energy-related innovations—in civilian nuclear power, clean-coal technologies, efficiency-related upgrades on the consumption side, and a variety of other areas—will be implemented for the first time. Whether it is foreign or domestic players who design and implement these innovations is open to question; that China will be the venue is almost beyond doubt. How this emerging reality will then feed back into Chinese economic development and affect China's position globally on the industrial innovation front represents an important issue for policy makers and commercial actors alike.

Trends in Energy Consumption

China accounted for 14.2 percent of the world's total energy consumption in 2005 (IEA 2007a). Virtually across the board in the energy sector, China represents the fastest-growing market in the world. Electric power generation, 70–80 percent of which is consumed by industry (a range that has remained relatively stable in the reform era) faces tremendous expansion pressures to meet the relatively conservative projections for industrial demand growth. The industrial sector is the driver of outcomes today; demand in the transport, urban residential, and commercial sectors remains relatively small but will grow significantly in the future (table 6.5).

Transport and Automobiles

For decades, primary energy consumption in China has been dominated by the electric power sector. This trend continues today at steady growth levels, predictably driving demand for domestic coal.

A newer, more dynamic, and less predictable phenomenon is the rising demand from the transport sector, demand that involves liquid hydrocarbons—petroleum today, but possibly liquefied natural gas and coal-based liquids in the future. As the government ramps up infrastructure investment and continues to promote the automobile industry, transportation-related energy demand is projected to rise 4.0–5.5 percent a year in the medium term. Noteworthy is both the pace of growth and the fact that the required fuels are domestically scarce.

The increase in demand for petroleum is already evident. By the start of 2004, China was just overtaking Japan as the world's second-largest

Table 6.5. Total Energy Consumption, by Sector, 1997–2005
(ten thousand tons coal equivalent)

Sector	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*
Industry	92,375.3	88,521.9	87,151.2	95,442.8	98,273.3	104,088.1	121,731.9	143,244.0	159,491.6
Total residential consumption	16,368.0	14,392.7	15,213.9	15,964.6	16,567.5	17,527.4	19,827.2	21,281.0	23,449.5
Transport, storage, and post	7,286.3	7,957.0	9,011.8	10,067.1	10,363.0	11,171.0	12,818.8	15,104.0	16,629.2
Farming, forestry, animal husbandry, fishery, and water conservancy	5,905.4	5,790.3	5,993.4	6,045.3	6,400.3	6,612.5	6,716.0	7,679.9	7,918.4
Wholesale and retail trade and catering	2,394.4	2,552.1	2,901.5	3,038.8	3,265.0	3,520.3	4,179.6	4,820.3	5,031.1
Construction	1,179.0	1,612.1	1,979.4	2,142.5	2,234.0	2,543.7	2,859.6	3,258.6	3,411.1
Other	4,702.8	5,212.6	5,562.5	5,851.5	6,096.4	6,334.1	6,818.7	7,838.8	8,691.2
Total	137,799.0	132,213.9	133,831.0	138,552.6	143,199.2	151,797.3	174,951.6	203,227.0	224,682.0

Source: NBS various years.
Note: Totals may not sum correctly because of rounding errors.

consumer of petroleum products. Almost a decade earlier in 1993, China had become a net importer of oil (U.S. Department of Energy 2006). China's oil demand is projected to reach 14.2 million barrels a day by 2025 (see table 6.2).

Chinese demand for oil imports rose steadily throughout the 1990s, at 4 percent a year; by 2005, domestically produced crude oil accounted for only 55 percent of total Chinese oil consumption. Strong demand for oil has made China a significant enough oil importer to move markets. The spring 2004 spike in oil prices was at least partly related to China's surging demand for imports, particularly in the context of an increasingly uncertain geopolitical situation in the Persian Gulf. Economic development naturally increases demand for transportation- and transport-related fuels. Rapid industrialization drives demand for electric power, which drives demand for coal, which must be transported through an increasingly extensive rail and road system. Similarly, expansion and integration of markets for intermediate industrial and final consumer goods means that increasing amounts of material must be transported by air, rail, and road. Throughout the 20th century, modernization has entailed the expansion of transport economies. And unlike electric power generation, transport depends almost exclusively on oil: transport accounted for 60.3 percent of world oil consumption in 2005, the single-largest sector by far (IEA 2007a).

In China, this natural shift is being accelerated and encouraged by governmental policy. The automobile sector has been promoted as a key "pillar" industry, on the basis of a series of presumed spillover effects. Its extensive network of supporting and related industries is expected to provide employment, and its technology intensity is expected to promote innovation and global competitiveness. Its final product simultaneously drives the deepening of financial markets (through auto financing), stimulates growth (through personal consumption), and meets demands for mobility and modernity on the part of an increasingly sophisticated emerging middle class.

China is hoping that the automobile industry will do for it in the 21st century what the industry did for the United States and Japan in the 20th century. The danger is that China is pursuing this industrial strategy at a time when petroleum resources globally are becoming stretched and popular awareness of the potential impact on already strained domestic environmental and infrastructure conditions is growing. In this sense, China is on a trajectory comparable to other developing nations, such as Thailand, where rapid growth in personal transportation led to severe traffic congestion and severe environmental problems in urban areas.

China's automobile sector has boomed since 2001. In 2002, China produced and sold 1 million cars, up 50 percent from the previous year. In 2006, China surpassed Japan as the world's second-largest auto market (behind the United States), with total sales of 7.2 million units ("China 2007 Auto Output"). By 2030 the total number of vehicles, estimated at 37 million vehicles in 2006, is expected to grow to 370 million (Rosen and Houser 2007). Between 2002 and 2012, Chinese purchases are expected to account for one-fifth of all new car sales in the world (Rosen and Houser 2007).

Automobiles create a variety of negative externalities. Although use of newer vehicles tends to increase fuel efficiency on a vehicle-mile basis, the trend globally in recent years has been toward decreases in fuel efficiency on a passenger-mile basis, as rising levels of automobile ownership have increased the use of single-occupant vehicles, increasing traffic congestion. Such conditions are already apparent in most major Chinese cities. Particularly when promoted officially as the anchor of a consumer economy and socially as a key indicator of sophistication and modernity, automobiles encourage extremely inefficient utilization of energy, with substantial environmental costs. Advances in internal combustion engine technology, infrastructure, and "smart" traffic management systems will lead to efficiency gains in the future, but they are likely to be offset by the inefficiencies of declining mass-transit use and the rising costs of pollution. China's macroeconomic growth requires the expansion of the transport economy, but automobiles need not be a primary mode of transportation. That they have become one is a reflection of choice rather than necessity.

This choice induces energy-related externalities in urban planning. Promotion of automobiles necessitates massive road and infrastructure construction. Severe constraints on land in Chinese cities and limited public funds mean that construction of this infrastructure comes at the expense of mass-transit systems. At the individual consumer level, automobile ownership has enabled movement, particularly by the wealthy, to suburbs, where parking is available, larger homes (associated with more energy-intensive heating and cooling, more appliances, and so forth) are possible, and commuting in a single-occupant vehicle is common.

The substantial investments being made in the extensive supporting energy infrastructure for automobiles—petroleum distribution facilities, filling stations, and so forth—raise the costs of switching to alternative transportation fuels in the future. This extensive supporting infrastructure creates a variety of vested interests that also make it difficult to switch to alternative fuels and alternative modes of transportation.

The decision to promote automobiles will have tremendous ramifications for China's ability to adapt to changing energy circumstances in the future. Significant vulnerabilities (urban pollution and congestion, dependence on external and uncertain sources of oil, and so forth) and substantial opportunity costs (investment in a public transport infrastructure, investment in alternative fuels, and so forth) are being incurred as a result.

Urban Residential and Retail Energy Demand

The second major shift in energy demand is coming from rising urban residential and commercial utilization. Urbanization and rising incomes are usually accompanied by steep increases in household electricity consumption. Acquisition of energy-consuming durable goods (washing machines, televisions, refrigerators, and PCs) becomes the norm, and demand for energy-intensive heating and cooling rises. In 1990, there were about 42 refrigerators and 59 color televisions and 0.34 air conditioners for every 100 urban households in China. By 2005, those figures had grown to 91, 135, and 81, respectively (NBS 2006).

Globally, increasing urban demand for electricity has moved forward in tardem with global information technology (IT) revolution. On the one hand, the proliferation of computers, routers, and related IT infrastructure has permitted the realization of certain energy efficiencies. Lean production has led to efficiencies in transport and transport-related fuels; digital transmission of information has reduced the need for face-to-face interaction and related travel; and IT–related smart traffic management systems ease energy-wasting congestion. On the other hand, increases in efficiency have been outmatched by the even greater increases in aggregate energy demand as residential and commercial consumers around the world are surrounding themselves with IT-related products and equipment. The net result has been that in the context of the IT revolution, countries as diverse as the United States and China have experienced increased demand for electricity in the urban household and retail sectors.

Urban populations are more directly exposed to the pollution effects of power generation. Thus, clean power generation becomes a primary concern, as does the desire to move heavy industry outside cities, increasing the need for energy-consuming transportation development. Pressure for clean power encourages the promotion of noncoal-fired power plants, increasing demand for fuels such as natural gas or liquefied natural gas, which, particularly in the east and southeast, increasingly come from overseas. Urban consumer electricity demand entails more-complex power management than traditional industrial utilization. Consumer demand fluctuates on a seasonal and daily basis; it not infrequently exhibits significant surges. Variability and intermittency create pressures for movement toward more flexible fuels and generating facilities and more-distributed modular power systems. Traditional large-scale coal-fired plants become far less attractive, whereas smaller-scale systems, often utilizing natural gas or other more energy-dense fuels, which can be brought on and off line, gain in appeal. As distributed power systems (based on fossil fuels or renewable alternatives) proliferate, pressures increase to find an effective currency for energy, a storage fuel (liquefied hydrogen, liquefied coal, coal-based syngas, or a variety of other options) that can be transported easily across complex networks of smaller power-generation facilities and multiple utilizations.

Rising urban demand creates pressures for substantial change in urban energy infrastructure, energy management, and technological development. Concerns about energy consumption should force thoughtful consideration of public choices about urbanization strategy. Even with an effective push toward efficient distributed power systems, China will still likely suffer stiff energy penalties if policies of dispersed urbanization are pursued. This is particularly true in transport, because smaller-scale, more-dispersed locales are less suited than large compact settings to extensive intraurban public transportation development. At the same time, dispersed urbanization creates pressures for more-extensive, energy-intensive interurban transport, whether by road, rail, ship, or air.

Trends in Energy Production and Supply

Domestic production and supply of all fuels have increased since 2001. Despite those efforts, supply has been outstripped by demand.

Coal

In 2005, 76.4 percent of China's primary energy production came from coal, 12.6 percent from petroleum, 3.3 percent from natural gas, and less than 7.7 percent from nuclear, hydropower, and wind (NBS 2006). In terms of the narrow definition of cost, coal is the cheapest fuel for large power plants. The power industry in China is by far the largest consumer of primary energy. Moreover, heavy industry—which is likely to remain a substantial component of the Chinese economy, regardless of gradual shifts toward services and more information-intensive sectors—is a massive consumer of crude coal.

While over the long run, coal's share in overall national energy consumption will gradually fall, absolute demand for coal will continue to rise, and for the foreseeable future, coal will remain the mainstay of China's energy supply (MIT 2007).

Efficiency gains can be realized at various stages, including in the processing and conversion, transportation, storage, and final consumption of coal. Several projects exist for the colocation of large coal-fired power plants near large, high-quality, low-sulfur content mines. One advantage of locating coal near these mines is that crude coal no longer need be transported across great distances. Options for utilizing the power that is generated include transmitting coal by wire across power lines, with some loss resulting in the process; creating coal-based liquid fuels, which could be transported relatively cheaply and could substitute for petroleum in the transport sector; producing coal slurry, which could be transported by pipeline; and, potentially in the future, producing liquefied hydrogen.

A number of experimental projects are under way, including the Shenhua Group's coal liquefaction facility in Inner Mongolia and a variety of other efforts involving coal gasification and coalbed methane production (UNESCO 2007). China has also expressed interest in experimental decarbonization and carbon dioxide sequestration technologies for coal-based power generation.

Petroleum

Use of petroleum and natural gas, while still a small portion of China's total energy supply, has accelerated in recent years. This trend is consistent with pressures associated with modernization and other policy-induced factors (particularly the emphasis on automobile production and ownership). Rising use of petroleum and natural gas increases dependence on overseas energy resources (table 6.6).

In response to this growing dependence on imported oil, Chinese firms have been acquiring interests in overseas upstream exploration and production. Concessions have been acquired in Azerbaijan, Républica Bolivariana de Venezuela, Indonesia, Islamic Republic of Iran, Iraq, Kazakhstan, Peru, and Sudan (U.S. Department of Energy 2006). The potential geopolitical risks are obvious, as is the challenge of competing with other import-dependent oil consumers in East Asia, namely, Japan and the Republic of Korea.

Natural Gas

Natural gas, which has never been an important fuel in China, began to receive substantial attention in the mid- to late-1990s. Accounting for 3 percent of total energy consumption in 2005 (NBS 2006), natural gas

Table 6.6. Imports and Exports of Energy, by Type, 1991–2005

(ten thousand metric tonnes, unless otherwise noted)

Item	*1991*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*
Imports												
Coal	136.8	163.5	321.7	201.3	158.6	167.3	212.0	249.0	1081.0	1109.8	1861.4	2,617.1
Crude oil	597.3	3400.6	2261.7	3546.6	2732.0	3661.4	7027.0	6026.0	6941.0	9102.0	12272.0	12,681.7
Gasoline	11.2	15.9	7.9	8.4	1.5	0.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Diesel	319.6	612.3	465.1	742.8	310.8	30.9	25.9	27.5	47.7	84.9	274.9	53.2
Kerosene	2.6	76.1	65.9	138.1	129.1	211.2	255.5	201.9	214.5	210.3	282.0	328.3
Fuel oil	124.6	659.1	942.6	1,371.1	1,627.2	1,757.0	1,480.0	1,823.6	1,659.7	2,395.5	3,059.2	2,608.6
Liquefied petroleum gas	n.a.	232.6	355.0	358.2	476.6	322.3	481.7	488.9	626.2	636.7	641.0	617.0
Other petroleum products	11.5	95.7	106.5	176.1	190.6	208.1	161.5	201.3	384.3	432.1	384.2	443.4
Natural gas (10^8 cubic meters)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Electricity (10^8 kWh)	31.1	6.4	1.2	0.9	0.2	3.7	15.5	18.0	23.0	29.8	34.0	50.1
Exports												
Coal	2,000.1	2,861.7	3,648.4	3,073.0	3,229.7	3,743.9	5,505.0	9,012.0	8,384.0	9,402.9	8,666.4	7,172.4
Crude oil	2,259.8	1,822.7	2,040.3	1,982.9	1,560.0	716.7	1,031.0	755.0	766.0	813.3	549.2	806.7
Gasoline	250.2	185.5	131.4	178.2	182.0	413.8	455.2	572.5	612.0	754.2	540.7	560.0
Diesel	121.0	130.6	157.4	232.1	98.5	60.5	55.5	25.6	124.0	224.0	63.7	147.6
Kerosene	32.1	37.4	74.4	72.3	91.6	125.0	198.8	182.2	170.0	201.7	205.0	268.7

(*continued*)

Table 6.6. Imports and Exports of Energy, by Type, 1991–2005 (*continued*)

(ten thousand metric tonnes, unless otherwise noted)

Item	*1991*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*
Fuel oil	69.5	27.8	36.6	51.7	57.5	25.5	33.4	44.1	64.0	76.1	181.7	230.0
Liquefied petroleum gas	1.1	7.1	33.3	39.2	50.2	7.5	1.6	2.1	5.6	2.4	3.2	2.7
Other petroleum products	148.8	131.1	117.3	155.7	202.5	221.0	280.5	325.5	246.0	261.8	360.7	473.0
Natural gas (10^8 cubic meters)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	24.4	29.7
Electricity (10^8 kilowatts)	2.6	60.3	37.1	72.0	71.7	91.5	98.8	101.9	97.0	103.4	94.8	111.9
Coke	108.3	886.1	768.6	1,058.1	1,146.4	997.4	1,520.0	1,385.0	1,357.0	1,472.1	1,501.2	1,276.4

Source: NBS various years.

n.a. Not available.

is expected to become an increasingly important fuel in the future as Chinese cities seek cleaner sources of energy (author interviews). Construction of the extensive infrastructure needed to support this fuel—pipelines to distribute gas; shipping trains, port terminals, and gasification facilities needed to handle imported liquefied natural gas—is well under way (Watts 2006).

Nuclear Power

Nuclear power has been developing rapidly, albeit from a low base, particularly with respect to the electricity sector. Generally speaking, nuclear power is a more expensive means of generating electricity than coal or natural gas.

In 2005, the government declared its goal of adding 40 GW of civilian nuclear power capacity by 2020. China's nine civilian nuclear reactors had a total generating capacity of roughly 7 GW in 2006 ("China's Goal" 2006). Nuclear power accounted for 2.3 percent of Chinese electricity generation and 0.85 percent of total Chinese energy production in 2004 (IEA 2007b). Even with the most ambitious growth program, nuclear power will likely account for little more than 5 percent of total energy supply in the coming decades.

Hydropower

Hydropower represents an important component of Chinese electric power generation, although it accounts for a relatively small component of total energy production. In 2004 hydropower accounted for 2 percent of total Chinese energy production and 16 percent of electric power generation (IEA 2007b).

Increasing hydropower's contribution to China's overall energy mix is difficult, because the sources of hydropower tend to be in the center and west of the country, far from the main areas of regional demand along the coast. The costs and energy inefficiencies associated with large-scale national transmission and distribution systems are immense and arguably prohibitive. These inefficiencies are exacerbated by the significant sociopolitical and environmental costs of large-scale hydropower projects.

Policy Directions for the Future

China's overall energy strategy is somewhat confused and uncoordinated—not unlike that of the world's other large consuming nations, including the United States. China has pursued a number of ambitious efficiency goals and conducted a variety of interesting local experiments. These include Beijing municipality's establishment of coal-free zones, Shanghai's maglev train, regional pollution-rights trading programs, a national tax on high-sulfur coal, and municipal efforts to shift public buses over to cleaner burning fuels. This multiplicity of approaches, however, particularly when combined with other national goals that impinge indirectly on energy, creates confusion and unintended consequences. Not unlike approaches to other aspects of institutional reform in China, energy policy has been fragmented, both horizontally and vertically. Numerous experiments, competing standards, and alternative microlevel approaches have been allowed to proliferate. At the same time, at the central level, as in most countries, various aspects of energy policy—or policy areas that impinge on energy issues—end up spread in uncoordinated fashion across a range of administrative organs. Such diffusion and fragmentation make all the more difficult the internalization of the externalities associated with national energy choices.

Whether by default or design, national industrial policy is energy policy. The decision to promote automobile production and consumption has implications for energy demand and urban planning; it also diverts research and development (R&D) resources away from alternative energy projects.

Macroeconomic growth policy is also energy policy. Policies that promote growth and urbanization not only increase demand for energy, they also alter the kinds of energy demanded.

Environmental regulatory policy is also energy policy, to the extent that it shifts the relative costs of fuels and the availability of energy-efficient appliances and materials. Health care policy is also energy policy, for it ultimately must cope with the impact of pollution on people. Finally, given increasing dependence on foreign energy sources, foreign policy is energy policy because ultimately it must be directed toward guaranteeing steady overseas supplies.

Meeting China's energy needs does not necessarily require centralized solutions, such as large-scale regional power-generation projects or nationally integrated power grids. Quite to the contrary, distributed, modularized power arrangements are in many cases better suited to China's highly varied geographic, demographic, and developmental landscape. The point is that given the centrality of energy policy to China's development goals, that centrality demands concerted attention and comprehensive cross-bureaucratic coordination.

By virtue of its market size and rapid rate of growth, China has the ability to make markets. In setting and enforcing tough energy-efficiency standards for consumer appliances and vehicles, the government leaves foreign producers little choice but to comply and innovate. Similarly, to the extent that domestic producers are forced to meet these standards, they develop core competencies in the design, development, and production of energy-efficient products, competencies for which global markets will only grow as energy constraints become more binding on all nations in the future.

As they chart their way to a more sustainable national energy posture, Chinese policy makers face important choices over a wide range of technologies and energy-related sectors. The areas and recommendations listed below are intended to outline the domains across which change is both possible and likely to proceed.

Improving Energy Efficiency

Rather than promoting automobiles or semiconductors as drivers of national innovation, the government should direct industrial policy toward the development of alternative-energy vehicles and renewable energy technologies. A national effort on these fronts not only would address domestic energy supply issues, but also would set up Chinese producers to become key innovators in an increasingly energy-constrained world. In short, China should use its power as a global producer and global consumer to make energy efficiency and energy-related innovation the core of its national industrial competitiveness.

China must deepen its commitment to end-use, energy-efficiency improvements. In many cases, regulations are already in place but not uniformly enforced. As the building of urban commercial and residential space ramps up, it is imperative that the government promote energy-efficient designs and construction materials. By the beginning of 2007, China had become the world's largest construction market, adding roughly 2 billion square meters of floor space every year (Worldwatch Institute 2007). As of the end of 2006, the manufacturing and transport of building materials, the construction of new residential and commercial space, and the heating and cooling of buildings consumed 45 percent of China's total primary energy. The 11th Five Year Plan (2006–10) calls for energy savings of 50 percent in new buildings, but local developers are loathe to pay the higher up-front costs for energy-efficient materials and building systems. Given the potential long-term energy—and, by extension, cost-savings from more-efficient construction techniques and materials—to government needs to enforce its emerging building standards and to educate the public at large about the overall economic and environmental benefits.

It is also imperative that the government enforce the new fuel standards for automobiles that it promulgated in 2004. Particularly given the appeal of its automotive market for global producers, China has every reason to become a global leader in pushing vehicle fuel and emissions standards. The first phase of the new standards went into effect in 2005, and the second phase will commence in 2008. Enforcement has been, and will continue to be, a main challenge in this process. Lax enforcement threatens to vitiate not just the standards but the credibility of the government more broadly.

End-use efficiency enhancement must be coupled with measures to ensure that efficiency gains do not lead to expanded usage, as they have in many countries. Achieving this goal will inevitably involve complex management of domestic tariff structures. In transport, for example, the government will almost certainly have to explore restrictions on automobile access to urban areas (along the lines of London's congestion pricing or Singapore's road-use pricing).

Allowing Market Forces to Operate

It is critical that energy prices be permitted to reflect market forces of supply and demand. For the most part, coal prices in China do reflect current domestic supply and demand conditions, but prices for oil and electricity clearly do not. The current system of setting domestic oil prices based on international levels (through a formula based on monthly averages in Singapore, Rotterdam, and New York) insulates domestic prices from local market guidance and leads to shortages. Oil prices need to be freed up domestically, so that domestic suppliers and consumers can adjust accordingly.

Similarly, retail electricity prices tend to be shielded from market guidance. Prices are kept artificially low, facilitating even more rapid growth in household appliances and unprecedented high peak power loads in major Chinese cities. What results are blackouts and brownouts. Electricity prices must be allowed to reflect basic fuel prices, for coal, oil, or natural gas.

Shifting to Gasification

Although coal will remain the dominant primary energy source, emphasis must shift from combustion technologies to gasification. Such technologies permit the production of cleaner gas and liquid coal-based fuels, alternatives to imported natural gas and petroleum. Gasification and liquefaction also facilitate potentially commercially viable carbon dioxide capture and sequestration, thus addressing the emission not only of sulfur dioxide but also of carbon-related greenhouse gases. These technologies are still experimental today; focused research and development efforts are required to bring down costs and attain commercial viability. Such improvements are arguably more important—and more globally applicable—than anything else China could do today in the area of national industrial policy.

Integrating Renewable Energy Sources on a Large Scale

With the development of more-modular, distributed power systems, the ability to integrate renewable energy sources on a large scale becomes increasingly feasible. As suggested by the government's 2005 National Renewable Energy Law, there is potential for far greater use of wind and solar energy. Using Japan's example to craft a regulatory framework that supports photovoltaic use in urban residential and commercial buildings or Germany's Freiburg model to promote both wind and solar power at the municipal level ("Germany Sets Shining" 2007), China could substantially increase its use of alternative renewables. Large-scale wind farms in the west could be linked to urban centers by high-voltage DC transmission lines. With or without a shift toward hydrogen, China should aim to rely on alternative wind and solar power for 10 percent of its total energy supply by 2020. This would involve using sizable tracts of land not too far from centers of consumption.

Price Reform and Marketization in the Power Sector

It is in the power sector that some of the most dramatic changes in China's energy posture are manifested today. Driven both by industrial and urban household consumption, demand for electricity is soaring in China. As China rushes to meet this demand by building new generation facilities, expanding transmission networks, and securing new sources for key fuels, the ramifications for everything from living standards to overall national security are vast. On the electricity supply side, China faces urgent decisions regarding types of generation technologies and fuel feedstocks to invest in, the location of new generation facilities, and the upgrading of transmission networks to transport power regionally and nationally. On the demand side, equally substantial issues are associated with how, where, and when consumers use power.

The choices made today have monumental consequences for the future. Through these choices, China can launch itself on a path of sustainable energy utilization—a path that will at once foster growth, rising living standards, and stability, both within and beyond China's borders.

Principles of Marketization and Pricing in the Power Sector

Technological innovation and efficiency-promoting regulation in the power sector are important elements of a long-term strategy. But the most fundamental element—the one on which the success of further reforms will hinge—is the issue of price reform and marketization. Prices in any market are essential not just for collecting revenue but also for ensuring sufficient supply and efficient utilization. To the extent that price signals are clear and unrestricted, they indicate to consumers the cost of producing the goods or services consumed; they indicate to producers the willingness of consumers to pay. In theory, the market-clearing price should settle at the intersection of the marginal cost of the last producer and the marginal value to the last consumer. It is through this price that resource allocation should ultimately be determined.

Pricing for power is not so simple. Electricity consumption flows over time in a pattern of wide peaks and troughs. Because electricity cannot be effectively stored in low-demand periods, it must be generated when needed. This fact has several important ramifications for the prices of electricity generation.

First, it makes sense economically to build generating plants of varying technologies and fuel types. Some plants should be able to run all the time at low cost (without being easily be ramped up or down in the short run); others should be able to start and stop on short notice.

Second, as demand rises and falls, certain generating plants will come on- and offline. The determination of the order by which this takes place ("dispatch") should be driven by short-run marginal cost. Through "merit-order dispatch," plants with the lowest marginal costs are brought online first, with those with higher marginal costs brought online in succession as demand rises. In this manner, short-run costs to the system as a whole are minimized.

Third, the price paid by the final customer should be set at the marginal cost of the system as a whole. The marginal cost of a generating system is the running cost of the last (most expensive) generating plant brought online each hour plus the value to the consumer of electricity at times when the system is short of capacity. In other words, output prices for generation should be set at the running costs of the marginal producer for each hour plus—for peak hours—a charge that recovers the investment cost of a peaking plant.

Transmission pricing, in its intermediary position between generation and distribution, has its own complexities. In a marketized electricity sector, one would expect to see a variety of competing generators that are dispatched on merit order. Given current wire-based technologies, however, transmission tends to be a monopoly activity necessitating some sort of regulated price. If the goal were simply to keep the transmission company solvent, one could divide total needed revenues by all the electricity sold, thus creating a "postage stamp" for use of the transmission system. Such a mechanism would ensure cash flow to cover the transmission company's existing cost structure, but it would not provide any pressures or incentives to shift the underlying technologies or management practices driving that cost structure. To achieve the incentive effects needed for efficient resource allocation and utilization, however, a more complex, market-oriented tariff is necessary, for two main reasons.

First, for efficient real-time use of a transmission network, users who at any given time are willing to pay more (and thus value the network more) need to be given priority over those who do not. Prices must ultimately manage congestion, a problem that if left unresolved leads to power outages and instability in the power system. The costs of such strain must be internalized. One mechanism for doing so involves the use of "nodal pricing." In any power system, unique "prices" for electricity can be defined at each node of the transmission system. Such prices vary locationally, depending on the amount of congestion in the system at a given point and the distance from generating plants (because distance drives the amount of electricity lost through transmission). In a marketized system, generators are paid the price at their location, while large consumers and distribution companies pay the price at their location. Congestion rents accumulate when nodal prices diverge. Regulation and supervision is then required to ensure that the transmission company—a local or regional monopoly in most cases—does not grab these rents and thus face incentives to increase congestion.

Second, marketized transmission prices are necessary to guide longer-term location and investment decisions, whether for electricity producers and consumers. Electricity generators generally like to be near their fuels, while major industrial consumers like to be near their markets and customers. Transmission tariffs need to reflect the systemic costs (caused by increased congestion or increased electrical losses) imposed by such decisions. The combination of a "postage stamp" transmission access fee and nodal price transmission tariff can achieve this reflection.

In summary, efficient, sustainable utilization of energy resources depends on myriad interconnected decisions by producers and consumers. The market, operating through the mechanism of price, is the most effective mechanism for guiding these decisions. Given the unique features of the electric power sector, however, marketization can proceed only if certain conditions are met. Because of the differing market structures of generation, transmission, and distribution, these three areas must be separated out in terms of both pricing and ownership. It is not enough simply to aggregate a series of charges related to electricity production and delivery and then divide them by a unit of electricity sold. Rather, to facilitate merit-order dispatch on the generation side—a critical underpinning of market pricing—competition must be permitted among generators.

Moreover, to ensure that dispatch actually proceeds on the basis of marginal cost, ownership of generation must be separated from ownership of transmission. To the extent that transmission entities are permitted to own generators, conflicts of interest inevitably arise, because transmitters favor their own generators in the dispatch ordering process and block the entry of new generators. Furthermore, particularly given the key role of regulation in the less competitive parts of the power sector (transmission and distribution), regulatory power must be separated from ownership.

Although the application of competition and market pricing generally begins in generation, it must not stop there. Particularly for systems facing immediate pressures for physical expansion, transmission pricing must go beyond mere access fees to ultimately reflect the costs of congestion and distance-induced losses. It is only at that point that price will effectively guide the sort of longer-term investment decisions by electricity producers and consumers that deeply affect the efficacy and physical status of the power system as a whole.

Reform and Marketization in the Chinese Power Sector

Market restructuring of the power sector has been a clear policy goal of the government since at least the mid-1990s. The 1996 Electricity Law permitted the entry of nonstate entities into the generating sector, recognized the need for electricity prices to cover producer costs, and acknowledged the need to separate the regulatory function of the government from the ownership role of power producers. This law was followed in 1998 by State Council Document 146, which mandated the separation of ownership of electricity generation from the transmission network, thus providing the means for an unbundling of generation and transmission prices and the means for merit-order dispatch.

State Council Document 5, issued in 2002, pushed the agenda substantially forward by calling for full competition in the power sector, beginning with generation. Market trials permitting generators to sell power directly to large customers were permitted. The document also identified a series of longer-term goals, including (a) the formal separation of generation from transmission in terms of ownership and regulation; (b) the establishment of competitive regional markets for dispatching generators; (c) the establishment of new pricing mechanisms, including mechanisms that take into account environmental impacts; and (d) the development of market-oriented pricing mechanisms for all parts of the electricity supply chain, including not just generation but also transmission, distribution, and retail pricing.

That the government committed itself to this highly ambitious and progressive agenda is both extraordinary and commendable. In at least one area—the freeing up of rules on power plant financing—the successes are indisputable. Changes appear to have been far less dramatic in other areas, although information is anecdotal. Diversification of financing for—and ownership over—power plants has driven a substantial ramping up of generating capacity since 2002.

At the same time, a vast gap remains between these goals and reality on the ground. Several reforms need to be made.

Improve the pricing of electricity. China's system of electricity pricing remains rigid, inefficient, and nonmarket oriented. Those are basically two types of tariffs: one for the purchase of power by provincial or regional power companies from independent power producers and one for the purchase by final consumers from the power company. The first tariff is determined contractually on a generator-by-generator basis. The second tariff is fixed, varying only by class of consumer (industrial versus household, high-voltage versus low-voltage, and so forth). The vast complexity in pricing is based not on time, place, or extent of usage—the factors one would expect market pricing to be based on—but on the nature of the customer. Moreover, these tariffs are unresponsive to shifts in supply and demand.

Unbundle generation and transmission pricing. No clear mechanism exists for passing along efficiency-related cost reductions on the part of generators to consumers, and no clear mechanism has been set for raising the funds needed to construct and upgrade transmission and distribution networks. No mechanism exists for incorporating into the final retail price of electricity the costs arising from system congestion and electricity loss through transmission.

Implement a clear method of market-oriented, merit-based generator dispatch. Dispatch hours (running times) are currently allocated to plants based on the principle of "fair" distribution. Because merit-order dispatch does not occur—and indeed cannot occur, to the extent that generation and transmission prices remain bundled—electricity prices remain fundamentally nonmarket oriented.

Simplify cross-subsidies and increase transparency of differential pricing systems. A substantial portion of electricity consumers—namely, the urban household sector—pay a low price for electricity, which is subsidized by higher-voltage industrial customers and the power generators themselves. Generators find themselves caught between liberalized, rising fuel costs and governmental restrictions on the amount that can be charged for electricity production. Even some of the newer power projects that have power purchase agreements (PPAs) with regional grid companies—which mandate prices higher than national standards—have faced substantial problems. The PPA mandated prices have been overridden by governmental pricing bureaus in the name of fighting inflation. Moreover, in regions where surplus power exists, state grid companies in some cases have refused to abide by the PPA take-or-pay clauses to which they initially agreed.

Implement regulatory restructuring. To the extent that the distinction between transmission company and generator and between commercial operator and governmental regulator remains blurry, real marketization is unlikely to occur. The problems of inflexible tariffs, bundled tariffs, nonmarket-based dispatch, price subsidies, and regulatory conflicts of interest are deeply intertwined. These problems fundamentally impede the sort of market-oriented price reforms that are absolutely necessary to guide the behavior of commercial producers and consumers as well as long-term investment decisions.

China can and should pursue a variety of means of ensuring energy security for the future. Among these means are regulatory regimes that encourage energy conservation, diversification into new fuels, and development and dissemination of energy-saving technologies. In the near term, however, price reform in the power sector stands out as not just the single-greatest policy challenge but also the one that, if met, will yield the highest near-term returns and have the most profound impact on the behavior of energy producers and the growing numbers of urban consumers alike.

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