Energy in China today

Where now for the world's energy giant?

Highlights

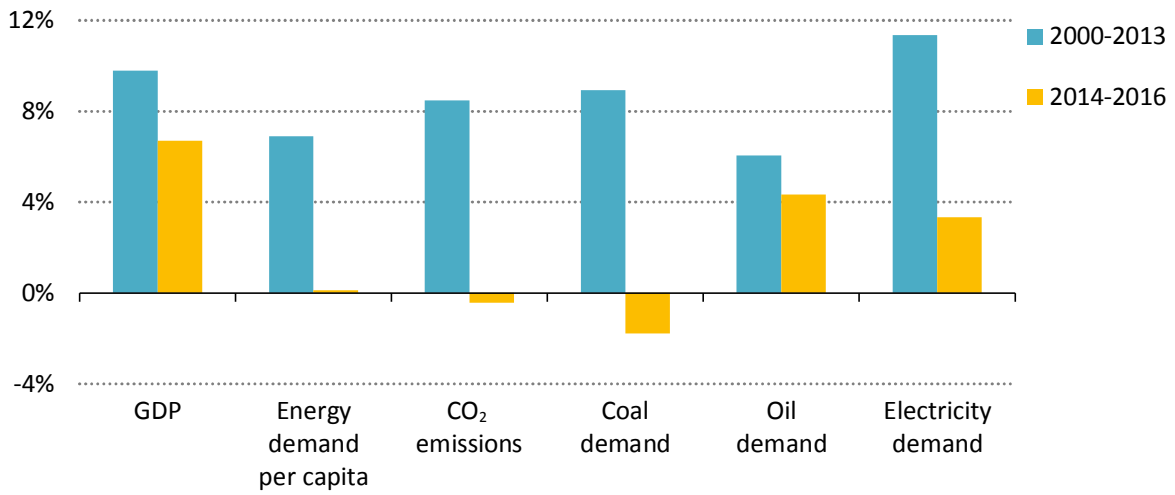
- China is changing. The economy is progressively moving away from reliance on heavy industry and towards domestic consumption, higher value-added manufacturing and services. Energy demand growth has slowed considerably in recent years, from an annual average of more than 8% between 2000 and 2010, to less than 3% per year since 2010. This reflects structural shifts in the economy as well as a strong policy focus on energy efficiency.
- In parallel, the dominance of coal and, to a degree, oil products in the structure of energy use is under challenge from more environmentally benign sources of energy. Coal use has fallen for three straight years since 2013. China is already the world's largest investor in renewables-based generation, a leader in energy efficiency policies, new technologies and other areas where energy is intersecting with the digital economy, and the world's largest market for electric vehicles.
- China's influence in global energy markets extends to all fuels and technologies. China is a pivotal country for global coal markets, accounting for around half of global production and consumption; it is the world's largest importer of oil, a rising force in global gas markets, the largest exporter of solar equipment and a leading player in almost all low-carbon technologies. Chinese companies have also become major investors in a wide range of energy projects abroad.
- There are major divergences among China's provinces and regions in economic and demographic trends, resource availability and energy use. Economic activity and energy demand are concentrated in the coastal eastern provinces, home to almost 35% of the population. Addressing regional disparities and improving infrastructure across the country is a major priority for the government.
- China's rapid economic rise over the past four decades has had significant effects on its environment and public health. The government has long recognised the extent of the problems and has imposed stringent policies to arrest the decline in air and water quality as well as to curb growth in greenhouse-gas emissions. This is another major priority for government action.
- The long-term goals of China's energy policies are defined by the president's call for an "energy revolution" in June 2014, which provides broad guidance for the energy five-year plans and other policies, as well as for the Energy Production and Consumption Revolution Strategy published in 2017. The overarching aim is to build a more secure, sustainable, diverse and efficient energy future.

12.1 Introducing the special focus on China

A special focus on the People's Republic of China (China) in the *World Energy Outlook – 2017 (WEO-2017)* should need no particular justification given the size of the country, the scale of its energy sector and its weight in global energy affairs. The huge changes in economic and energy policy underway in China at present are having an impact not just in the country and region but also in global energy markets: with 1.4 billion citizens and the second-largest economy in the world, what happens in energy in China matters.

For years, the dominant energy narrative on China concentrated on the extraordinary pace of its development, the country's success in lifting hundreds of millions of its citizens out of poverty – including energy poverty – and the voracious demand that this created for energy resources of all kinds, but primarily for coal and oil (Figure 12.1). Elements of this narrative remain valid today, and the energy infrastructure and environmental implications of this period of soaring growth will be with China for many decades to come. The country is changing course, however, and its new direction will have consequences that are no less significant for China and the world than the earlier period of energy-intensive development.

Figure 12.1 ▷ Comparisons in average annual growth rates for selected indicators in China, 2000-2013 versus 2014-2016



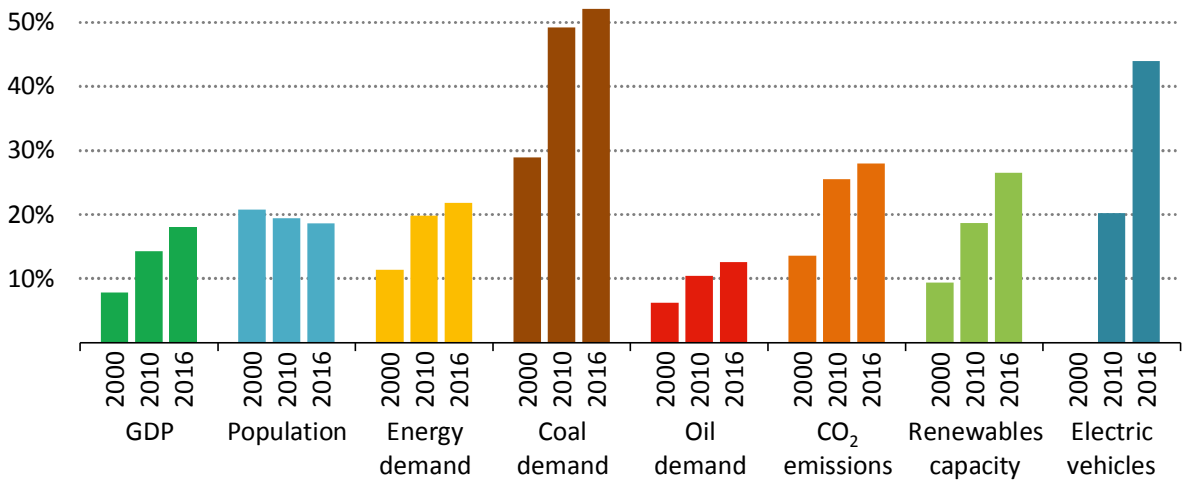
While the economy continued to grow strongly in 2014-2016, the implications for energy demand and CO_2 emissions were radically different than in previous years

Note: GDP = gross domestic product ($2016 billion, PPP).

The outlook for China depends on the outcome of a number of transitions that are underway, supported by policies aimed at securing a more sustainable model for China's future prosperity. The economy is starting to orientate away from a reliance on export-

driven heavy industrial sectors towards domestic consumption, higher value-added manufacturing and services. In parallel, more environmentally benign sources of energy are challenging the dominance of coal and (to a degree) oil products in the structure of energy use. The first fruits of China's declaration of a new "energy revolution" in 2014 are already visible (Figure 12.2).

Figure 12. ▷ China's share of selected global indicators



China has an immense presence in global energy across a range of fuels and technologies

Note: GDP = gross domestic product ($2016 billion, PPP).

For this in-depth assessment of China's energy sector and its prospects to 2040, we have conducted an extensive review of existing policies, regulations and programmes affecting the energy sector, as well as announced intentions. In each sector, we assess China's record of achievement and examine what this may imply for the speed of future action. Table 12.5 contains a summary of China's domestic policy objectives taken into consideration in the New Policies Scenario.

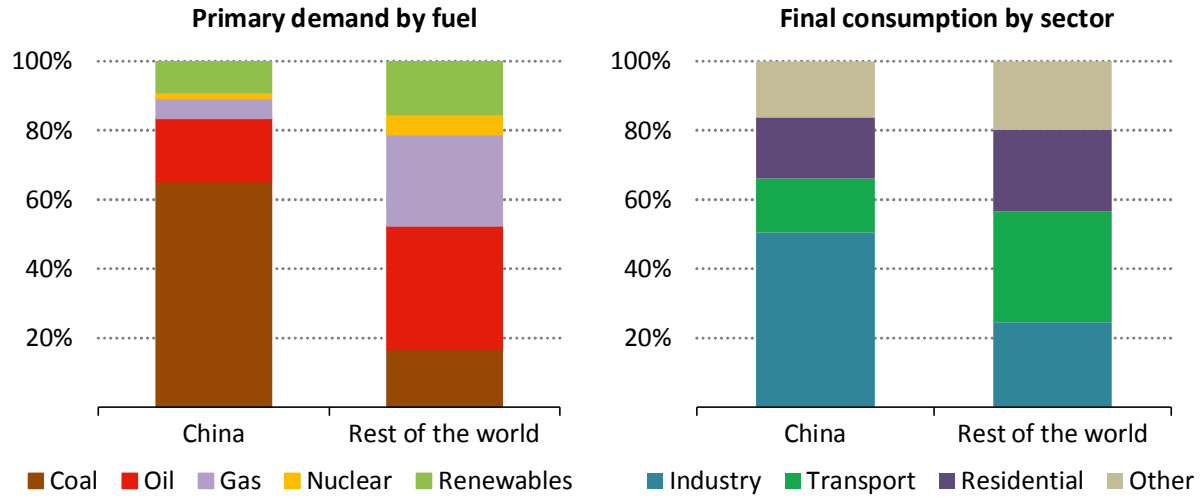
This report comes against a backdrop of a strong and growing partnership between China and the International Energy Agency (IEA), including a comprehensive three-year IEA/China Association agreement work programme, and with support from the newly created IEA-China liaison office in Beijing.[1] With major reforms underway, described in detail in the 13th Five-Year Plan, the aim of this special report is not to prescribe a path for China, but rather to provide a coherent framework in which China's own policy choices can be assessed. We consider their implications not only for the country's development, energy security and environment, but also for the integrated global energy system in which China plays a leading role.

1. This analysis has benefited greatly from regular discussions with Chinese officials, industry representatives and experts, notably during a high-level *WEO* workshop held in Beijing in February 2017, as well as from the input of Chinese colleagues seconded to the International Energy Agency.

12.2 Energy trends in China today

Coal largely fuelled the rapid industrial and economic growth that led to China becoming the world's largest energy consumer in 2009. Growth in demand for coal has averaged almost 7% each year since 2000: at the start of this period, China accounted for less than one-third of global coal demand, and its share is now more than half. Coal now accounts for almost two-thirds of China's primary energy demand, catering for much of the country's huge industrial demand for energy and providing the backbone of China's immense power system, which has accommodated a quadrupling in electricity demand since 2000. Despite the recent changes in momentum and direction, the starting point for our energy outlook is still an energy economy that, compared with the global average, has an atypical mix of primary fuels and a structure of consumption that is very heavily weighted towards industry (Figure 12.3).

Figure 12.3 ▷ Comparison of China's primary energy demand by fuel and final consumption by sector with the rest of the world average, 2016



The legacy of China's precipitous economic rise is a system heavily skewed towards coal and energy use in industry

Note: TPED = total primary energy demand; TFC = total final consumption; also see note with Table 12.1.

12.2.1 Energy demand

Between 2000 and 2016, total primary energy demand in China increased by more than 160%, at an annual average rate of 6%. This was lower than the average annual GDP growth of almost 10%, a divergence that brought a steady decline in energy intensity (Table 12.1). As noted, coal was responsible for the lion's share of this growth, but oil demand also rose sharply and China is now the largest oil-importing country in the world. The other major component of China's energy mix in 2000, after coal and oil products, was solid biomass, which was widely used for cooking and sometimes also for

heating. One of the less recognised energy achievements of China over the last two decades has been a dramatic reduction in the population depending on solid biomass for energy. In the last 15 years, 260 million people have gained access to modern fuels as urbanisation, 100% electrification and the extension of liquefied petroleum gas and natural gas supply have made alternatives more accessible and attractive.

Table 12. ▷ Selected energy and economic indicators for China, 2000-2016

Indicator	2000	2005	2010	2016	Change 2000/16
GDP ($2016 billion, PPP)	5 278	8 318	14 023	21 721	312%
Share of world GDP	8%	10%	14%	18%	-
GDP per capita ($2016, PPP)	4 158	6 347	10 428	15 685	277%
Total primary energy demand (Mtoe)	1 143	1 794	2 551	3 006	163%
Primary energy demand/capita (toe)	0.90	1.37	1.90	2.17	141%
Total CO_2 emissions (Mt)	3 127	5 399	7 726	8 973	187%
Energy intensity TPED/GDP (toe per $1 000, PPP)	0.22	0.22	0.18	0.14	-36%
Carbon intensity TPED CO_2/GDP (tCO_2 per $1 000, PPP)	0.59	0.65	0.55	0.41	-30%

Note: GDP = gross domestic product; PPP = purchasing power parity; Mtoe = million tonnes of oil equivalent; toe = tonne of oil equivalent; Mt = million tonnes.

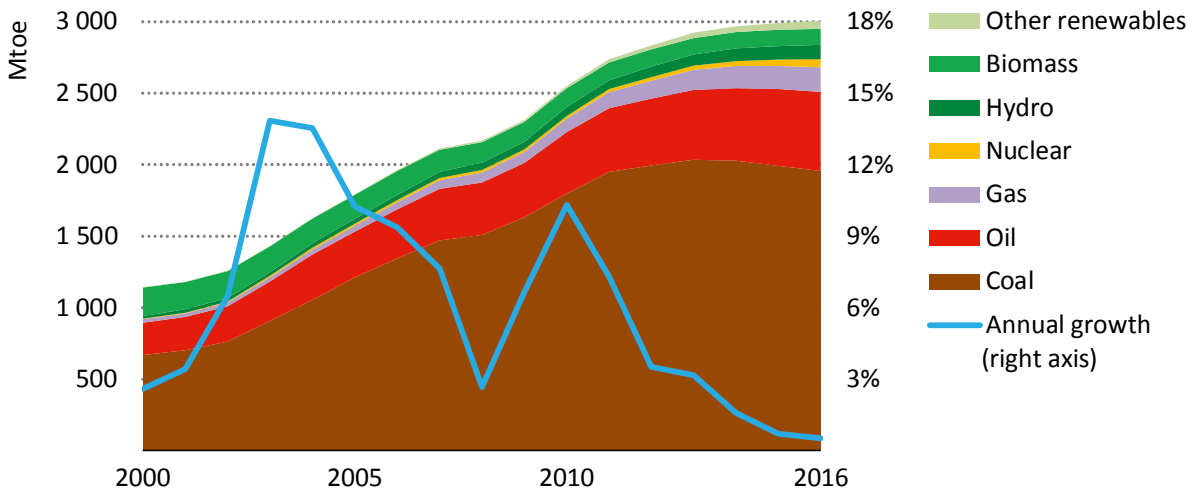
Notes on energy data: The national energy data used in this report are from IEA statistics and balances. These are taken or derived from China's National Bureau of Statistics (NBS), but differences in methodology mean that there are some variations between IEA and NBS data. These include the definition and method of calculating total primary energy demand (TPED); in some instances, projections of TPED calculated according to the NBS methodology are presented alongside the IEA number to aid comparison. All provincial and other sub-national data are sourced directly from the NBS and may not be entirely consistent with the national totals. The IEA, in close consultation with the NBS, regularly reviews and updates its China energy data to ensure it accurately incorporates China's latest published energy statistics.

Over the last decade, some new features have emerged more prominently in the primary energy mix, as China's policies have sought to move away from the strong reliance on coal, bring more diversity to its energy mix and tackle some burgeoning environmental issues, notably the deterioration in air quality (Figure 12.4). Natural gas has been a prime beneficiary of this policy drive, and its share in the energy mix has more than doubled over the last ten years, albeit from a base that was only a small fraction of the global average. China has built pipelines and liquefied natural gas (LNG) regasification terminals linking the country with new sources of gas (including a large-scale connection with resource-rich Turkmenistan and additional plans with Russia). The use of natural gas has increased among all energy end-use sectors in China, with the power generation and heat sectors accounting for a large part of the increase.

The impressive growth of low-carbon energy sources has been largely concentrated in the power sector, although China also accounts for more than 70% of the world solar thermal market. Generation from nuclear plants has increased ten-fold since 2000 and hydropower

has increased five-fold, albeit both from relatively low bases. More recently, China has also led the world in expanding wind and solar energy: its renewables-based power capacity (including large-scale hydro) now exceeds that of the European Union and is more than double that of the United States.

Figure 12. ▷ Primary energy demand by fuel in China



Growth in energy demand has slowed, coal (probably) has peaked, developments suggest that China's energy future may look quite different from its past

The rate of growth in energy demand has slowed significantly in recent years. Between 2000 and 2010, energy demand increased on average by 8.4% per year: since 2010, this figure has fallen to just below 3%, and since 2014, it has slowed still further. This reflects the start of major structural shifts in the economy, as well as China's position at the forefront of many aspects of energy efficiency regulation, particularly in the industrial sector: mandatory standards now cover more than 58% of China's final consumption, a figure well above global coverage of 32%.

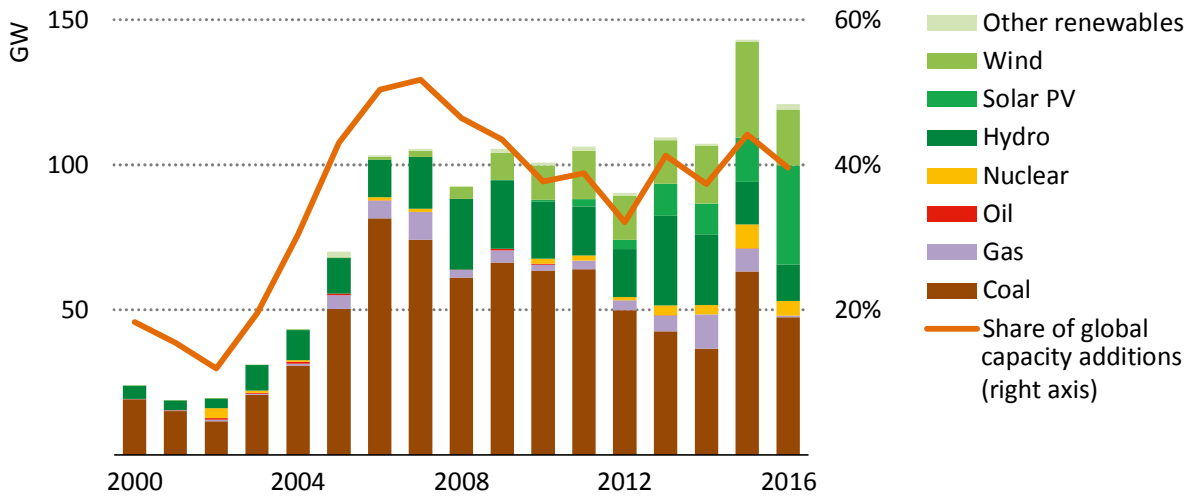
As demand growth has slowed, especially in the heavier industrial sectors, and as new sources of supply have entered the picture, some potential inflection points in China's energy trends have started to be visible. Coal consumption has fallen for three straight years since 2013 and – barring an exceptionally dry hydro year or some other event that might lead to a spike in coal demand – is increasingly unlikely to regain its former heights. Furthermore, China's energy-related carbon dioxide (CO_2) emissions declined in 2016, after 15 years of more than 7% annual growth.

Power sector

China has the largest installed power generation capacity in the world by a wide margin – it is 40% higher than that of the United States, which has the second-largest system in the world. Nearly 60% of its more than 1 600 gigawatts (GW) of installed capacity is coal-fired. Although the direction is unmistakeable, with coal's share of total capacity having fallen by

ten percentage points since 2010, the shift away from coal is likely to be gradual. China's fleet of coal-fired power plants is relatively young: more than half of it is less than ten years old. It is also relatively efficient: much of the plant built in the past decade is supercritical (24%) or ultra-supercritical (20%), operating at much higher efficiencies. As a result, the average efficiency of coal-fired generation in China has increased from 32% in 2000 to 37% today (excluding CHP). Much of it is also equipped with advanced air pollution controls to comply with an emissions standard that was introduced in 2012 in order to cut local pollutants. New ultra-low emission standards that will be phased in between 2017 and 2020 are set to bring further investment in pollution controls.

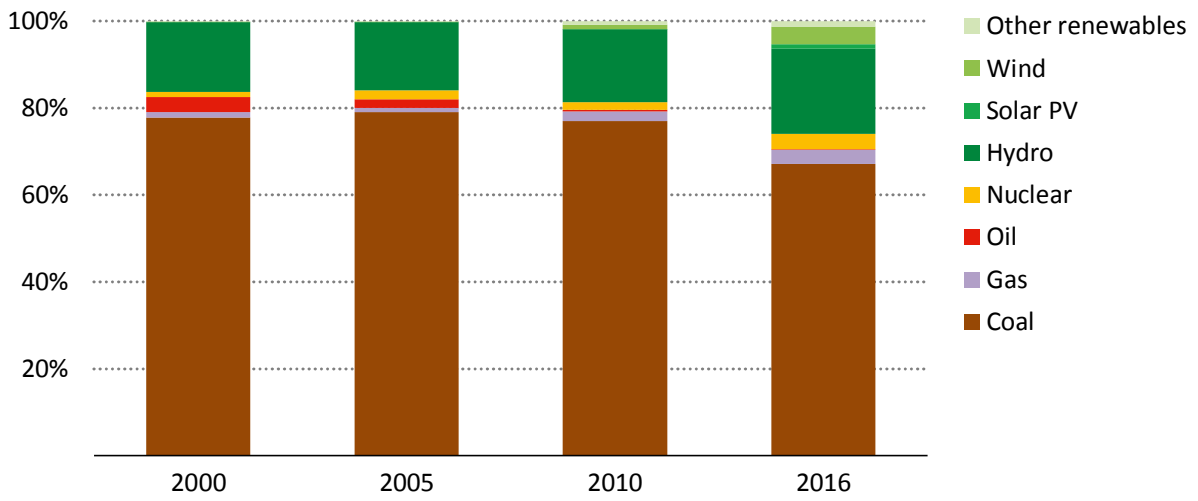
Figure 12.5 ▷ Annual power generation capacity additions by type in China



Since 2013, the majority of capacity additions to China's power system have come from wind, solar PV, hydropower and nuclear

China accounted for over two-fifths of global electricity capacity additions in the past decade, with an average of 108 GW installed each year (Figure 12.5). Since 2013, more than half of these additions have been in renewables and (to a lesser extent) in nuclear power. In terms of renewables, China ranks first in the world in installed capacity of hydropower, wind and solar photovoltaic (PV) power. The switch towards renewables in new power investment decisions has boosted their share in China's capacity to more than one-third, from less than a quarter ten years ago. Wind power, which now accounts for almost 10% of China's total capacity, has edged past nuclear and natural gas to become China's third-largest source of power supply (after coal and hydropower). Solar PV has experienced very strong growth, with installed capacity increasing by more than 75 GW between 2010 and 2016. China is among the world's leaders in nuclear power generation, with capacity increasing from 2.3 GW in 2000 to 33.6 GW in 2016: almost half of global nuclear capacity under construction today is in China.

Figure 12.6 ▷ Power generation mix in China



Coal and hydropower dominate the power generation mix, but a broader diversity has emerged since 2010

The large expansion in capacity, especially in the last few years, has coincided with a period of slowing electricity demand growth, which has dropped from 12% per year in the decade to 2010 to just over 6% a year since then. As a result, China has found itself with excess coal-fired capacity, which has pushed down utilisation rates: this coincided in 2016 with a rise in coal prices, which made a further dent in the margins of these plants. At the same time, the rise in variable renewables, wind power in particular, has shone a spotlight on the limited flexibility of China's power system (despite its high share of hydropower): as much as 17% of wind power generation was curtailed in 2016 because the system was unable to accommodate it. In these circumstances, China's continued strong support for low-carbon generation, including new measures that would allow renewable generators to participate in markets without the use of feed-in tariffs, has inevitably meant looking at broader questions of power sector reform (examined in detail in Chapter 13).

End-use sectors

The pattern of end-use energy consumption in China across the main sectors (industry, transport, buildings and agriculture) shows continued dominance of industry, which makes it an outlier compared with global averages. Industrial demand drove 60% of the growth in final consumption which has taken place since 2000, largely because of a rise in energy demand for manufacturing steel, cement, chemicals and other energy-intensive products. Today China's industrial sector accounts for more than half of total final energy consumption (Figure 12.8). Energy for transport and the buildings sector lag far behind.[2] This has significant implications for the structure of energy expenditure in China (Spotlight).

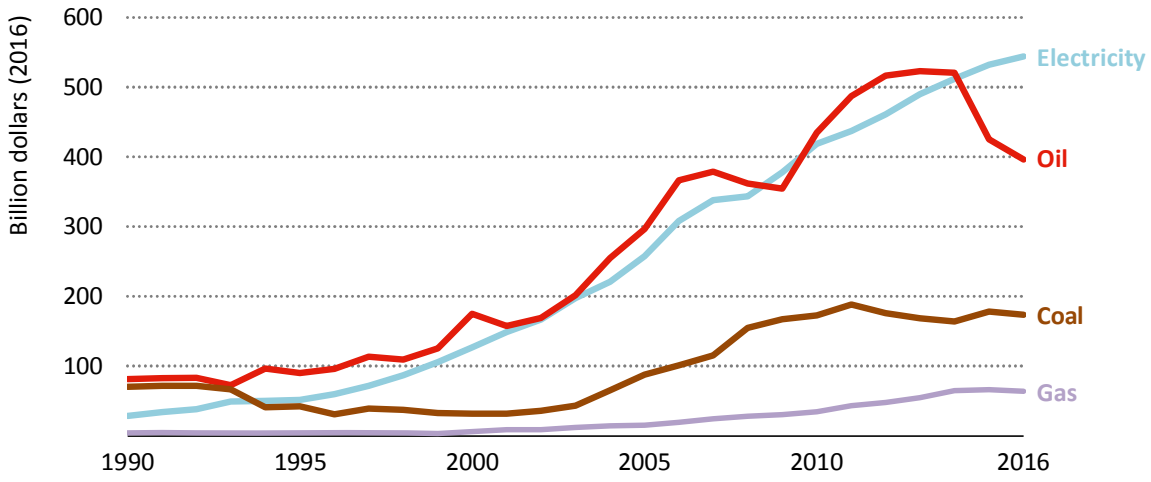
2. The buildings sector includes energy used in residential, commercial and institutional buildings.

SPOTLIGHT

A trillion dollar question: what are China's energy consumers spending their money on?

Oil products dominate end-user expenditure on energy in most major developed and developing economies. This is not the case in China, however, where a much lower (though still very significant) level of expenditure on oil means that electricity accounts for the largest share of expenditure (Figure 12.7).

Figure 12.7 ▷ Historical end-user energy expenditure in China



The prominence of electricity in China's end-user energy expenditure contrasts with a global picture in which oil products take the largest share

Some distinctive aspects of China's economic structure and energy sector explain the relatively low share of expenditure on oil compared to other major economies, and the implications that has for China's pattern of end-use energy expenditure.

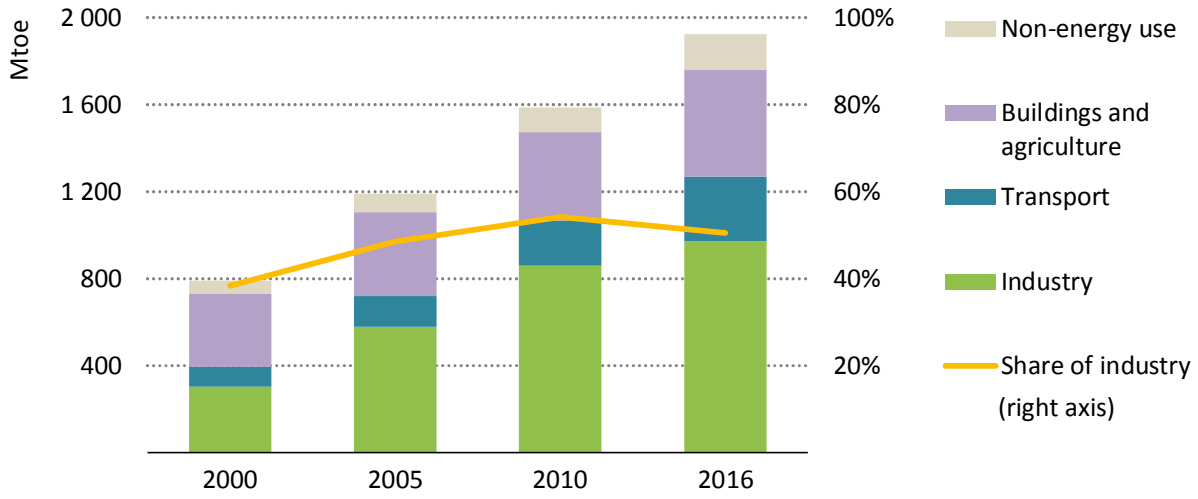
- A key point is that, although a structural transition is underway, industry still dominates China's energy use, and coal still dominates industry's energy use. The effect is to push up the overall share of coal in China's total final consumption (35% compared with an average in the rest of world of less than 5%) and to push down considerably the share of oil (26% in China versus more than 40% in the rest of the world).
- The dominance of industry in terms of energy use also has a huge impact on the overall pattern of energy expenditure in China, which is very different from that in advanced economies where for every dollar spent by industry on energy, households spend $2 (residential and passenger vehicle expenditure, including oil for transport). This relationship is reversed in China: for every dollar spent by a Chinese household on energy, over $3 is spent by industry.
- Because of the dominance of coal, the share of oil in China's industrial energy mix is half the global average. China has a slightly higher share of electricity in the

energy mix than the global average (some 3% above the global average of 26%). The result is that the ratio of oil consumption to electricity consumption in China is very different from the rest of the world: China consumes nearly twice as much electricity as the rest of the world for every barrel of oil consumed.

- Although there has been a large measure of liberalisation, subsidies remain in place for oil consumption in China. This does not necessarily render oil more attractive but it results in lower expenditure on oil. On the other hand, electricity prices in China are actually quite high by comparison to countries such as the United States.

From this starting point, adjustments to China's consumption patterns to bring them towards today's global average would imply a major upswing in oil demand (primarily at the expense of coal). This could see oil-based expenditure overtake electricity – especially if oil prices were to rise from their current levels. There is another possibility, however, which is that China pursues a path leading to much broader electrification of end-uses, including in the traditional stronghold of oil use in transport, alongside a parallel decarbonisation of electricity supply. Under these circumstances, the dominance of electricity in end-use expenditure could be maintained, and even strengthened, establishing a distinctive pattern of energy use.

Figure 12.8 ▷ Total final energy consumption by sector in China



Energy-intensive branches of industry led the rise in China's final energy consumption, but other sectors are set to take over as sources of future growth

There are clear signs of a shift in patterns of end-use consumption, as steel and cement production in particular falls and growth shifts towards technological innovation, consumer spending and services. Over the last five years, industrial energy demand growth has slowed to an annual average of 1.4%, while in the transport and services sectors both have annual average increases of 4.6%. While overall oil demand continues to show robust

growth in transport, signs of a broader economic adjustment are also visible. Demand for diesel, used primarily for freight and therefore correlated with industrial activity, fell in 2016. By contrast, gasoline demand continued its rapid rise, primarily for private passenger cars: gasoline-fuelled vehicle sales grew at 16% year-on-year in 2016. Also in 2016, China saw sales of almost 350 000 electric passenger vehicles and more than 35 000 electric buses, underlining its position as the world's largest market for electric vehicles.

12.2.2 Focus on energy in China's regions and pro

Unsurprisingly for a country the size of China, there are major divergences in economic and demographic trends, resource availability and energy use across the country. These have a major impact in shaping national and provincial policies, as well as infrastructure development. For the purposes of this part of the *Outlook*, we consider four main regions, which correspond to the four economic zones that are used for planning and statistical purposes in China:

- **East:** including the affluent coastal provinces of Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan.
- **Central:** including Shanxi, Anhui, Jiangxi, Henan, Hubei and Hunan provinces.
- **West**: including the vast inland reaches which are generally poorer and more sparsely populated, though it also includes the industrial centres of Sichuan and Chongqing, and the provinces of Inner Mongolia, Guangxi, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang.
- **Northeast**: including the three traditional industrial provinces Liaoning, Jilin and Heilongjiang.

Overall, two-thirds of China's population lives in East and Central China (four of the five most populated provinces, Guangdong, Henan, Jiangsu and Shandong are located within these two regions). One way of illustrating the uneven distribution of population is to take the notional Heihe-Tengchong Line, running from Heihe in the north to Tengchong in the south, which divides the country in two parts (Figure 12.9). The area west of this line (some 60% of the total area of China) contains only 6% of the population. The smaller area to the east (some 40% of the total area of China) is home to 94% of the population.

The vast bulk of all economic activity also occurs in the area to the east of the Heihe-Tengchong Line, which is responsible for more than half of the national GDP. The most developed provinces such as Guangdong, Jiangsu, Shandong and Zhejiang are all located in the coastal area. The inland provinces, by contrast, have fallen behind the prosperous regions closer to the coast, prompting a range of government actions to address these disparities. Each region has an overall regional strategy: the "go west" strategy for the West; the "revitalisation of the old industrial base" for the Northeast; the "rise of the Central region"; and the "leading development" for the East. The central government provides fiscal transfers to poorer provinces: almost a third of the provinces get more than half their financial resources from central government.

Figure 12.9 ▷ China's provinces by population density and main regions in 2015

The map presents data of provinces in China.
This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

In energy terms, each region has its distinctive profile (Table 12.2, Figure 12.10). The geographical location of energy demand is broadly consistent with the distribution of population and GDP. Industrial coastal provinces in the East – notably Shandong, Hebei and Jiangsu – tend to have the highest energy demand, much higher than in western parts of the country, although eastern provinces with a concentration of services or higher value manufacturing (such as Shanghai) have higher GDP without the same impact on energy consumption. Considered by sector, industry takes the largest share of final consumption in almost all regions with the exception of Beijing, where energy use in buildings is the largest energy-consuming sector. Energy use in transport also correlates with GDP, and is highest in the East and in some Central provinces.

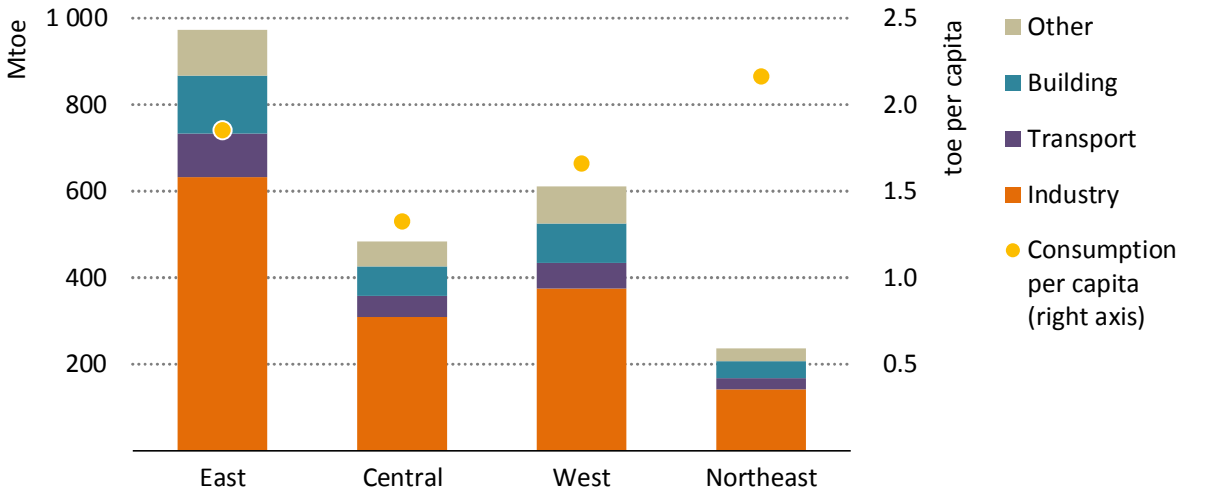
Table 12.2 ▷ Selected indicators for population, GDP, energy use and trade by region and province in China, 2015

Region / provin	Population (million)	GDP ($ billion)	GDP per capit ($)	Electricity demand per capita (kWh)	TFC (Mtoe)	Energ surplus (+) / deficit (-) (Mtoe)
East	**525.2**	**5 988**	**11 402**	**5 247**	**973**	**-668**
Beijing	21.7	370	17 020	4 388	36	-30
Tianjin	15.5	266	17 164	5 175	46	2
Hebei	74.3	479	6 445	4 277	173	-137
Shanghai	24.2	403	16 703	5 820	66	-48
Jiangsu	79.8	1 126	14 114	6 413	153	-162
Zhejiang	55.4	689	12 431	6 416	96	-84
Fujian	38.4	417	10 865	4 824	59	-22
Shandong	98.5	1 012	10 273	5 197	188	-73
Guangdong	108.5	1 169	10 776	4 895	145	-114
Hainan	9.1	59	6 526	2 990	11	0
Central	**364.9**	**2 359**	**6 466**	**2 866**	**484**	**9**
Shanxi	36.6	205	5 594	4 741	89	308
Anhui	61.4	353	5 751	2 669	68	-31
Jiangxi	45.7	269	5 881	2 381	47	-35
Henan	94.8	594	6 267	3 038	112	-84
Hubei	58.5	474	8 107	2 845	88	-82
Hunan	67.8	464	6 841	2 134	79	-66
West	**371.3**	**2 328**	**6 270**	**4 151**	**611**	**537**
Inner Mongolia	25.1	286	11 402	10 127	96	318
Guangxi	48.0	270	5 625	2 782	53	-33
Chongqing	30.2	252	8 364	2 901	47	-26
Sichuan	82.0	483	5 881	2 429	105	-38
Guizhou	35.3	169	4 777	3 326	50	25
Yunnan	47.4	219	4 611	3 034	51	-15
Tibet	3.2	16	5 086	1 251	*n/a*	*n/a*
Shaanxi	37.9	289	7 629	3 221	59	253
Gansu	26.0	109	4 193	4 226	37	-13
Qinghai	5.9	39	6 600	11 190	18	-4
Ningxia	6.7	47	6 998	13 149	26	-5
Xinjiang	23.6	150	6 344	9 154	71	77
Northeast	**109.5**	**928**	**8 480**	**3 203**	**237**	**-132**
Liaoning	43.8	460	10 504	4 530	123	-94
Jilin	27.5	226	8 202	2 368	49	-43
Heilongjiang	38.1	242	6 353	2 280	64	6

Note: Mtoe = million tonnes of oil equivalent; kWh = kilowatt-hour; TFC = total final consumption.

Source: China's National Bureau of Statistics (NBS).

Figure 12.10 ▷ Total final energy consumption by sector in China, 2015



Industry is the largest energy-consuming sector in almost all provinces across China, with the exception of Beijing

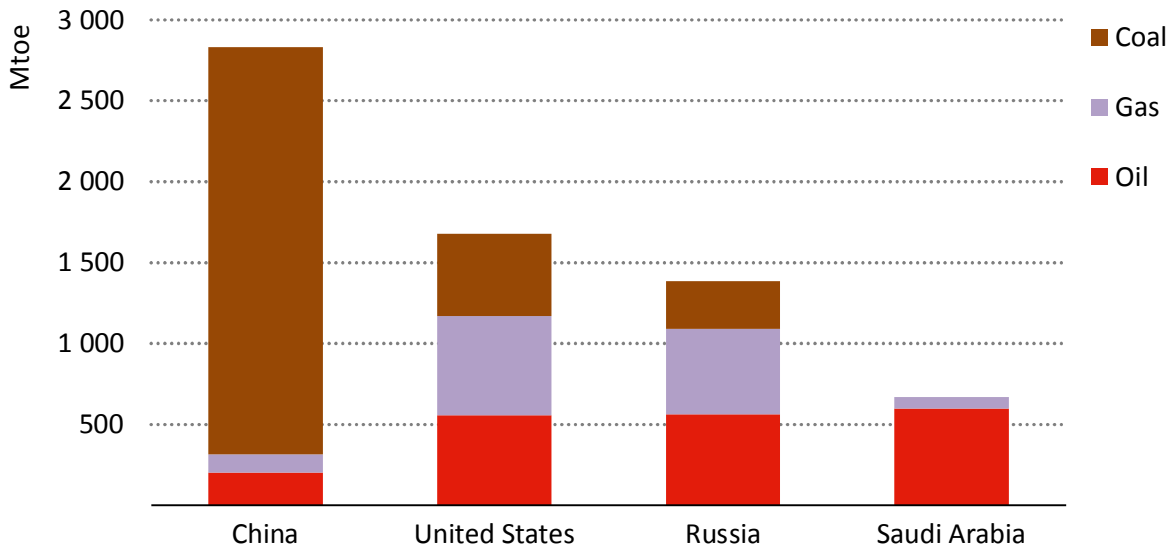
The structure of energy demand by fuel also varies significantly among the regions. The share of coal in energy demand is highest in the Central region, while the eastern provinces tend to have a higher share of oil and electricity in total final consumption. Natural gas consumption is concentrated in areas with indigenous production (around the Sichuan basin in the West) or in parts of country well served by imports, via pipeline (e.g. Xinjiang) or LNG along the coast (e.g. Guangdong).

Matching China's resources, production and demand

China is, by some distance, the largest global producer of fossil fuels. The country's oil output has been in decline in recent years, but at 4 million barrels per day (mb/d) in 2016, it remains the world's seventh-largest producer. Natural gas output of 137 billion cubic metres (bcm) in 2016 is significant, enough to put it in the top-six producers globally, albeit a long way behind the global gas powerhouses of the United States and Russia. However, it is China's vast coal production that makes it the world's largest producer of fossil fuels (Figure 12.11).

Coal production is scattered across China with almost every province having a number of mining operations. However, output is highly concentrated, with three provinces – Inner Mongolia, Shaanxi and Shanxi – accounting for over 60% of domestic coal production. These provinces are all located in the West and Central regions, relatively far from the major demand centres along the coast (Figure 12.12). Moreover, one of China's most promising future prospects for low-cost coal is in Xinjiang in the west, even further away from today's centres of coal demand. This geographical mismatch of supply and demand implies massive amounts of coal need to be hauled over thousands of kilometres (km) from producers to consumers. Railways and coastal shipping (and typically a combination of the two) do most of the heavy lifting, although truck transport for short distances is also common.

Figure 12.11 ▷ Total fossil-fuel production in selected countries, 2016



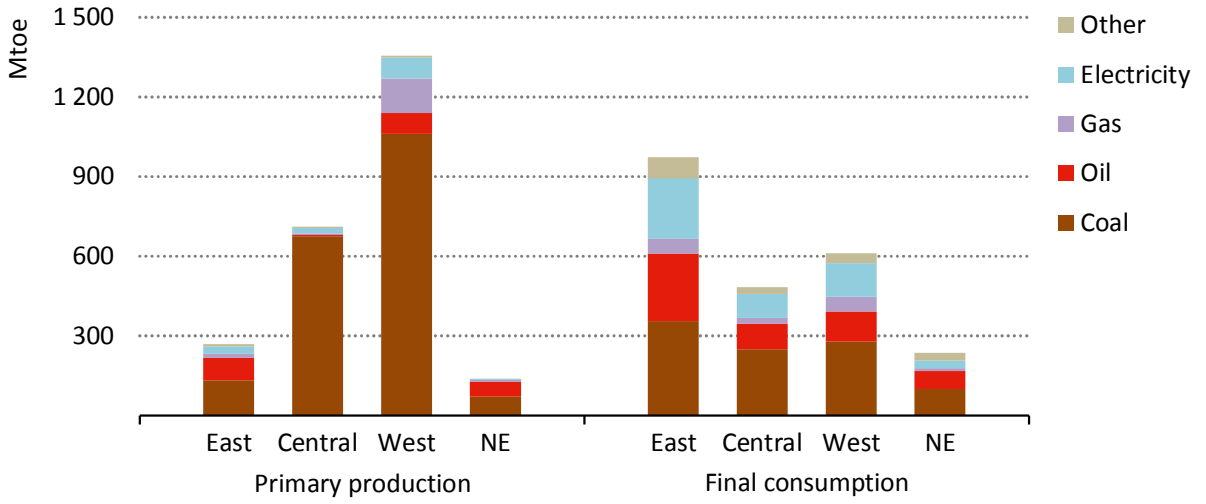
Coal production makes China, by far, the largest global producer of fossil fuels

Railways transported some 2 billion tonnes of coal in 2015 (coal has long been the primary cargo handled by China's railways, accounting for some 60% of total tonnage). Several large railway corridors link the coalfields in Shanxi, Shaanxi and Inner Mongolia with loading ports in the northern provinces of Hebei, Tianjin, Liaoning and Shandong, with the biggest and most important port in Qinhuangdao. The distance between the mines and the ports varies but broadly falls into a range of 600 km to 1 000 km. Ships then distribute the coal along the coastal rim from Jiangsu to Guangxi, where there is competition with imported coal. Transport is a critical cost component: getting coal from Inner Mongolia or Shanxi to Guangdong can easily add around $25 per tonne to the delivered cost. One option to reduce coal transport is to develop coal-fired power plants near the coalmines and transmit electricity with high-voltage direct current lines to demand centres.

China's oil production is slightly less concentrated than is the case for coal. The Daqing oilfield in Heilongjiang province (Northeast region) is the largest oil-producing complex in the country. The Shengli oil field is another major production centre, located in Shandong province (East region). Both Daqing and Shengli are mature areas where production began in the 1960s; as such, they both face challenges with high decline rates and water cuts (i.e. ratio of water to produced hydrocarbons). Most production in the West is in Shaanxi and Xinjiang provinces. Production of natural gas is largely in the West: in Sichuan (the traditional centre of the domestic gas industry), Shaanxi and Xinjiang.

Among the renewable sources of energy, four provinces (Yunnan, Sichuan, Guizhou and Guangxi, in the West region) produce nearly 60% of all hydropower output, (although the Three Gorges dam – the largest in the world – is in Hubei province in the Central region). The centre of China's solar industry – and therefore of the world's solar industry – is the Yangtze River Delta, an area that includes Shanghai and parts of two provinces to its west. Solar and wind power installations tend to be concentrated in the West region in provinces such as Gansu and Xinjiang.

Figure 12.12 ▷ Primary energy production and total final energy consumption by fuel and region in China, 2015



A major infrastructure challenge for China is to bring primary energy from provinces in the west to the major consumption areas near the coast

Note: NE = Northeast.

12.2.3 China and global energy

China is the world's largest producer of fossil fuels, but its output still falls short of the country's demand for coal, oil and gas. As a result, it is also the world's largest importer of fossil fuels. China's importance in global energy markets extends well beyond its role as a producer and importer of fossil fuels; it is also a major investor in energy projects and infrastructure in many parts of the world, particularly in developing countries (Box 12.1). In addition, China is an increasingly important developer and exporter of energy technologies, including many clean energy technologies. As a result, China's energy policy choices have implications that stretch well beyond its borders – and beyond the energy sector.

Box 1 ▷ Chinese energy investments abroad

Initially as part of the government's "Going Abroad" strategy, and since 2013 in the context of the Belt and Road Initiative[3], the activity of Chinese-owned energy companies abroad has become a major and important element of international flows of investment and technology. The drive for international investment has been underpinned in part by a strategic desire to strengthen regional connectivity and to build new supply

3. The vision of the Belt and Road Initiative extends well beyond energy, and encompasses the creation of a network of railways, roads, pipelines, maritime routes, ports and utility networks that link China with Central Asia, the Caucuses, the Middle East, and eventually Southern and Central Europe (and even as far as Africa and South America). The "Belt" aspect relates mainly to overland routes while the "Road" is to enhance maritime interconnectivity.

chains, given China's growing dependence on imported energy resources. Commercial factors are also at play, including the search for markets against a backdrop of domestic overcapacity and the desire to foster new capabilities and technical expertise. The initiative enjoys considerable political support, which was underlined by a high-level international forum held in Beijing in early 2017.

As a result, major Chinese energy companies have established a global footprint over the last decade. In the oil and gas sector, Chinese national oil companies increased their overseas equity production to an estimated 3 mb/d in 2016 (IEA, 2017). Thanks to mergers, acquisitions and participation in various consortia, Chinese companies are an established presence in all the major upstream markets and have emerged in some instances as a preferred partner for resource-rich countries because of the access that they provide to the growing Chinese market. They have further expanded their supply chains by investing in pipelines, storage facilities, refineries and sales and trading capacity. The desire to secure assets took them into some high-risk countries, for example South Sudan, where geopolitical and security challenges have entailed heavy reliance on diplomatic support from the Chinese government.

Africa has been a particular focus for Chinese companies and their involvement has gone well beyond oil and gas. In sub-Saharan Africa, Chinese companies operating as the main contractor for power generation projects were responsible for 30% of new capacity additions in 2010-15. Chinese investors are active in all fuels, natural gas, coal, renewables with a particular focus on hydropower projects and across the supply chains, including projects for cross-border transmission lines, and local urban and rural distribution networks.

In many parts of Asia, notably in Southeast Asia, China has emerged as a major financier of coal and hydropower projects. While exact financial figures are difficult to obtain, the number and size of planned power plants built or financed by Chinese enterprises suggest that the scale of Chinese projects in Southeast Asia's power sector is significant. It extends to Latin America as well: the State Grid Corporation of China (SGCC), the world's biggest utility company, has become the largest power generation and distribution company in Brazil.

The Chinese government established a $40 billion Silk Road Fund in 2014 to finance investments in a number of key projects. Lending from Chinese development banks has also been the predominant source of finance, and the China-backed Asian Infrastructure Investment Bank, a multilateral institution, has a mandate that also allows it to provide funding for some related projects.

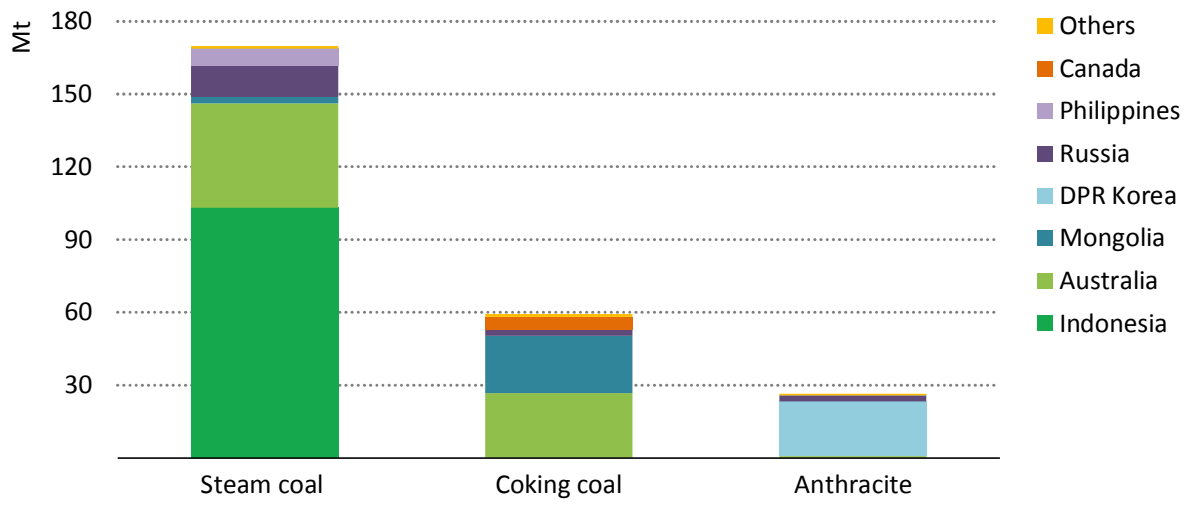
Coal

China is a pivotal country for global coal markets and its role has evolved dramatically in recent years. In 2007, China exported more than 50 million tonnes (Mt) of coal, mainly to Japan and Korea, but in 2009, it switched to becoming a net importer as domestic coal demand expanded considerably. In its first year as a net importer, China became the

second-largest coal importer in the world, after Japan. In 2011, China overtook Japan to become the world's largest coal importer. In 2013, coal imports reached over 300 Mt, the largest amount of coal ever imported in one year by any country. That was a turning point: since 2013, coal demand has declined, leaving the domestic coal market structurally oversupplied and dampening import volumes.

The level of future coal imports depends in large part on policies to limit China's output and restructure the industry (see Chapter 14). The arena for competition between domestic and imported coal is in the southern coastal provinces: a substantial amount of coal is shipped from China's northern ports (nearer the production centres) to its southern ports (consumption centres) to meet demand and those southern ports are also where imported coal arrives. Approximately 900 Mt of coking coal and steam coal combined arrived by sea at the coastal region in 2016. Around 600 Mt of this volume was shipped from domestic sources and the remainder was imported, mainly from Indonesia and Australia (Figure 12.13). Anthracite imports in 2016 came mostly from the Democratic People's Republic of Korea (DPR Korea) (22.5 Mt), though such imports were suspended in early 2017.

Figure 12.13 ▷ Chinese coal imports by source, 2016



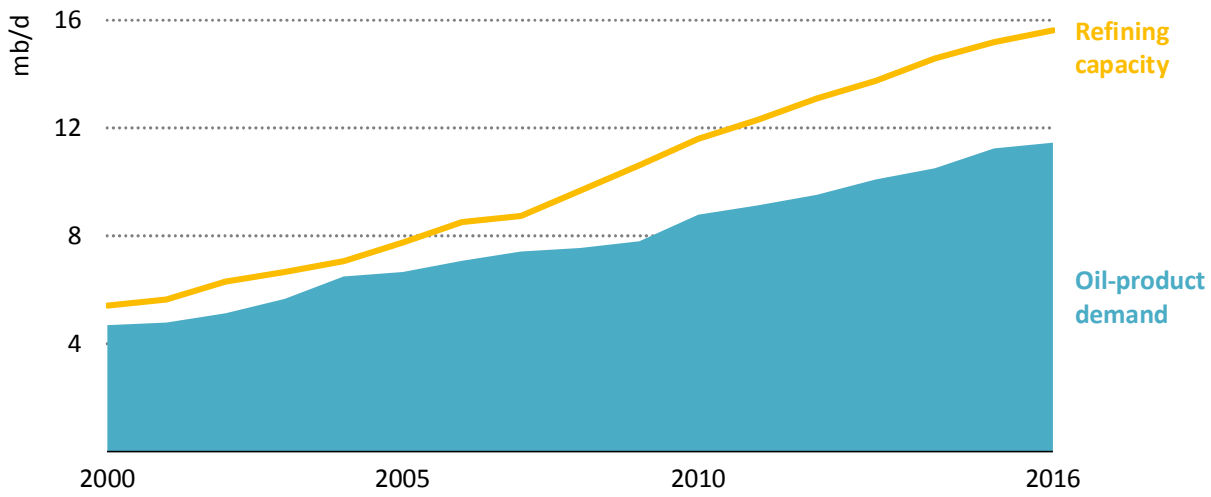
Indonesia and Australia account for the bulk of China's steam coal imports

Oil

Imports of crude oil have risen steadily in recent years. In 2016, China imported 7.6 mb/d of crude oil; an increase of 13% compared to the previous year. More than 1 mb/d of oil imports are now delivered to China via pipelines from Russia, Kazakhstan and Myanmar that were constructed over the last decade to diversify crude oil sources and limit reliance on seaborne trade via the congested Strait of Malacca. Although Russia recently displaced Saudi Arabia as its largest single source of crude oil imports, China nonetheless remains dependent on the Middle East for almost half of its import volumes.

Refining capacity in China has grown by almost three-times over the past 15 years, from 5.4 mb/d in 2000 to 15.6 mb/d in 2016, and its share in the global refining market has more than doubled from 7% to 16%. China now has more refining capacity than any other country except for the United States. During most of the first decade of this century, refining capacity grew roughly in line with rising demand for oil products. However, capacity additions started to outpace demand growth from the late 2000s (Figure 12.14), leading to a surplus of certain oil products, in particular diesel, and reduced utilisation of capacity. China became a net exporter of key refined products, with combined exports of gasoline, diesel and kerosene reaching over 500 thousand barrels per day (kb/d) in 2016, and its position as an exporter of refined products is now one of the factors driving its crude oil imports.

Figure 12.14 ▷ Refining capacity and demand for oil products in China



The surge in refining capacity since the late-2000s has made China both a large importer of crude oil and a net exporter of key refined products

12

Natural gas

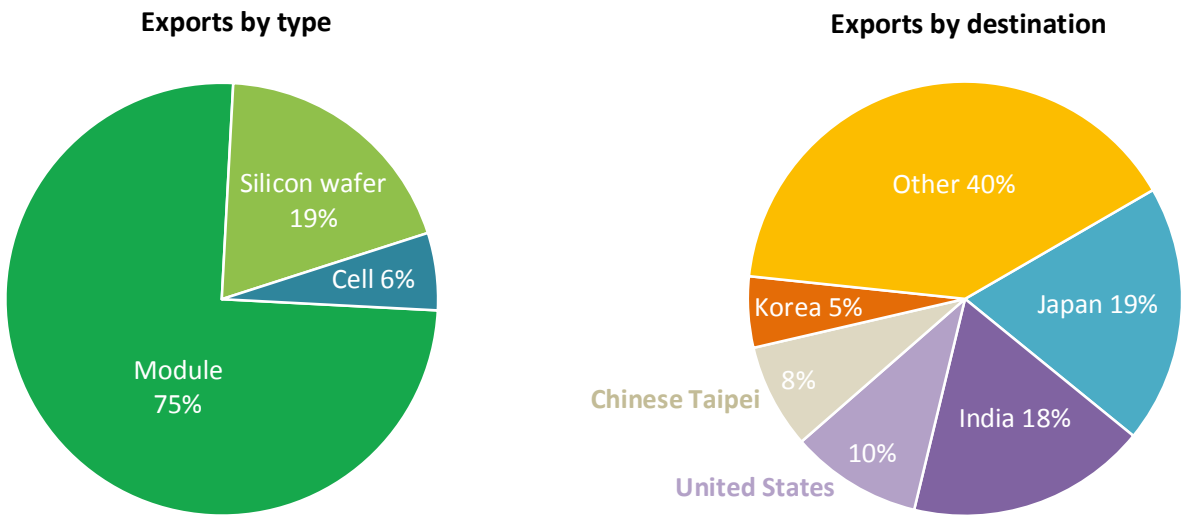
As with oil, natural gas imports have been growing steadily in recent years. China was the fourth-largest natural gas importer in the world in 2016: natural gas imports totalled 72 bcm, just under half of which were delivered as LNG from 16 countries, with the remainder coming by pipeline from Turkmenistan, Uzbekistan, Myanmar and Kazakhstan. Australia was the largest source of LNG and Turkmenistan the main source of pipeline imports. The first LNG regasification terminal started operation in 2006: by mid-2017, there were 17 LNG regasification terminals in operation with a combined capacity of some 70 bcm/year. Pipeline trade began in 2010 with the first line of the Central Asia Gas Pipeline, which connects with the domestic west-east system to supply the main gas-consuming areas in the East region. By 2016, the total capacity of the four pipelines in operation (three Central Asia Gas Pipelines and the China-Myanmar pipeline) was 67 bcm/year. The Power

of Siberia, a pipeline to bring up to 38 bcm/year of Russian gas into Northeast China, is under construction and is expected to start deliveries in the early 2020s.

Clean energy technologies

China is a powerful force in the market for many renewable energy technologies. It dominates global solar manufacturing and has played a huge role in bringing down costs across the solar industry, both through innovation and through a huge expansion in manufacturing capacity that has often run ahead of demand. The rapidly growing domestic market absorbs most of the output, yet China was the world's largest solar product exporter in 2016 with its biggest markets in Japan and India and with sales of around $14 billion, including more than 20 GW of PV modules (Figure 12.15). China leads the global market for solar water heating technologies too: in 2015, Chinese companies were estimated to hold about 95% of the patents for core technologies in this area (CGI, 2015). China is also an important manufacturer of wind turbines, which are mostly sold in the domestic market. Nonetheless, China exported wind turbines to 28 destinations between 2007 and 2015 with its biggest export markets in the United States, Panama, Ethiopia, Australia and Pakistan: the 148 wind turbine units it exported in 2015 had a combined capacity of 275 megawatts (MW).

Figure 12.1 ▷ Solar PV exports from China, 2016



China dominates the global market for solar PV modules

Note: Share of solar PV export sales.

Nuclear

Chinese nuclear power technology has progressed rapidly in recent years. Co-operation with France, United States, Russia and Canada has allowed for a steady improvement in capacities and technologies and China has developed its own second- and third-generation pressurised water reactor (PWR) technologies. Since the 1990s, the China General Nuclear

Power Corporation (CGNPC) has built four nuclear reactors for Pakistan using second-generation PWR technologies (a fifth was finished in September 2017) and it is building another two reactors in Pakistan using its third-generation technology. CGNPC also signed a contract with Argentina in 2015 to build two reactors, with construction planned to start in 2018 and 2020. It is collaborating with Electricite de France (EdF) on the Hinkley Point C project in the United Kingdom, in which it has taken a 33.5% stake. Nuclear power technology has become an important element of China's export policy and Chinese companies are discussing new export possibilities with a range of countries including Argentina, Romania, South Africa and Turkey.

12.3 Factors affecting China's energy development

The projections for the energy outlook for China presented in the following chapters are derived by means of the same overall approach and scenarios as those in the rest of this *World Energy Outlook* (see Chapter 1), but with additional analysis to draw out the policy choices facing China and their implications, not only for the country but also the rest of the world.

- The **Current Policies Scenario** provides a set of projections based on existing policies and measures. It does not include announced policies or targets, and therefore provides a baseline against which to assess their impact.
- The **New Policies Scenario** is the primary focus throughout the analysis and it takes into consideration both existing policies and measures as well as China's announced policy ambitions, such as the targets set out in the 13th Five-Year Plan and other policy plans. In areas where specific policies have already been developed, the New Policies Scenario also incorporates the "Energy Production and Consumption Revolution Strategy" (described in section 12.3.5).
- The **Sustainable Development Scenario**, which sets out what it would take to provide universal access to modern energy services by 2030, to significantly reduce air pollution and to take urgent action to tackle climate change, provides a context for discussion of the longer-term qualitative aspirations for energy sector transformation, set out in the Revolution Strategy (see Chapter 15).

None of these scenarios is a forecast. Rather they provide a framework for considering China's energy outlook and the implications of various policies and strategic choices. The design and intent of these scenarios is usefully brought out by a look back to 2007, the last time that the *WEO* prepared an in-depth analysis of China, when the main scenario, called the Reference Scenario, did not take into account future policy evolution (Box 12.2).

In the remainder of this chapter, we introduce five of the factors that will play a huge role in influencing the direction of China's energy development over the coming decades: the economy; demographic pressures and urbanisation; environmental issues, including water constraints as well as emissions of local air pollutants and greenhouse gases; investment flows; and policies. Policies are particularly important in China, where the record of policy

implementation and of reaching declared targets is very strong. There are many other elements in play, however, notably the market mechanisms that are set to take an ever-more important role in China's energy sector, as well as the structural changes underway in the economy.

Box 12.2 ▷ Looking back to the future: the China focus in *WEO-2007*

The Reference Scenario in the *WEO-2007* focus on China and India provided a set of projections that were based on the policies that were firmly in place at the time (in a way analogous to today's Current Policies Scenario). As such, it provided a business-as-usual set of projections that understated the eventual pace of growth of China's energy demand. A GDP growth assumption of 7.7% a year over the period to 2015 in the *WEO-2007* (reflecting the consensus of the time) turned out to be lower than the actual pace of economic expansion, which was closer to 10% a year, despite the global economic slowdown in the late 2000s. This pushed up China's total primary energy demand to 2 990 Mtoe by 2015, significantly above the 2 850 Mtoe projected for that year in the *WEO-2007* Reference Scenario.

The key differences in consumption by fuel between the projections and the actual energy mix in 2015 relate to subsequent changes in strategic energy orientation in China (once announced, these would now be incorporated as new policies in our methodology). The step-change in China's ambitions for renewables deployment is the main element, though the point also applies to a policy shift in favour of increased use of natural gas. Both of these policy directions shifted energy use away from coal. The share of coal in total primary demand projected for 2015 in *WEO-2007* is very close to the eventual outcome for that year (around two-thirds). However, the share of coal-fired power in the generation mix turned out to be 82% in 2015, six percentage points lower than the projected 88%, because of new policies that encouraged more solar, wind and natural gas-fired power.

Throughout the analysis, we reflect on the way that changes in some key underlying assumptions could affect China's path and the implications for global trends. China's size and its importance in global energy affairs mean that even relatively small variations in projected outcomes can have large knock-on effects. Chapter 15 examines in detail two key uncertainties:

- The first is the pace at which China moves ahead with its economic transition from heavier to lighter industrial branches, and from export-oriented industrial output to services and domestic consumption. We posit a ten-year delay in this transition, compared with the pace assumed in the New Policies Scenario, and explore the implications for a range of economic and energy indicators.

- The second is the possibility of China moving ahead even more rapidly with its clean energy transition, via a virtuous circle of more ambitious policies and more rapid cost reductions for some key renewable technologies.

In addition to these two extended analyses, Chapters 13 and 14 also include a host of other sensitivity cases and "what-if's", illustrating the way that different sets of circumstances and choices could move China away from the pathway projected in the New Policies Scenario. For example, we look in Chapter 13 at the issue of vehicle ownership levels in China, a critical indicator for future oil consumption. We examine what might happen if there is more widespread adoption of policies to limit growth in vehicle ownership in cities in the Central and Western regions, where ownership is relatively low today (and where most of the growth is projected to occur in the New Policies Scenario). In Chapter 14, we explore a range of potential pathways for production of shale gas in China, for which the resource estimates are huge, but actual production (with a few exceptions) has been slower than anticipated.

12.3.1 Economic transition

China has the world's second-largest economy and, even with the recent slowdown, it continues to expand at impressive speed. Growth in GDP has averaged almost 8% per year since 2010 (compared to an OECD[4] average of 1.8% over the same period), though this declined to around 6.8% in 2015 and 6.6% in 2016. In purchasing power parity (PPP) terms, China's GDP in 2016 was $21.7 trillion, or 18% of global GDP and GDP per capita is around one-third of the OECD average (measured in PPP terms). Industrialisation has been the main source of growth, and industry accounted for 39% of GDP in 2016, a share markedly higher than that of most middle-income, developing and OECD countries: the services sector accounted for little over 50% of GDP and the agriculture sector for 9%.

China's economy is undergoing a deep transition: the previous model of resource-intensive economic growth, which emerged in the early 1970s, is gradually giving way to a more sustainable model driven by consumption and the services sector, the so-called "new normal" (Figure 12.16). A key objective of the government's 13th Five-Year Plan is to double 2010 income levels by 2020 (Box 12.3). This will require annual average growth of 6% over the next few years compared with 8% in the preceding five-year plan. To bring about the changes it seeks, the government is promoting a series of "supply-side" reforms, with a view to reduce the debt and liability levels in the corporate sector and reduce excess capacity in key industrial sectors, including coal and power. The pace and depth of these reforms will have a major impact on the both the economic and energy transition.

All the scenarios in this *Outlook* for China use the same economic growth assumptions: average annual growth remains at 6.1% until 2020, before slowing gradually to around 5% per year by the 2030s. This means that China's economy expands by an average of 4.5% a

4. Organisation for Economic Co-operation and Development (OECD) member countries.

year through to 2040, and is almost three-times its current size by 2040. China's share of the global economy continues to expand, increasing by five percentage points by 2040 to 23%, and GDP per capita increases to almost three-times its current level. The structure of growth reflects the assumed transition towards a more domestic- and service-oriented economy and lower reliance on manufacturing and exports: the share of the services sector in China's GDP increases steadily to 64% in 2040, and the share of industry falls from 39% today to 32% in 2040.

Box 12 ▷ China's 13th Five-Year Plan

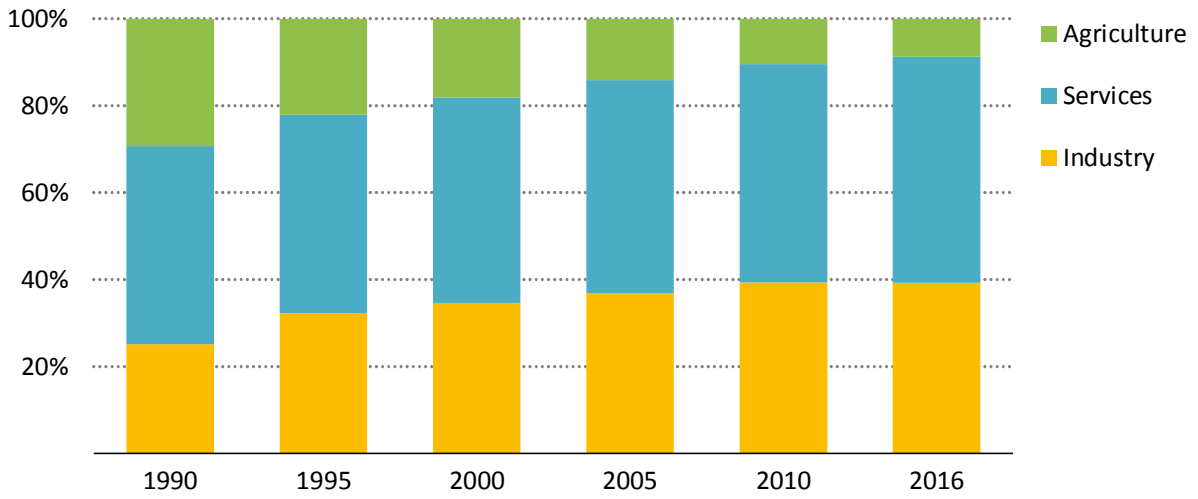
A succession of five-year plans has provided the overarching framework for China's economic and social development since the 1950s. Initially the main instrument of a planned economy, over time the plans have become more about setting policy direction and providing guidance, especially after China opened its doors to the outside world in 1978 and started to develop a more market-oriented economy. In March 2016, the government published the 13th Five-Year Plan (2016-2020) on Economic and Social Development. Based on this, central government departments and local governments must formulate sectoral/regional plans, for example on health, population, education, employment, culture and energy. The National Development and Reform Commission (NDRC) and the National Energy Administration (NEA) subsequently released their 13th Five-Year Plan (2016-2020) on Energy Development in December 2016. It sets out the main tasks and targets for the energy sector in the period to 2020, and the policies to support them. Some of the key indicators are presented in Table 12.3. The chapters that follow discuss in detail the way that these tasks, targets and policies shape our projections.

Table 12.3 ▷ Selected key energy and environment indicators in China's 13th Five-Year Plan

Indicator	2015*	2020
Nationwide total energy cap for all energy sources	-	Less than the equivalent of five billion tonnes of coal
GDP (trillion of CNY)	67.4	> 92.7
Permanent urban residents (%)	56.1	60
Services sector value added (%)	50.5	56
Non-fossil energy (% of TPED)	12	15
Reduction in energy intensity per unit of GDP (%)	-	1
Reduction in carbon emissions per unit of GDP (%)	-	18
Reduction in nitrogen oxides (%)	-	15
Reduction in sulfur dioxide (%)	-	1

Notes: * = where comparable. CNY = yuan renminbi.

Figure 12.16 ▷ Changing structure of the economy in China
(share of value added by sector)



China's rapid industrialisation is being followed by a robust expansion of the services sector in its economy

12.3.2 Demographics and urbanisation

Today approximately 1.4 billion people live in China – around one-fifth of the world's population – and the country has more than 140 cities with populations of over one million. The assumed demographic growth rate in China over the period to 2040 slows almost to a standstill (to an average of -0.1% per year), meaning that India overtakes China as the world's most populous country by 2022. The one-child policy, adopted in 1979 to curb population growth, and gradually eased from 2013 and again in 2015, is having a significant impact on the country's demographic profile, not only by slowing population growth, but also by reducing the share of the population that is of working age and introducing a noticeable gender imbalance. In the years ahead, older people are set to account for an increasing share of China's population, especially as life expectancy increases, generating a variety of social and economic challenges for policy-makers.

An increasing share of China's population is set to live in cities, continuing the trend of recent years: this share has already risen sharply from 36% in 2000 to 57% today, and reaches almost 75% by 2040 in our projections. This assumption is consistent with the government's own approach: under the government's National Urbanisation Plan for 2014-2020, a further 100 million rural dwellers will migrate to urban areas by 2020.

The implications of a more affluent and increasingly urban population for the energy sector are profound. In general, urban residents tend to consume more energy than those in rural areas, in large part because of differences in income levels. Urban sprawl, combined with inadequate provision of mass transit, can also push up consumption levels by increasing commuting distances and vehicle ownership, with potentially severe knock-on effects for air pollution. Conversely, the concentration of population in cities also offers scope for

more energy efficient heating, cooling, transport and other services: this is a point that the Chinese authorities look very likely to devote attention and effort to at municipal, provincial and national levels.

12.3.3 Environment

China's rapid economic rise over the past two decades has had a major impact on its environment and on public health. The country is the world's largest source of CO_2 emissions, and local air quality in many of its major cities fails to meet national and international health standards. Outdoor pollution is the cause of around one million premature deaths each year and household air pollution accounts for a further 0.9 million early deaths each year. Poor air quality reduces today's average life expectancy in China by almost 25 months (IEA, 2016). The response to these hazards – especially the "fight against pollution" and the drive to "make the skies blue again" – has become a priority in national policy-making.

Air pollution

The Chinese government has long recognised the extent of air pollution and the data reflect the impact of recent policies to address the issue. Nevertheless, air quality remains an acute problem in many parts of the country. According to the Ministry of Environmental Protection (quoted in the preamble to the 13th Environment Five-Year Plan), almost three-out-of-four Chinese cities have not yet met the required domestic air quality criteria. The main industrial centres, in particular Beijing, Tianjin and the Hebei province, continue to register the presence of high levels of all major air pollutants. We estimate that only about 2% of the population in China breathes air with a level of fine particulate matter ($PM_{2.5}$) concentrations that complies with the World Health Organization (WHO) guideline, and only 64% of the population breathes air that meets the standards of even the most modest WHO interim target-1.

A notable tightening of China's policy in this area came in 2013 with the Action Plan for Air Pollution Prevention and Control. The Action Plan is a roadmap at provincial level for efforts to improve air quality over the period 2013-2017. It aims to reduce $PM_{2.5}$ pollution towards the National Ambient Air Quality Standard of 35 micrometres per cubic metre ($\mu g/m^3$) (the WHO interim target-1). It also contains detailed measures to address other pollutants. Although the Action Plan is national in scope, it focuses on three regions in particular: the Beijing-Tianjin-Hebei area, the Yangtze River Delta and the Pearl River Delta. These regions have $PM_{2.5}$ reduction targets of 25%, 20% and 15% by 2017 (compared with 2012 levels), with the $PM_{2.5}$ concentration for Beijing capped at an annual average 60 $\mu g/m^3$. In December 2016, the State Council published the 13th Five-Year Plan for Ecological and Environmental Protection (2016-2020). According to the plan, China's 338 largest cities must meet "good" levels of air quality 80% of the time by 2020, compared with 76.7% in 2015, and large cities that did not meet standards for $PM_{2.5}$ concentrations by 2015 have to cut their average by 18% by 2020, compared with their 2015 level.

CO_2 emissions

The drive to improve air quality has a strong overlap with China's broader efforts to reduce its carbon intensity and limit CO_2 emissions. China's receptive stance on action to combat climate change was a fundamental factor in bringing the negotiations on the Paris Agreement to a successful conclusion in 2015. In its climate pledges, China announced three major objectives:

- To achieve peak CO_2 emissions around 2030 and make best efforts to peak earlier.
- To lower CO_2 emissions per unit of GDP by 60-65% by 2030, against a baseline of 2005.
- To increase the share of non-fossil fuels in primary energy consumption to around 20% by 2030.

China's Nationally Determined Contribution specifies a number of policies and measures to achieve these objectives. Some of the actions that have been taken are administrative and prescriptive in nature, notably in relation to energy efficiency improvements and the mandatory closure of small power plants. Some make use of market mechanisms and instruments, notably the planned launch of a national emissions trading system in 2017 covering the power sector, which is to be extended later to include key energy-intensive industrial sectors: this follows various pilot schemes in seven major provinces since 2013.[5]

Developments in China, including the expansion of generation from renewables and nuclear, increased energy efficiency and – most significantly – the peak in coal consumption in 2013, all played an important role in the flattening of global energy-related CO_2 emissions that has taken place since 2014. We estimate that China's energy-related CO_2 emissions actually fell slightly in 2016, marking the first break in a strong upward trend since 2000. It is though too early to claim 2016 as an inflection point for China's CO_2 emissions: the relationship between economic growth and energy consumption is changing rapidly, and the deployment of low-carbon sources is gaining momentum, but there is still likely to be upward pressure on emissions in the years to come.

Water resources

Although China has almost 19% of the world's population, it has just 6.5% of global renewable water resources. Almost 80% of its renewable surface water resources and 70% of its groundwater resources are located in the Yangtze River Basin and the parts of China to its south. Conversely, almost half the population, two-thirds of its cropland and 40% of its industrial activity are to the north of the Yangtze River Basin (World Bank, 2009). Approximately 70% of its supply comes from surface water, and the rest from groundwater.

Some 30% of China's land area, which is home to almost half of the population, is currently experiencing high levels of water stress (Wang, Zhong and Long, 2016). China's available

5. Cement and aluminium smelting are the first industrial branches expected to join the emissions trading system (ETS). Chemicals and petrochemicals, construction materials, iron and steel, other non-ferrous metals and paper could enter the ETS market at a later phase.

water resources are further constrained by high levels of pollution that renders a significant portion of its surface water unusable. Approximately a third of China's lakes and rivers are unfit for human consumption, and almost three-quaters of the watersheds that supply water to thirty of the fastest growing cities in China suffer from medium or high levels of water pollution. Land use and degradation caused about half of this pollution, as fertilisers, pesticides and livestock waste contaminate water bodies, and industrial activity is the main source of the remainder. China has sought to develop alternative water sources but the pace at which it is building desalination plants has slowed in recent years.

In recognition of the vital importance of water to its economic and social well-being, China has included a range of water-related targets in its 13th Five-Year Plan aimed at improving water quality, curtailing sources of water pollution, reducing water demand, increasing the share of alternative water resources, and improving water recycling and water conservation. Power generation accounted for 7% of China's total water withdrawals in 2016; coal-fired power plants, many of which are in water-stressed areas, were responsible for over 80% of this amount. In 2015, China released a Water Pollution Prevention and Control Action Plan, also known as the Water Ten Plan, containing its most comprehensive water policy to date. Aimed at protecting both surface and groundwater resources, the plan sets out ten measures with specific targets for 2020. These targets broadly covered several key action areas including control of pollution discharge with a strong focus on municipal wastewater treatment plants and industry; promotion of recycling and reuse throughout the economy; improved quality of drinking water; and strengthened management of water resources and better control over water extraction. The heightened focus on water management marks a break from the past when the focus was primarily on increasing water supply.

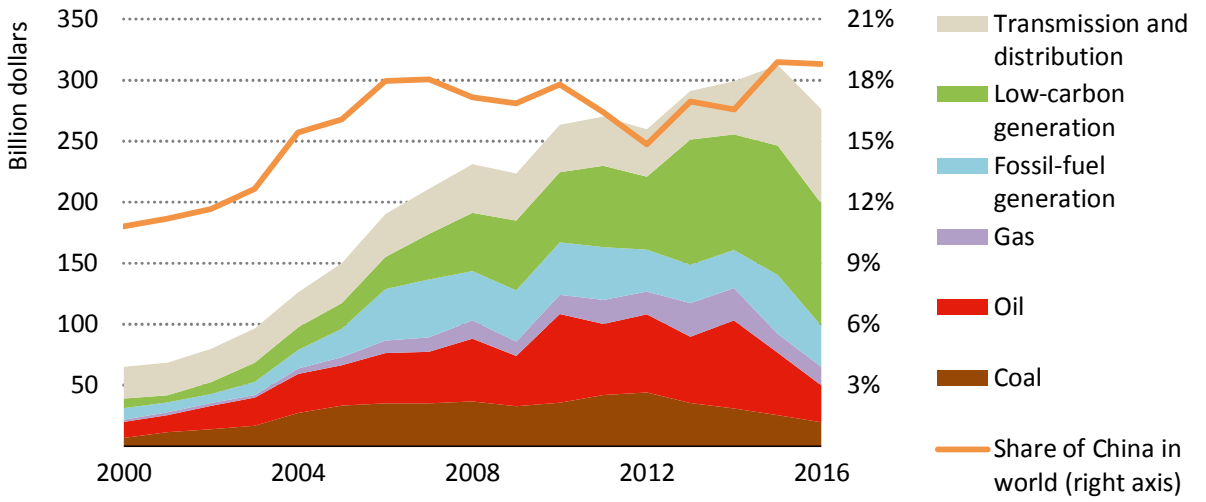
12.3.4 Investment

The scale and direction of energy investment is a crucial indicator for our *Outlook*. Many investments in energy-using infrastructure have long operational lifetimes, so past investment decisions in China continue to shape consumption well into the future. A case in point is the wave of investment in new coal-fired power capacity over the last ten years, which – unless it is retired or replaced early, or retrofitted with carbon capture and storage (CCS) – locks in patterns of Chinese coal use and emissions for decades to come.

Investment in China's energy sector in 2016 accounted for almost one-fifth of the estimated $1.7 trillion in energy-related capital expenditure worldwide. Its composition showed significant changes from that of previous years. Rising spending on low-carbon electricity supply, networks and energy efficiency accounted for a greater share of investment (IEA, 2017). Upgrades to the distribution system and investment in several large-scale transmission projects (designed to help transfer power from inland provinces to the east and resolve the problem of curtailed solar and wind output) meant an increase in spending on electricity networks. Upstream spending on oil and gas in China has been held back by lower prices, and there has been a slowdown in investment in new gas infrastructure. Companies have tended to postpone projects in response to uncertainty about the pace of demand growth and the planned unbundling of the gas sector (see Chapter 14). However,

investment in new oil infrastructure, both in transport and storage remained robust. China's coal-mining sector accounted for the largest part of global coal investment, but its share has been falling since a peak in 2012. In 2016, coal investment amount to around $14 billion, some 16% lower than the previous year, squeezed by continued overcapacity in many parts of the industry.

Figure 12.17 ▷ China energy supply investments



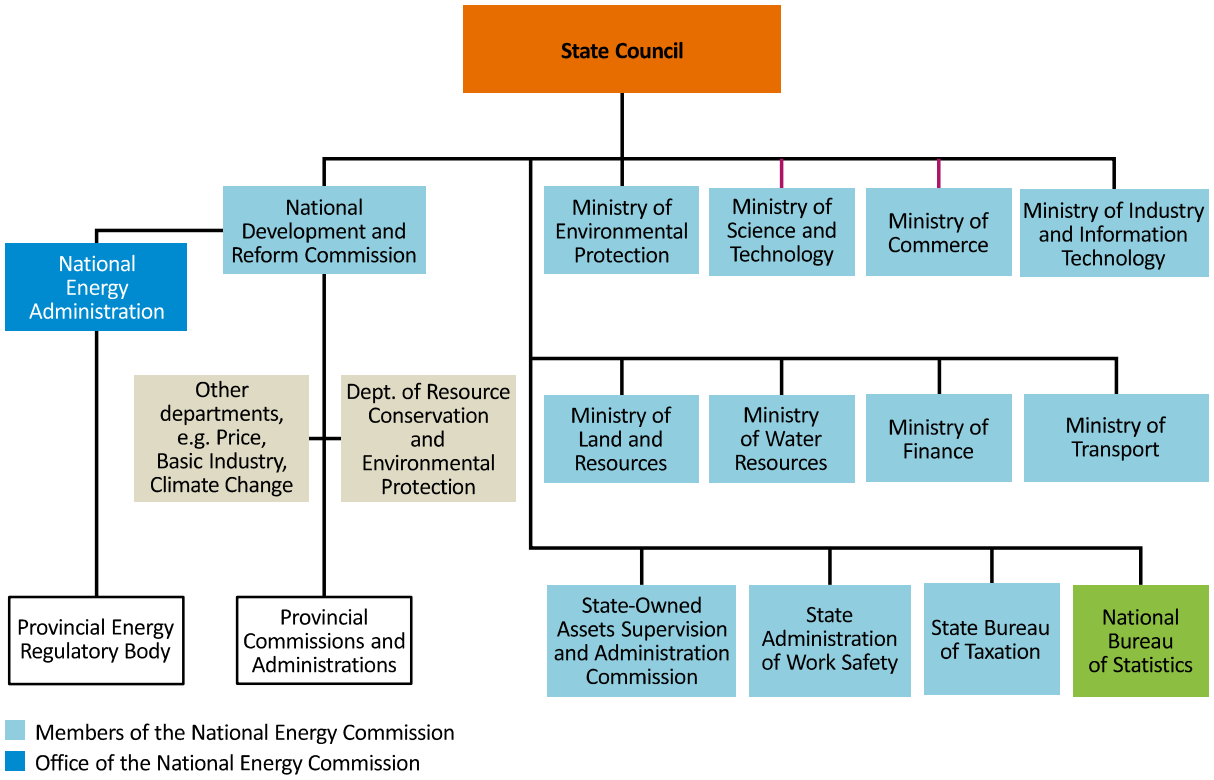
Low-carbon electricity supply and networks are driving energy investment in China

12.3.5 Energy governance and policies

The evolving administrative structure

A number of different bodies at national and local levels share responsibility for making and implementing energy policy in China (Figure 12.18). At central government level, the structure of the energy administration has evolved considerably in recent years. Individual ministries originally managed the various energy sources (e.g. coal, power, oil) and it was only in 1988 that China created for the first time a Ministry of Energy. China reversed this change five years later, and re-established line ministries for the coal industry and for power, along with several state-owned enterprises with activities and responsibilities in different parts of the energy sector. Another structural change took place in 2008 with the establishment of a new vice-ministerial level institution, the National Energy Administration (NEA), an organisation managed by the National Development and Reform Commission (NDRC). The NEA is responsible for making and implementing energy policies, such as the 13th Five-Year Plan, while the NDRC has a broader mandate for social and economic matters including climate change, pricing, energy efficiency, investment and resource conservation: energy plays an important role in all of these areas. In addition, directly under China's State Council, the State-owned Asset Supervision and Administration Commission (SASAC) is responsible for the supervision of China's State-Owned Enterprises and plays a key role in evaluating their performance and appointing top executives.

Figure 12.18 ▷ China's national administrative structure for energy



Alongside these leading institutions, a number of other government agencies have a say in China's energy governance. The importance of air quality in China has meant a prominent role for the Ministry of Environmental Protection, which is responsible for environmental standards and exerts increasing influence over the development and operation of energy projects. The Ministry of Science and Technology is responsible for technology innovation and for co-ordination of research and development activities in all areas including the energy sector. The Ministry of Land and Resources oversees the development of fossil-fuel resources and reserves, with the exception of hydropower resources, which fall under the Ministry of Water Resources. The State Administration of Work Safety is responsible for all work-related safety while the State Administration of Coal Mine Safety is responsible for coalmine safety. The Ministry of Commerce oversees energy trade. The Ministry of Finance and the State Bureau of Taxation are responsible for taxes and fees and are closely involved in any reforms that involve financial incentives. As well, provincial and municipal governments are taking an ever-increasing role in areas such as distributed energy and renewables as well as taking the lead in establishing both power and natural gas market systems at the provincial level.

In order to strengthen co-ordination among the various bodies charged with responsibilities in the energy sector, China established a National Energy Commission (NEC) in 2010. The NEC is chaired by the prime minister, and another vice prime minister (also a member of the Standing Committee of the Political Bureau) serves as deputy director. The NEC is the highest-ranked energy institution established in the Chinese system: all ministers

of energy-related ministries are members, and the NEA serves as a secretariat. The NEC meets every one or two years to discuss key energy policies: its most recent meeting was in November 2016 to discuss and approve the 13th Five-Year Plan on Energy Development.

From central planning to policy guidance and regulation

For a long time, the energy sector was part of the planned economy: investments typically required specific government authorisations and approvals at various levels, depending on their scale and scope. This situation changed with the onset of market reforms in China, especially after 2013 when the government launched a far-reaching modernisation of administrative structures that streamlined procedures, delegated authority, strengthened regulation and regulatory bodies and limited the scope for central micro-management of economic affairs.[6] In the energy sector, this meant the abolition by the NDRC and NEA of more than a dozen approval procedures and the transfer of many other responsibilities to provincial administrations, so that, for example, the relevant province approves new coal-fired power plants, electricity grid extensions and oil and gas pipelines. As a result, the role of the NDRC and NEA is increasingly focused on policies and regulations, including development of guidance for plans and supervision of the implementation of those plans. Within the overall framework established at national level, there is considerable scope for provincial and local governments to decide on their own courses of action.

Role of state-owned enterprises

State-owned enterprises (SOEs) play an important role in the Chinese economy, in particular in the energy sector. The main SOEs initially sprang from the various energy-related ministries: for example, China National Petroleum Corporation (CNPC) and Sinopec derived from the former Ministry of Oil. Over time, they have gradually separated from the government and emerged as distinct corporate entities. Today over 20 national-level SOEs (out of a total of around 100 supervised directly by the SASAC) focus or operate in the energy sector (Table 12.4). These national SOEs, combined with a large number of local SOEs, make up the bulk of the China's energy industry today: they are also the main drivers in the implementation of China's "Belt and Road" initiative in the energy sector. The "Big Three" oil companies (CNPC, Sinopec and CNOOC) dominate the oil and gas industry; the "Big Five" power generation companies (Huaneng, Datang, Huadian, Guodian and the State Power Investment Corporation) dominate power generation, accounting for almost 45% of total capacity in 2015; and the State Grid Corporation of China (SGCC) is the world's largest utility company.

6. The former State Electricity Regulation Commission, established in 2003, merged with the NEA in 2013, and new departments were set up in NEA for regulation of energy markets. Provincial energy regulation bodies affiliated directly with the NEA are also authorised to oversee the compliance of new projects with the various energy plans.

Table 12.4 ▷ Main state-owned energy-related enterprises in China

	Oil and gas	Coal	Power			
			Grid	Gener-ation*	Nuclear	Other**
China National Petroleum Corporation (CNPC)	●					
China Petroleum & Chemical Corporation (Sinopec)	●					
China National Offshore Oil Corporation (CNOOC)	●					
China Sinochem Group***	●					
China Shenhua Group		●		●		
China National Coal Group Corporation		●				
China Coal Technology & Engineering Group						●
State Grid Corporation of China			●			
China Southern Power Grid Corporation			●			
China Huaneng Group		○		●	○	
China Datang Corporation		○		●	○	
China Huadian Corporation	●	○		●		
China Guodian Corporation		○		●		
State Power Investment Corporation		○		●	●	
China Three Gorges Corporation				●		
State Development & Investment Corporation***				●		
China Resources Group***				●		
China General Nuclear Power Corporation				●	●	
China National Nuclear Corporation					●	
China Power Construction Corporation						●
China Energy Engineering Corporation						●
China Nuclear Engineering Group						●
Harbin Electric Corporation						●
Dongfang Electric Corporation						●
China XD Group Corporation						●
China Energy Conservation and Environmental Protection Group***						●

Notes: * Includes renewables. ** Includes energy project consulting, design and construction, energy equipment manufacture and energy efficiency. *** Business includes energy-related areas. ● = primary business; ○ = new business area.

China's energy-sector SOEs face similar challenges to all the country's SOEs, including weak governance, abundant non-commercial social responsibilities and a high level of debt. SOE reform is a high priority for the Chinese government, and is being carried out as part of the general reform initiative for SOEs launched in 2015, under which SOEs are being classified as either commercial or public utility/welfare firms, and commercial firms then further split into three types: competitive, monopoly and security-related. Each of these groups

will have different reform objectives and be subject to different regulatory requirements and methods of performance evaluation. The other main elements of the reform include undertaking listings in China or overseas, setting up boards, merging SOEs to create globally competitive national champions, and introducing mixed ownership to attract private shareholders. Some of those reforms are underway in the energy SOEs, such as the mixed ownership reform in Sinopec and CNPC. Consolidation is also playing a role, a good example being the merger of the China Power Investment Group and the State Nuclear Power Technology Corporation to form the State Power Investment Corporation in 2015. Co-ordinating the transformation of the energy sector with the reform of China's SOEs is a very demanding task, but one that is vital for the success of China's energy transition.

Industry associations and think-tanks

China's energy sector has a variety of industry associations across the different fuels: the China Electricity Council, China Petroleum and Chemical Industry Federation and China National Coal Association are among the most influential. These are autonomous institutions with membership drawn from enterprises, research institutions and universities; although many associations also started as state entities and many continue to enjoy a measure of state financial support. Their main function is to act as a bridge between government and enterprises, but their responsibilities can also cover areas such as data collection, research, training and international activities.

There are also many energy-related think-tanks, most of which are affiliated to the government or the SOEs. Examples include the Energy Research Institute (affiliated to the NDRC), the China Electric Institute (affiliated to the SGCC), the China Electric Power Planning & Engineering Institute (EPPEI, affiliated to the China Energy Engineering Corporation) and the China Energy Engineering Institute (affiliated to the China Power Construction Corporation). Some of these organisations are authorised by the government to undertake a public function: for example, the EPPEI operates as the National Power Planning Research Centre with the authorisation of the NEA. National think-tanks such as the Development Research Centre of the State Council and Chinese Academy of Social Sciences are also active in the energy sector.

China's energy policy

The likely future evolution of China's energy policy is fundamental to our long-term analysis, and there is a rich body of available material on its long-term policy ambitions. The energy agenda is defined by the call for an "energy revolution", made by China's president in June 2014; this serves as broad guidance for all the energy five-year plans and policies, as well as the Energy Production and Consumption Revolution Strategy (2016-2030) jointly published by the NDRC and NEA in 2017. The "energy revolution" is focused on four areas: energy consumption, supply, technology and institutions (the latter point incorporating the need for international energy co-operation), with the overarching aim of securing a more secure, sustainable, diverse and efficient energy future.

A number of broader Chinese strategies and initiatives also affect the outlook for energy. A good example is the proposed direction of domestic economic structural reform: the "Made in China 2025" initiative, issued by the State Council in 2015, promotes a vision of China's manufacturing future that is fundamentally different from the past reliance on energy-intensive output. Instead, it places emphasis on advanced industrial designs that are greener and more innovative, supported by targets on energy and emission intensities. Energy co-operation, investment and trade also form an important component of the "Belt and Road" initiative that aims to enhance connectivity and co-operation along strategic land and sea routes to China.

Table 12.5 ▷ Main goals of China's Energy Production and Consumption Revolution Strategy, 2016-2030

Targets by 2020 (recall the existing main targets from the 13th Five-Year Plan)
• Total primary energy consumption to be maintained below 5 000 million tonnes of coal equivalent (Mtce), with a further reduction in the share of coal (Table 12.3).
• Share of non-fossil fuels to reach 15% in the energy mix, clean energy to become the main contributor to energy growth (Table 12.3).
• Carbon intensity to be reduced by 18% from 2015 levels, energy intensity to be reduced by 15% from 2015 levels.
• Energy self-sufficiency to be above 80%.
• Average power intensity (electricity consumed per unit of value added) in industrial enterprises to reduce by over 10%.
• Coal consumption per unit of power produced for all existing power plants to be lower than 310 grammes of coal equivalent (gce)/kWh, for new built power plants to be lower than 300 gce/kWh.
• Water use efficiency in main energy production areas to achieve advanced global level.
• Full implementation of coal-fired boiler air pollution emission standards and elimination of all old and inefficient coal-fired boilers in major air pollution prevention and control areas.
Targets and goals by 2030
• Access to commercial energy services in rural areas.
• Total primary energy consumption to be kept below 6 000 Mtce.
• Share of non-fossil fuels to reach around 20% in the energy mix.
• Share of natural gas to reach about 15% in the energy mix.
• Incremental energy demand to be met mainly by clean energy.
• Energy intensity to reach current global average levels.
• Share of non-fossil fuel power generation in the total power generation strives to reach 50%.
• Share of ultra-low polluting coal-fired power plants to be more than 80% of the fleet.
• Recall climate change commitments: o To lower CO_2 emissions per unit of GDP by 60-65% by 2030 from 2005 levels. o CO_2 emissions to peak around 2030 and strive to peak sooner.
Vision towards 2050
• Primary energy consumption level to be stable, with more than half coming from non-fossil energy sources.
• China to become an important participant in global energy governance.

To supplement the economy-wide 13th Five-Year Plan and long-term national strategies, China issued a separate 13th Five-Year Plan for Energy Development in 2016, which was followed by a series of sub-plans on coal, oil, gas, power, renewables, shale gas, coalbed methane, nuclear, hydropower, wind, solar biomass, geothermal and energy technology innovation (Box 12.3). These documents all identify specific medium-term binding or indicative targets, and a tracking mechanism to monitor progress. Targets and goals are increasingly designed to accommodate the shift in China's evolution towards a more market-oriented system. Regional, provincial and municipal plans were also created which mirror national plans.

A final category of policy document focuses on specific issues or challenges, for example the 2013 Action Plan for Prevention and Control of Air Pollution, the 2014 National Plan for Tackling Climate Change (2014-2020) and the 2016 Energy Technology Revolution Innovation Plan (2016-2030). In emerging energy areas such as smart grids and energy storage, the authorities also issue guidelines to support innovation, research and deployment.

While policies continue to playing a vital role in driving the energy transition, the broad process of market and institutional reforms reflects the government's pledge to "let markets play a decisive role in the economy". Energy pricing reform is playing a key role in this process, as China moves towards liberalisation of natural gas prices, changes to network regulation for electricity and gas, and the establishment of power trading and emissions trading platforms. The next phase of reform in the power, oil and gas sectors is defined by the Opinions of the Central Committee of the Communist Party of China and the State Council on Further Deepening the Reform of the Electric Power System in 2015, and the Opinions on Deepening the Reform of Oil and Gas System of the State Council in 2017.